FOREWORD

Presentation of the Proceedings of the International Symposium on Tropical Root Crops, in a single volume would result in a publication of unwieldly proportions; division into two volumes was dictated by the amount of material to be published.

In Volume I. appeared the Introduction and Section I to III; in this Volume are Section IV to VI.

EGBERT A. TAI.
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CONTENTS

SWEET POTATO DISEASES AND THEIR CONTROL

— *by* —

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Sweet potato diseases may be caused by three general groups of pathogens: fungi, nematodes, and viruses. There are a few references in the literature to sweet potato diseases caused by bacteria; however, these diseases appear to be relatively minor ones and will not be considered here. The vegetative method of propagating sweet potatoes is an aspect of sweet potato culture that (a) enhances destructive effects of pathogens to that host and (b) plays an important role in devising control measures for these diseases.

Some sweet potato diseases caused by fungi, nematodes, and viruses will be discussed briefly as to causal agents and methods of control as at present applied in the U.S.A.

DISEASES CAUSED BY FUNGI

At least 50 different fungi have been associated with diseases of the sweet potato. Distinct diseases are caused by some 25 or more of these fungi. Some of the better known fungus diseases are discussed here.

1. *Stem Rot or Wilt,* caused by *Fusarium oxysporum* f. *batatas* (Wr.) Snyd. & Hans., has been reported principally from the U.S.A. and Japan, and occurs in a few other areas of the world. In the U.S.A. stem rot is at present controlled through the use of resistant varieties. Reaction to the stem rot fungus among sweet potato selections ranges from very susceptible to highly resistant, but not approaching immunity. Practical field control of stem rot usually is attained with intermediate levels of resistance. Susceptible varieties may be grown successfully in noninfested soils by using stem rot-free planting stock.

2. *Black Rot,* caused by *Ceratocystis fimbriata* (Ell. & Halst.) J. A. Elliott, has been reported from many countries where sweet potatoes are grown. Black rot affects aerial parts of plants as well as edible roots. In the U.S.A. control measures are based largely on exclusion of the pathogen from field plantings. In the absence of the sweet potato host, the causal fungus apparently does not survive in soils in the U.S.A. for longer than two years. The use of disease-free mother roots treated with a recommended fungicide and planted in noninfested soils assures a black rot-free crop of sweet potatoes.

Supplementary control measures are necessary in instances where black rot-affected sweet potatoes are washed and packaged for shipment. These supplementary measures are concerned with disinfestation of the washing and packaging equipment with an approved fungicide to prevent spread of the disease to disease-free sweet potatoes subsequently handled in the same equipment.

The black rot fungus can be killed at temperatures which are not lethal to sweet potato roots. The following hot air treatments were used successfully in experiments where relatively small volumes of sweet potatoes were involved: 50°C for 6 hours, 43°C for 24 hours, and 35°C for 5 days.

Although there is a commercially valuable level of resistance to black rot among sweet potato selections tested, control of the disease through resistant varieties has not been attained. It is likely that the highest level of resistance at present available in sweet potato selections is not adequate to effect commercial control of black rot.

C. fimbriata has been recorded from several host plants other than sweet potato. These plants include *Hevea brasiliensis, Coffea arabica, Theobroma cacao, Platanus occidentalis, Prunus* spp., and *Crotalaria* sp. It appears, however, that these host forms of *C. fimbriata,* with the possible exception of the one from *Crotalaria* sp., are not pathogenic to sweet potatoes.

3. *Scurf,* caused by *Monilochaetes infuscans* Ell. & Halst. ex. Harter, apparently is not as widely distributed over the world as black rot. Control of scurf also is based largely on exclusion of the pathogen from field plantings in a manner similar to that described for black rot The use of cuttings instead of root-bearing sprouts is especially effective in reducing spread of the scurf pathogen from affected "seed" roots to field plantings.

There are differences in susceptibility of sweet potato selections to the scurf fungus, but known levels of resistance to it are relatively low and, therefore, of limited value in combatting the disease.

4. *Soil Rot,* caused by *Streptomyces ipomoea* (Person & W. J. Martin) Waks. & Henrici, apparently is not widely distributed over the world. It is, however, the most important field disease of sweet potatoes in the state of Louisiana, U. S. A., and is found in other parts of the country as well. Soil rot is a soil-borne disease that may become severe in soils having pH values above 5.2. One of the control measures is based on the fact that the pathogen does not cause losses in soils with pH values of 5.2 or lower. This means of control, however, poses problems where certain crops, requiring higher pH values for economical production in Louisiana soils, are used in rotation with sweet potatoes. Where manipulation of soil pH is not desirable, the soil rot fungus can be controlled by use of fungicidal fumigants (as chloropicrin, or fumigants containing methyl isothiocyanate) applied in-the-row as a preplant treatment. These fumigants are nematocidal as well as fungicidal.

Sweet potato selections range from very susceptible to moderately resistant in their reaction to the soil rot fungus. At present, there are no varieties with adequate soil rot resistance to effect commercial control of the disease; however, progress is being made in developing varieties that may be useful toward that end.

5. *Soft, Rot,* caused by *Rhizopus stolonifer* (Ehr. ex Fr.) Lind. and several other species of *Rhizopus,* principally affects edible roots. Soft rot probably is widely distributed wherever sweet potatoes are grown, but apparently causes greater losses in more temperate areas. Control measures are based on prevention of wounding sweet potatoes (to avoid creating portals of entry for the fungus), and proper curing of roots before storage. A most effective chemical, 2, 6-dichloro-4-nitroaniline, has been approved for use on sweet potatoes in the U.S.A. with a 10 ppm tolerance on sweet potatoes. Applied at 3 to 4 ppm on roots the chemical is highly effective in preventing soft rot development in sweet potatoes.

Sweet potato selections differ considerably in their susceptibility to the soft rot fungus. No acceptable level of resistance to soft rot in sweet potatoes has been discovered to date.

6. *Sclerotial Blight and Circular Spot,* caused by *Sclerotium rolfsii* Sacc., are diseases that affect the aerial parts of plants (blight) as well as the edible root (circular spot). The sclerotial blight often becomes severe in plant beds. Recent experiments indicate the effectiveness of 2, 6-dichloro-4-nitroaniline in preventing this disease in plant beds; it is possible that an economically feasible control measure will result from these experiments. At present control measures are based only upon exclusion of the pathogen through rotation.

7. *Java Black Rot,* caused by *Diplodia tubericola* (Ell. & Ev.) Taub. *(Physalospora rhodina* (Berk. & Curt.) Cke.), is a disease of the enlarged root, but may also cause damage in plant beds. Under conditions in Louisiana, U.S.A., the disease becomes severe mainly in cases where sweet potatoes have been subjected to such stress conditions as excessive heat or cold and excessive soil moisture.

Limited screening for resistance to the Java black rot fungus suggests differences in susceptibility among sweet potato selections.

8. *Charcoal Rot,* caused by *Macrophomina phaseoli* (Maubl.) Ashby, is found commonly in the U.S.A. and other parts of the world. In the U.S.A. it is severe mainly following previous injury to the sweet potatoes. Little is known about possible resistance to charcoal rot.

9. *Leaf Diseases* caused by fungi are of relatively little importance in the U.S.A. *Phyllosticta* leaf blight caused by *Phyllosticta batatas* (Thuem.) Cke., and white rust, caused by *Albugo ipomoeae-panduratae* (Schw.) Swing. are found generally in sweet potato plantings. Relatively high levels of resistance to both diseases are available among sweet potato selections. Rust caused by *Coleosporium ipomoeae* (Schw.) Burr., and *Cercospora* leaf spot, caused by *Cercospora* sp., have been reported on sweet potatoes from some sections of the U.S.A., but are not commonly found. *Alternaria* leaf spot is occasionally observed; it is believed that *Alternaria* sp. is primarily a secondary invader.

10. *Other Diseases* caused by fungi include foot rot caused by *Plenodomus destruens* Harter, which damages plants in seed beds and occasionally affects enlarged roots; dry rot caused by *Diaporthe batatatis* Harter and Field; surface rot caused by *Fusarium* spp: *Penicillium* decay; mottle necrosis caused by species of *Pythium* and *Phytophthora;* etc.

DISEASES CAUSED BY NEMATODES

There are many species of plant parasitic nematodes commonly found associated with sweet potato roots. Some of these nematodes are known to feed and propagate on roots of sweet potatoes without causing appreciable pathologic effects. Among this group are several species of *Pratylenchus, Helicotylenchus* sp.,*Tylenchorhynchus martini* Fielding 1956, *Tylenchorhynchus* sp., *Trichodorus christei* Allen,1957, and *Trichodorus* sp.

There are several other nematodes that cause distinct damage to sweet potatoes. The diseases caused by these nematodes are discussed briefly.

1. *Root Knot,* caused by *Meloidogyne incognita* (Kofoid & White, 1919) Chitwood, 1949; *Meloidogyne hapla* Chitwood, 1949; and *Meloidogyne javanica* (Treub, 1885) Chitwood, 1949, is widely distributed throughout the world. It is commonly found where susceptible sweet potato varieties are grown. Control of the root knot nematodes in susceptible varieties of sweet potatoes involves the use of disease-free "seed" bedded in nematocide-treated beds and planted in root knot nematode-free soils, or in soils treated with nematocides.

There are root knot nematode-resistant varieties available for planting in some sections of the U.S.A. A desirable moist-type sweet potato variety (so called because the sweet potato flesh is moist after baking, in contrast to the dry type that is dry and mealy after baking), having adequate resistance to root knot is not yet available. Progress is being made toward development of such a root knot-resistant, moist-flesh variety in the breeding programme at Louisiana State University.

2. *Sting Nematode Damage,* caused by *Belonolaimus* sp., is a destructive disease in a limited acreage of infested soils in the U.S.A. The sting nematode is an ectoparasite that causes severe stunting of sweet potato plants thereby greatly reducing yields. Soil fumigation with nematocides reduces damage by the sting nematode.

3. *Reniform Nematode Damage,* caused by *Rotylenchulus reniformis* Lindford and Oliveira, 1940, is also destructive in a limited acreage of infested soils in the U.S.A. The reniform nematode has been recorded from many tropical and subtropical areas of the world. It is an endoparasite that propagates abundantly on sweet potatoes and causes striking yield reductions. Fumigation of infested soils with the dichloropropenes results in good yield increases.

There appears to be some level of resistance among the relatively few sweet potato selections that have been screened for resistance to this nematode. Apparently factors that govern resistance to the reniform nematode are different from those that govern resistance to root-knot nematodes.

4. *Other Nematode Diseases* have been reported as caused by *Radopholus similis* (Cobb, 1893) Thorne, 1949, and by *Ditylenchus dipsaci* (Kuhn, 1857) Filipjev, 1936. These diseases have rarely been recorded after their original description.

DISEASES CAUSED BY VIRUSES

During the past two decades several virus diseases of sweet potatoes have been recognized. The causal viruses all appear to be systemic and readily transmitted from sweet potato to sweet potato by grafting either from enlarged roots or from stem portions. There are nonpersisent as well as persistent viruses involved. Among the nonpersistent viruses all, except one, are readily transmitted from sweet potato to sweet potato by aphids; the one exception (investigated by O. H. Elmer, 1960) was transmitted from sweet potato to sweet potato by grafting only. Apparently the nonpersistent viruses that infect sweet potatoes are transmitted from sweet potato to sweet potato with difficulty, if at all, by mechanical means other than by grafting and aphid inoculation. The persistent viruses that infect sweet potato are transmitted by whiteflies.

Relatively few investigations have been made on specific viruses that cause diseases of sweet potatoes. The nonpersistent viruses appear to be very unstable.

The persistent viruses (whitefly-transmitted viruses) have been recognized only in recent years as causing diseases of sweet potatoes. Therefore, characterization of viruses that cause diseases of sweet potatoes, is at present limited to symptomatology and transmission.

The sweet potato virus diseases as herein grouped by the writer are discussed briefly.

1. *Internal Cork,* a disease caused by a virus or a complex of viruses, is characterized by internal root necrosis prominent in enlarged roots of the sweet potato. Yields appear not to be affected. Symptoms on the growing plant consist of chlorotic leaf spotting, vein-clearing, vein-banding, and purple ring-spotting of foliage. These above-ground symptoms are similar, if not identical, with those caused by the leaf spot virus.

The virus is readily transmitted by several aphids, the most efficient in Louisiana, U.S.A., being the cotton aphid, *Aphis gossypii* (Glover). The aphids acquire the virus within a few seconds and lose infectivity within a few minutes, generally. The host range of the virus or viruses involved appears to be limited to plants of the Convolvulaceae.

Reaction of sweet potato selections ranges from very susceptible to highly resistant to internal cork, or, more specifically, to the root necrosis characteristic of the disease. The virus (or viruses) that causes the necrotic spotting in susceptible varieties appears to be carried in all of the resistant selections assayed. Resistance to the root necrosis appears to predominate among sweet potato selections that have been tested. Resistant varieties (e.g., Centennial, Julian, Nugget) have been developed in the U.S.A.

Control of internal cork in susceptible varieties is relatively easily attained in Louisiana, U.S.A., by growing internal cork-free plants even at relatively short distances away from diseased plantings.

2. *Leaf Spot,* caused by a nonpersistent, aphid-transmitted virus, is characterized by the same above-ground symptoms as those described for internal cork. Root necrosis does not develop when sweet potato varieties susceptible to internal cork, but free of the disease, are inoculated with the leaf spot virus. However, internal cork root necrosis does develop when the internal cork virus is introduced into susceptible varieties already infected with the leaf spot virus. Thus, there appears to be no protection by the leaf spot virus against infection by the internal cork virus.

Leaf spot virus apparently does not affect sweet potato yields. Resistance to leaf spot virus has not been found among sweet potato selections tested.

3. *Feathery Mottle Complex,* caused by a complex of viruses, is characterized by dwarfing of plants, resulting in striking yield reductions. The viruses involved in this disease appear to be the internal cork virus or viruses, the leaf spot virus, and a whitefly-transmitted virus. None of the viruses individually seems to cause the severe symptoms that result when the three viruses are present together. The whiteflies implicated in transmission of the third virus in the complex are *Bemisia tabaci* (Genn.) and *Trialeurodes abutilonea* (Hald.). This disease is limited in distribution in the U.S.A., and it has been reduced to insignificant proportions by a

combination of removal of diseased plants and use of insecticides in areas where it had become severe.

Relatively little research has been done on the feathery mottle complex. However, it is suggested that this disease possibly is similar to several virus diseases described from other parts of the world. It has been reported that the whitefly-transmitted virus has been eliminated from affected plants by a combination of heat treatment and tip cuttings.

Relatively little is known about varietal reaction to feathery mottle complex. Resistance was not discovered from limited screening of sweet potato selections in the U.S.A.

4. *Mosiac,* caused by a strain of tobacco mosiac virus, is a disease of certain dry-flesh, or Jersey-type sweet potato varieties in the U.S.A. Mosiac has been reported from relatively few plants in one or two isolated areas. The disease has been readily transmitted from sweet potato to sweet potato by grafting but not by any other means. There is relatively little spread of mosaic under field conditions. Transmission from sweet potato root sap to tobacco plants has been reported. Transmission by sap inoculation from tobacco to tobacco and a number of other plants, including sweet potatoes, has been reported. Apparently there is resistance to mosaic among sweet potato selections.

5. *Russet Crack,* described in 1964, is characterized by a russet type of discoloration and cracking of the enlarged roots. Chlorotic spotting followed by necrotic spotting of the foliage of certain varieties is associated with the disease. The disease is transmitted from diseased to healthy sweet potato plants by grafting. Spread of russet crack in field plantings has been abundant in some cases. The disease is at present limited to the north-eastern part of the U.S.A. Indications are that a whitefly, *Trialeurodes abutilonea* (Hald.), is a vector of russet crack virus, and that the virus involved is distinct from the whitefly-transmitted virus in the feathery mottle complex.

6. *Other Viruses* reported from sweet potatoes include strains of tobacco ringspot virus and cucumber mosaic virus.

SUMMARY

It is apparent that disease resistance at present plays an important role in controlling the ravages of sweet potato diseases. The author believes that resistance to additional diseases will be discovered as more and more sweet potato seedlings and selections are systematically screened for resistance to particular diseases. It is also apparent that other control measures are very important in combatting sweet potato diseases. These include the following practices : (a) use of disease-free "seed" potatoes; (b) selection of planting sites; (c) "seed" and soil treatment with fungicides and/or nematocides; and (d) use of cuttings instead of root-bearing sprouts for making field plantings.

APPENDIX

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DISCUSSION

Chairman :

On behalf of this Symposium I wish to thank Professor Martin. I also take this opportunity to make two comments and to ask Professor Martin two questions.

My first comment is that, from my own preliminary observations on sweet potato diseases, it would appear that our main problems in the Caribbean are caused by **C. fimbriata and Rhizopus** species. Of these the black rot disease caused by **C. fimbriata** is by far the more important.

My other comment is linked with two questions. The present emphasis on the economic need to increase food crop production in the developing countries may well lead to an increase in sweet potato cultivation. Professor Martin, you have indicated that at present the level of resistance to black rot in sweet potato is unlikely to be adequate for economic control of the disease. The pathogen, **C. fimbriata,** is already widespread in the Caribbean islands, and black rot accounts for very heavy losses. The level of soil contamination seems likely to increase, first, because there is no climatic extreme such as winter to help kill the pathogen; secondly, because some territories practise unbroken sweet potato cultivation on the same land; and thirdly, because of inter-island trade. Further, our harvesting and post-harvest handling methods for sweet potatoes are still far from satisfactory. This increases proneness to tuber infection.

Professor Martin, would you like to comment on the likelihood of black rot to increase in importance in this area? And would you also kindly give us a little more detail on the fungicidal treatment and hot-air treatment?

W. Martin (U.S.A.) :

In the United States frost helps to kill off both pathogens and insect pests of sweet potatoes. I appreciate the problems you have here, because you do not have winter, but I am still optimistic about the possibilities of controlling black rot here.

With regard to resistant varieties, we are still searching for higher levels of resistance, but I do not wish to minimise the importance of the resistance to black rot that is at present available in some sweet potato selections. I would certainly recommend the planting of these varieties.

Concerning fungicidal control of black rot I wish to say that pre-planting chemical applications constitute a promising control measure. This method costs about $8.00-$10.00 U.S. per acre and is therefore economical. Unfortunately, we have nothing as effective against black rot as 2,6-dichloro-4-nitroaniline is against soft rot. Although there are many materials that will kill the black rot fungus and prevent secondary spread onto the root, most of these materials produce a burning type of injury and cause the sweet potato tuber to look even more unattractive than when attacked by the black rot fungus. There is not a big enough margin between the fungicidal dosages and phytotoxic dosages. I think, however, that it is desirable to screen many of the newer chemicals.

E. Trujillo (Hawaii) :

Professor Martin, is there any evidence that insect vectors are involved in the transmission of **C. fimbriata** in the black rot disease?

W. Martin (U.S.A.) :

I think Dr. Iton should answer that question as he has told me of instances of insect transmission of **C. fimbriata** in other crops.

E. Iton (Trinidad) :

C. fimbriata is transmitted by insects in several other plant diseases. From my limited observation in the Southern Caribbean, there appears to be no insect transmission of **Ceratocystis** as a pathogen of sweet potatoes in the field. I also have no indication of insect transmission of the pathogen among stored sweet potatoes, but I am fairly confident that there is transmission of **Ceratocystis** by mites within the sweet potato stores. There is a high population of mites in most sweet potato depots and **C. fimbriata** sexual spores, which are discharged in a mucilaginous matrix, do adhere readily to the bodies of these creatures.

B. Williams (Trinidad):

Dr. Martin, in these parts we have had many reports from different sources that clonal deterioration occurs in our sweet potato varieties. Indeed, our breeding programme has been criticised in some quarters on this account. It has been said that we release our new varieties too early. This criticism is, however, mere speculation. Nevertheless, there is a well-documented case of this decline in yield. Professor Harland, perhaps one of the earliest sweet potato breeders in the world, early in this century developed a variety, V 52, in St. Vincent. This is a good variety and the annual reports of the Departments of Agriculture show that it has been included in most trials throughout the years, but a decline in yield can be detected in it.

Recently we sent material from all sweet potato varieties collected at St. Augustine for investigation by Sir Fredrick Bawden at Rothamsted, England. He informed us that checks under the electron microscope had shown no evidence of virus particles in the material. He has plans, however, to test extracts against test plants to confirm whether viruses were absent.

Professor Martin, do you think that the clonal deterioration reported in this region could be explained by reference to (1) your observation of nematode population build-up in cultivation over the years and (2) Dr. Iton's point in the opportunity for pathogen build-up to occur in these areas?

W. Martin (U.S.A.):

First, about the viruses. The aphid-transmitted viruses are very unstable. At present a virus expert and I are trying to find some way to stabilize these viruses so that we can see them under the electron microscope. So far the only ways by which we can detect them are by symptoms manifested in the plant and by transmission tests. I am therefore not suprised that examination with the electron microscope revealed nothing.

With regard to nematodes we would have to investigate the soil to determine which species are present. For example, the reniform nematode, is an extremely destructive parasite of sweet potato and I understand from one of your staff members in this institution that it is present in some of the soils here. This nematode may well be causing your varieties to deteriorate.

R. Barnes (Trinidad):

Professor Martin, you mentioned that the factors determining resistance against the reniform nematode and the root knot nematode appeared to be different. Is this conclusion based on observations on varietal selections? Do varieties either go down to one or the other nematode, or has work been actually done on the factors which govern resistance?

W. Martin (U.S.A.):

I should have put quotation marks around the term factors. This conclusion is based on the fact that our root-knot-resistant varieties are very susceptible in most cases to the reniform nematode and the varieties most resistant to the reniform nematode are actually most susceptible to the root knot nematode.

E. Gooding (Barbados):

Professor Martin, we saw in the field the other day Irish potatoes affected by

Sclerotium. Do you think that 2, 6-dichloro-4-nitroaniline would be successful against this fungus on Irish potatoes?

W. Martin (U.S.A.):

Was it attacked by **Sclerotium rolfsii?**

E. Gooding (Barbados):

I am not sure, Mr. Haynes described it as **Sclerotium,** he did not specifically say **Sclerotium rolfsii.**

R. Pierre (Trinidad):

I should like to confirm that the species involved in the Irish potato disease is **Sclerotium rolfsii.**

W. Martin (U.S.A.):

This may be an extremely interesting chemical to try. The sweet potato itself can take concentrations of 600 lb. of active material per acre of this chemical and not show any evidence of phytotoxicity.

E. Gooding (Barbados):

Would it be desirable to treat the potato before planting ?

W. Martin (U.S.A.):

This is our approach to disease control in our sweet potato seed beds. The chemical has a life of about ten to fifteen days but protection may be necessary over a longer period of time. Of course, it is possible to increase the rates of application but the cost of this chemical at rates high enough to control **Sclerotium** in a crop like Irish potatoes over a long period of time will be prohibitive.

E. Gooding (Barbados):

Professor Martin, I wonder whether the internal spotting of yams which I described yesterday is similar to the internal cork of sweet potatoes which you depicted in your photographs ?

W. Martin (U.S.A.):

This condition in yams is very interesting and I would certainly like to see it investigated. It would also be interesting to determine whether the white fly-transmitted viruses in many other tropical plants are the same types that are found in sweet potatoes.

S. Harland (Peru):

May I be permitted Mr. Chairman to make a short comment on a comment. Regarding the question of degeneration in sweet potatoes, I think the important point to emphasize is that the sweet potato, being a high polyploid, is an intensely mutable product and we know, from many other sources, that mutation in minute physiological and morphological characters takes place in many organisms with a velocity many times greater than that of the gross morphological characters that we observe. There are two kinds of 'mutations' — the hidden or invisible type which leads to very rapid changes in the adaptive complex (of course, yield is one of those things) and the degeneration through virus. Now, I think myself that the sweet potato is a plant which is admirably suited for intensive study from this point of view. I think the point about degeneration is well taken, I feel quite convinced that clones may rapidly decline from a very high yield when they are new to a position of stability as the years go by.

DISEASES OF THE GENUS *COLOCASIA* IN THE PACIFIC AREA AND THEIR CONTROL

— *by* —

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Colocasia esculenta (L.) Schott is one of the oldest cultivated crops. Chinese books mention taros (dasheen) as early as 100 B.C. and it was grown in Egypt before the time of Pliny (23—79 A.D.), for he mentions it as one of the established food plants of the country. The earliest European navigators saw it cultivated in Japan and as far south as New Zealand (29). Buck (2) suggests that the finest taros were carried from Indonesia to New Guinea and relayed by Melanesians to their eastern outpost, Fiji. From Fiji the finer taros were relayed to Central Polynesia via volcanic islands. The first relaying station in Western Polynesia was Samoa; from here taros spread to the Society Islands and as far north as Hawaii. Such movements might have occurred somewhere after 1 A.D. The different migrations of Indo-Malayan groups resulted in the spread of the crop to the Philippines and the Micronesian islands.

C. esculenta grows best in damp soils. In the Pacific Islands the swamp is considered by the natives as the crutch of life because of its suitability for taro culture. For the primitive agriculturist this swamp-loving plant collects the richness of the earth washed from the surrounding low hills and converts it into starchy food. Taro is grown today on volcanic islands both in "wetland" and "upland" culture. Wetland culture is practised in valleys with abundant water and easily flooded soils. For this type of culture the islanders have perfected techniques such as irrigating terraces or fields as in New Caledonia, Fiji, Western Samoa, and other islands. The paddy culture, originally oriental, is typical of Hawaii. Upland taro culture is practised in areas with annual rainfall above 70 inches and soils that drain easily. On low islands and atolls the crop is planted in pits meticulously carved in the coral and composted with abundant organic material.

The crop is subject to several diseases, some of which are of rather recent origin, while others probably are as old as the crop itself. Members of the family Pythiaceae are without doubt the most serious pathogens of the crop.

TARO LEAF BLIGHT

Phytophthora colocasiae Rac. was first described by Raciborski (24) in Java in 1900. Its occurrence in India as early as 1905 points to Southeast Asia as the centre of origin for the disease. From this part of the world the disease spread to the Pacific. Butler (3) reports it in Formosa in 1911, Gomez (13) in the Philippines in 1916. The disease reached Hawaii about 1920. It is known to occur in New Guinea and Australia. In 1946 Parham (19) found it in the British Solomons and in 1948 it was reported in Fiji (20) for the first time. The disease occurs in China (25) and Japan, also in the Caroline and the Mariana Islands. The disease has not been reported from Western or American Samoa or the Tonga, Cook, Society or Marquesas Islands. It appears likely that the disease has spread in recent times in three directions: from Java to the North Pacific (Hawaii) via Taiwan and Japan; from Java to the Central Pacific (Micronesia) via the Philippines; and from Java to the South Pacific via New Guinea, Australia, the Solomons and Fiji.

In the early stages the disease is characterized by purplish to brownish water-soaked circular lesions, measuring from 1 to 2 cm in diameter. A clear yellowish liquid exudes from the infected area. Lesions are zonate because of differences in growth rates during night and day, and sporulation during the night when temperatures are lower. As the lesions enlarge and coalesce the leaf shows irregular patches of dead tissue and eventually the whole lamina is affected. Epidemics develop when the night-day temperatures are 20-22°C, and 25-28°C, respectively, and humidities of about 65 per cent during the day to 100 per cent at night are accompanied by overcast, rainy weather. Under such conditions a taro field can be blighted in five to seven days (27). Epidemics can occur throughout the year. This disease is of such severity in the Solomons and Ponape that it is a limiting factor in taro production. In Hawaii and Fiji there is greater seasonal variation in temperatures and the disease is less destructive during the winter months when the night temperatures drop below 20°C. Low temperatures limit the sporulation of the fungus and reduce the possibility of epidemics despite high humidities and rain (27).

The taro plant is resistant to blight during the young stages of development because the leaf surface does not retain water droplets for a sufficiently long period. In young plants the leaf blade hangs at an angle which restricts water retention on the smooth surface. When plants are four and one half months old the luxuriant growth and overcrowding of the foliage hinder air movement and help to maintain high humidities. *Phytophthora* blight at that stage can be severe. In addition to the high humidities prevailing at that stage large numbers of leaves extend horizontally and the cup-shaped base of the lamina then retains rain water. Free moisture is necessary for germination of zoosporangia and zoospores and for subsequent leaf infection.

The disease has been successfully controlled in Hawaii by applications of copper fungicides when the plants are four to nine months old. Yield increases of up to 50 per cent have been recorded (28). The control of *Phytophthora* not only increases yield but also reduces the incidence of "Loliloli" taro a minor physiological disease. Bordeaux mixture and copper fungicides have been reported to provide adequate control of the disease (20, 22, 28), but varieties resistant to *P. colocasiae* should provide the most practical answer for native island agriculture. Deshmukh (9) has reported resistance in the var. Ahina. A comprehensive survey of the genus *Colocasia* and adequate testing of varieties for resistance are needed. Crosses and production of viable seed have been reported by Kikuta *et al.* (14). Therefore, it is probable that resistance can be incorporated into commercial varieties. On the other hand, it is advocated that since *Xanthosoma* spp. are similar in nutritional value and are resistant to *P. colocasiae* (12, 21), outstanding varieties of this genus should be introduced to replace the susceptible *C. esculenta*. Such an undertaking would involve changes in the habits and practices of the subsistence type agriculturist of the Pacific.

TARO ROTS

Soft Rot

The soft rot caused by *Pythium* is probably more widely distributed than any other disease of the crop. Soft rot caused by different *Pythium* spp. has been reported from many areas of the world where the crop is grown (6, 7, 8, 10, 23). *Pythium* spp. can be seed-borne and there is no doubt that this disease was spread with the original planting material introduced in the oceanic islands by Polynesians and other migratory groups.

Losses of up to 80 per cent caused by *Pythium aphanidermatum* (Edson) Fitzpatrick, *Pythium graminicolum* Subramanian, and *Pythium splendens* Brown, have been observed in Palau, Samoa and Hawaii. Bugnicourt (6) has reported heavy losses in the New Hebrides due to *Pythium irregulare* (Buisman). The symptoms of soft rot are characteristic. The plant shows wilting and chlorosis and proliferation of roots at the base of the shoot. The corm becomes soft and mushy and the rot is usually accompanied by an acrid, putrid odour. When the disease occurs in new plantings the young shoots usually die and replanting is necessary.

Dry Rot

In many instances conditions are not ideal for soft rot development and the plants lose only a few roots. Temperatures below 25°C inhibit *Pythium* root rot, and soil and water temperatures apparently influence occurrence of soft rot. This suggests that the damage caused to feeder roots and large roots by *Pythium* spp. may be responsible for the disease known as dry rot or "guava seed". Parris (21) failed to reproduce dry rot under laboratory conditions and concluded that the disease is not attributable to a specific organism. However, he suggested that unfavourable conditions causing root death appear to be responsible for the disease.

Neither dry nor soft rot occurs in upland taros but both diseases are common in wetland taros. Apparently, resistance to soft rot and dry rot does occur. The Hawaiian varieties tested by Parris (21), namely Kai Kea and Kai Uliuli, were resistant to soft rot. The high-yielding varieties Piialii, Piko Uliuli and Piko Kea were highly susceptible. Four of the taro varieties in the *Mana* group and Kai Kea were immune to dry rot. Kai Uliuli combined resistance to soft rot and dry rot (21, 23). Again, breeding and selection of resistant varieties to soft rot should be fully explored if we are to upgrade the subsistence agriculture of the Pacific dweller. Dadant (8) reported that immersing the tubers for 30 minutes in a 0.2 per cent aqueous solution of Solusanigran before planting prevents *Pythium* rot. Tests conducted in Hawaii by the author with Captan as a soil drench and as a dip for planting materials have shown promise for acid soils. Captan is inactivated in alkaline soil and provides little or no control of the disease.

THE MINOR TARO DISEASES

Sclerotium Rot

This disease of upland taro has been reported from Fiji (10), the Philippine Islands (11), and Hawaii (21). Affected plants are usually stunted and corms are rotted at the base where abundant sclerotia of the pathogen develop. The condition is caused by *Sclerotium rolfsii* Sacc. Sclerotia of the pathogen persist in the soil and the disease is usually serious during warm, wet periods. It can be controlled effectively with Terraclor and Botran soil drenches at 10 to 20 lbs per acre.

Root-knot nematode damage

Meloidogyne spp. cause damage to upland taro whenever the crop is planted in soils infested with these nematodes. They produce characteristic galls on the roots and swellings and malformations on the corm. In Hawaii root-knot is particularly severe on dasheen (21), sometimes causing total losses. As the nematodes are spread with the tuber, dissemination over long distances is possible. However, it is possible to destroy the nematodes by treating the tubers in water at 50°C for 40 minutes (4). This treatment provides clean planting material. Fumigation with Telone, Nemagon, or DD is recommended for infested soils.

Cladosporium leaf spot

This disease occurs in Hawaii (21), New Caledonia (5), New Hebrides (15), Western and American Samoa, the Carolines and the Marianas. The distribution of this pathogen throughout the Pacific basin suggests that the disease is one of the earliest on taro. The disease attacks wetland and upland taros and occurs mainly on the older leaves (5). In the early stages the upper surface of the leaves shows light yellow to Havana green spots. On the lower surface are dark brown spots due to the superficial hyphae, sporophores and conidia of the pathogen. Apparently fungicidal control is uneconomic because the disease does not cause appreciable losses.

Other Diseases

Endoconidiophora sp. (17) and viruses (10, 16) have also been reported as pathogens of taro. The extent to which viruses are implicated in yield decline is not known. The whole subject clearly requires further study. Apparently there has been little research on the viruses attacking the Araceae family, and those reported on *Colocasia* have not been identified. The bacterial leaf spot of *Colocasia* from India (1) has not been recorded in the Pacific.

SUMMARY

Phytophthora blight and *Pythium* corm and root rot are the most serious diseases of *Colocasia esculenta* in the Pacific basin. Southeast Asia appears to be the centre of origin of *Phytophthora colocasiae* and its spread to islands in Micronesia, Polynesia and Melanesia is relatively recent. *Pythium* spp. and *P. colocasiae* are corm-borne and both diseases can be easily spread by infected planting material. Climatic factors, especially temperature, humidity and rainfall, determine the outbreak of epidemics caused by these pathogens. Successful chemical control is possible but costly. The development of resistant varieties would be more suitable for the subsistence agriculture practices of the islanders. Because resistance to both diseases is present within the genus *Colocasia* and related genera, a serious attempt to produce suitable resistant varieties by breeding and selection is advocated. Available information concerning nematode damage and leaf diseases other than that caused by *Phytophthora* is restricted to brief descriptions of pathogens and symptoms. A few reports of virus diseases appear in the literature, but as these are inconclusive they require further clarification.

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DISCUSSION

Chairman :

On behalf of this Symposium I wish to thank Dr. Trujillo. I wish also to open the discussion by remarking that Dr. Trujillo's paper is quite timely in these parts. The aroids, like several other root crops in the Caribbean region, have been frequently referred to as relatively free of disease. However, as we become more conscious of plant pathology as an integral part of agricultural industry, we are recognising the fallacy of this popular conception. Recently, we in the Crop Protection Division have observed foliar infections of tannia and dasheen and, in fact, photographs of some of these are now on display in the laboratory demonstration upstairs. This may well mark the beginning of investigations on these problems.

E. Tai (Trinidad) :

I would like to ask Dr. Trujillo whether he has come across a disease known as "saltpetre" this was described about fifty years ago in Jamaica by Ashby. The disease is supposedly caused by a **Sphaerostilbe** sp. It begins like a vascular wilt and develops into a soft rot.

E. Trujillo (Hawaii) :

We do not have that type of disease in the Pacific. However, in Japan there is in aroids a type of rot which is similar to black rot of sweet potatoes. In Hawaii we have what is known as "Loli-loli". Affected corms are very light and fibrous. This I consider to be a physiological disease. It is caused by the fact that after the corms have accumulated much starch and are almost mature, foliar infections, for example, by **Phytophthora** occur, killing the leaves. This is followed by the production of new leaves which causes the depletion of the starch stored in the corms and results in the condition described.

There are also nutrient deficiency diseases in aroids in the Pacific area.

L. Edwards (St. Kitts) :

Dr. Trujillo, in your penultimate slide you showed us a disease which resulted in water soaked spots on the leaves. I have seen similar symptoms on the leaves of papaya affected by an unidentified disease in Nevis. Dr. Bird of Puerto Rico discovered the pathogen to be **Corynespora.** I should like to know if you ever found**Corynespora** causing a disease of taro.

E. Trujillo (Hawaii) :

No, we have not seen any **Corynespora** in taro, but we have seen it in papaw. We must be aware that there are sometimes invalid descriptions in the literature. People sometimes report saprophytic fungi as being pathogens with establishing their pathogenicity.

B. Williams (Trinidad) :

I thought I heard Dr. Trujillo say that taro set seed in the Pacific areas. Is that correct ?

E. Trujillo (Hawaii) :

Yes, they do produce seeds. As a matter of fact, a large number of varieties produce flowers readily and in my paper I referred to literature on work that was done in Hawaii on the production of seeds.

WEED CONTROL IN ROOT CROPS GROWN IN THE WEST INDIES

— *by* —

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Chemical weed control in tropical root crops has recently been reviewed by the first author (1), and the results of experiments on dasheen, tannia, yam, sweet potato and cassava carried out in Trinidad up to early 1966 have been reported by Kasasian (2). The purpose of this paper is to report subsequent work and present the results of experiments on other root crops.

SWEET POTATO *(Ipomoea batatas* (L.) Lam.)

Several years' experiments had shown the most promising treatments to be mixtures of amiben with TCA or diphenamid applied immediately after planting slips, or paraquat,(using a spray shield to keep the spray off the crop) when the vines were turned. A screening experiment, using a logarithmic sprayer, carried out early in 1966 suggested that propazine and Glenbar were also promising treatments. Two replicated (x4) yield trials were therefore carried out later in the year and the results are presented in Table I.

Table 1. Tuber yields of sweet potato (cv. 0 49) expressed as % of weedfree controls

Experiment 1

Treatment		Yield	Weeks of weed control
Amiben	1 + TCA 5 lb/ac a. i.	98.5	6
"	1 + diphenamid 2	116.5	8
norea	2	118.3	6
"	4	118.0	8
norea	2 + TCA 5	122.2	9
propazine	2	99.7	6
"	4	96.8	7
"	2 + TCA 5	107.9	9
sindone	4	89.9	5.5
"	2 + propazine 2	117.6	5.5
amiben	1 + " 2	110.0	7
"	1 + norea 2	111.1	5.5
Glenbar	2	118.3	4.5
"	4	110.6	6.5
"	2 + amiben 1	108.1	7
Weed free control		100.0	–
L.S.D. 5%		27.1	
Coefficient of variation		17.4%	

Experiment 2

Treatment	Yield	Weeks of weed control
Amiben 1.5 + TCA 5 lb/ac	82.6	5
propazine 1	62.6	6
" 2	61.5	6
" 1 + TCA 5	63.0	7
" 1 + Amiben 1.5	63.8	9
Weedfree control	100.0	–
Unweeded "	39.2	3
L.S.D. 5%	30.4	
Coefficient of variation	30.0%	

The first trial carried out at the beginning of the wet season showed that propazine 2 + TCA 5 lb/ac, norea 2 + TCA 5 lb/ac, amiben 1 + diphenamid 2 lb/ac and norea 4 lb/ac gave the best weed control without affecting the yield. In the second trial carried out later in the season, propazine proved to be injurious to the vines, in many cases resulting in death of the plant. The difference in tolerance to propazine is thought to be due to the difference in time of application after planting: in the first trial where no damage was observed, application was made three days after planting the slips and in the second, the slips were sprayed the day following planting. This tends to be confirmed by the results of the preliminary trial in which regrowth several months old tolerated up to 8 lb/ac of propazine. It would appear therefore that spraying with propazine either alone or in mixtures should be delayed for a few days following planting.

The weed control requirements of the crop were also studied in a weed competition experiment laid down towards the end of 1966. This was arranged in an 8 x 8 latin square design using cv. 0 49. Table II shows the treatments and results.

Table II. Tuber yields of sweet potato (cv. 0 49) 3½ months after planting

Treatment	Yield	% Weed cover at harvest
Weedfree	100.0	2
One weeding at 3 weeks	81.4*	56
Two weedings at 3 & 6 weeks	86.0	26
Three " " 3, 6 & 9 "	91.5	8
One " " 4 "	82.4*	31
Two " " 4 & 8 "	85.7*	14
Three " " 4, 8 & 12 "	84.5*	3
No weeding	45.4*	99
L.S.D. 5 %	14.8	
Coefficient of variation	17.9%	

It seems therefore that weeding should not be delayed as long as three weeks; at four weeks a permanent set back has been caused. There appears to be little advantage in weeding after the first three to four weeks, hence the yield reductions on the amiben + TCA plots seem more likely to be due to phytotoxicity than to weed competition and the better results from amiben + diphenamid are probably due more to its greater safety than to the longer period of weed control obtained.

YAMS *(Dioscorea alata* L.)

The tolerance of yams to herbicides applied before crop emergence had been demonstrated in several years' trials and was again confirmed in 1966/67 in Jamaica when plots treated with 3 lb/ac diuron and linuron outyielded the controls and plots treated with 3 lb/ac simazine and atrazine gave 99–100 percent of the yield of the weeded control. In Trinidad it had been found that the addition of 5 lb/ac of TCA to the urea or triazine herbicides improved weed control without significantly affecting the yield; in Jamaica, however, it was found to cause a significant reduction in yield without improving weed control. This difference is presumably due to the soil in the Jamaican experiment being much more permeable. A number of newer soil-acting herbicides were screened at the same time and promising results were given by 1 and 2 lb/ac bromacil and terbacil. Yields were unaffected by 4 lb/ac metobromuron but were reduced by fluometuron at 1 or 2 lb/ac. Four months after planting additional plots were given a basally directed spray of 5 or 10 lb/ac dalapon. The yams were not tall enough to escape foliar contamination altogether and this caused some leaf distortion but there was no effect on yield.

In Trinidad two months after an initial pre-emergence application of diuron 3 lb/ac + TCA 5 lb/ac, directed sprays of dalapon 3, 6 & 9 lb/ac and paraquat 0.5 lb/ac were applied. Injury on the lower parts of the vines was greatest with the higher rates of dalapon and least with the lowest rate and with paraquat. The latter treatment caused no loss of yield but non-significant reductions in yield occurred with all rates of dalapon. These trials suggest that paraquat and dalapon might be useful as post-emergence treatments provided the crop is grown on supports and care is taken to keep the spray off the vines as much as possible.

Table III. Root yields of yams 6½ months after planting

Treatment	Yield
Sprayed and kept weedfree	100.0
" not weeded	79.7
Not sprayed, not weeded	37.0*
Sprayed and weeded every month	105.6
" " " " 2 months	81.4
" " " " 3 "	72.6*
L.S.D. 5%	22.7
Coefficient of variation	23.7%
Rainfall 1st month	13.35 in.
2nd "	10.00
3rd "	7.74
4th "	6.61
5th "	3.41
6th "	6.70
7th "	2.27

Two weed competition experiments were carried out in 1966/7, one in Trinidad and one in Jamaica. In Trinidad the yams were given an initial pre-emergence spraying with 3 lb/ac diuron + 5 lb/ac TCA and this was followed two months later by the first manual weeding (by hoe). Weeding thereafter was either every month, every two months or every three months. The three controls were either: (1) sprayed and then kept weedfree; (2) sprayed but not weeded; (3) neither sprayed nor weeded — see Table III.

In Jamaica no preliminary spraying was carried out and Table IV shows the treatment and results.

Table IV. Root yields of yams harvested 8 months after planting

Treatment	Yield
Weeding (by hoe) every month	100.0
" " " " 2 months	63.4
" " " " 3 "	34.6*
" after 6 and 12 weeks, then every 3 months	97.8*
No weeding	25.8*
L.S.D. 5%	69.0
Coefficient of variation	58.8%
Rainfall 1st month	9.74 in.
2nd "	16.17
3rd "	5.76
4th "	3.78
5th "	8.57
6th "	2.65
7th "	1.35

It will be seen that in both experiments the complete absence of any weeding resulted in yield reductions of approximately 70%. Where a pre-emergence spraying (in Trinidad) kept the weeds in control for 8 weeks bi-monthly weeding yielded 81% as much as those kept weedfree and 3-monthly weeding 73%; where no pre-emergence herbicide was used (in Jamaica) bi-monthly weeding yielded only 63% as much as those weeded monthly and 3-monthly weeding 35%.

In Trinidad pre-emergence spraying and no weeding yielded as much as spraying and weeding bi-monthly; and in Jamaica weeding at six and twelve weeks and then every three months yielded as much as plots weeded monthly. Taken together both experiments suggest that if yams receive a pre-emergence spraying, which should control the weeds for two to three months, little subsequent weeding would be necessary.

IRISH POTATO *(Solanum tuberosum* L.*)*

In preliminary trials, promising treatments were prometryne, ametryne, linuron, diphenamid, TCA, amiben, monolinuron, pyriclor, metobromuron and norea. The addition of 5 lb/ac of TCA to 1.5 lb/ac of either linuron or prometryne markedly increased the degree of weed control and caused little injury to the crop. Table V gives the results of a replicated (x6) pre-emergence trial.

Table V. Tuber yields of Irish potato (cv. Arka) 3 months after planting

Treatment	Yield	Weeks of Weed Control
Weedfree	100.0	–
linuron 1.5 lb/ac	96.7	7
" 1.5 + TCA 5	92.7	10
prometryne 1.5	101.2	7
" + TCA 5	93.5	9
L.S.D. 5%	25.6	
Coefficient of variation	22.0%	

None of the other compounds gave as good weed control as linuron and prometryne and there appears to be no point in testing them further, except for pyriclor which appears to be fairly promising for the control of *Cyperus rotundus* and might be useful in areas where this weed is prevalent. However, in a pre-emergence trial on cv. Patrones current at the time of writing, pyriclor is having an adverse effect on crop growth whereas terbacil at 1 lb/ac is giving good control of nutgrass without crop injury. Other promising treatments in this trial are 1.5 and 3.0 lb/ac of fluometuron and Ciba 6313 [N-(4-bromo-3-chlorophenyl)-N'-methoxy-N'-methyl urea].

CARROTS *(Daucus carota* L.)

Over 20 experiments have been carried out on carrots (Danvers Half Long and 126) in Trinidad and Jamaica and these have led to the conclusion that the most promising pre-emergence treatments (i.e. those giving the best weed control without crop injury) are prometryne and linuron and the most promising post-emergence treatments are mineral oils and prometryne. In pre-emergence yield experiments prometryne caused no injury at rates up to 2 lb/ac in five trials; linuron caused injury once in the four experiments in which it was applied at 1 and 2 lb/ac (but the one case in which 4 lb/ac was used resulted in injury); amiben was safe at up to 3 lb/ac in three experiments and trifluralin at up to 8 lb/ac in one trial; diphenamid proved injurious at 2 lb/ac and prometone at even 0.5 lb/ac.

Kerosene, TVO and White Spirit have been compared as post-emergence sprays in three yield trials and little difference was found between them either with respect to weed control or crop tolerance. As kerosene is the least expensive, most of the remaining trials with oils were confined to it. In three experiments application was made at 2 or 4 hourly intervals from 06.00 – 18.00 hours — no consistent difference between times was shown and there appeared to be no correlation with relative humidity or temperature.

Post-emergence prometryne has proved non-injurious at up to 2 lb/ac and nitrofen at up to 4 lb/ac; linuron has proved damaging at even 1 lb/ac but in one experiment carrots over 3 in. were not injured wheras smaller ones were. It seems probable that repeated applications of prometryne or nitrofen to prevent weed emergence or, on older carrots, linuron, may well be the answer and this is currently under test.

Carrots have proved to be tolerant of EPTC applied before planting for nutgrass control and in two recent experiments in Jamaica it was found that only three days need elapse between treatment and sowing.

Numerous other herbicides have been tested pre- and post-emergence in the greenhouse and in the field (see Herbicide Research Unit reports) but the only observations of special interest are the unreliable results with propazine (used commercially in carrots in some parts of the world) and the tolerance exhibited towards Ciba 6313 [N-(4-bromo-3-chlorophenyl)-N'-methoxy-N'-methyl urea] and Ciba 6989 (2, 4'-dinitro-4-trifluoromethyl-diphenylether).

GINGER *(Zingiber officinale* Rosc.*)*

A single preliminary pre-emergence experiment was carried out in 1961 and the results obtained suggested that the crop was fairly tolerant of herbicidal rates of simazine, atrazine, atraton, prometon, ametryne, prometryne, amiben, diuron, neburon, TCA and dalapon but not of fenac.

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DISCUSSION

Chairman :

On behalf of this Symposium I wish to thank Messrs. Kasasian and Seeyave for their interesting paper. I now invite discussion.

E. Gooding (Barbados) :

Mr. Chairman, Mr. Kasasian just put forward a most interesting idea, that yams could be used in rotation with very severe herbicide treatments even when these are used for very long term weed control. I did not quite hear, however, what he suggested one could apply to yams to control nutgrass.

L. Kasasian (Jamaica) :

The two treatments are bromacil, which you may know as Hyvar-X and terbacil, which is known under the name of Sinbar. I must say that we have only done work on these two compounds for one year, but all the other work we have done on yams has shown that they are likely to withstand anything we put on. I think there is every chance that it would be quite safe to use these herbicides.*

Chairman :

Any other comments or questions? In the absence of any further contributions I now declare this session closed, thanking all the major participants and also those who contributed from the floor.

* A subsequent herbicide trial in Trinidad has shown that terbacil and bromacil at 3 lb/acre/pre-emergence were highly toxic to yams cv. Oriental.

DISTRIBUTION OF SWEET POTATO WEEVILS IN THE FRENCH WEST INDIES

— *by* —

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Throughout the French West Indies the environment is suitable for the cultivation of sweet potato *(Ipomoea batatas* (L.) Lam.) and this crop is widespread except in the northern dependencies where it is becoming scarce. In fact, in St. Barthelemy it has almost disappeared. The crop is grown only by peasant farmers. The holdings are small and cultural practices are of a poor standard. The greater part of the produce is used for home-consumption. New plantings are established chiefly during the rainy season (June to December). Both vine cuttings and tuber pieces are used as planting material. Harvesting begins four months after planting and continues over a long period, depending on the need for tubers. Very often the vines are left in the field. These root and produce tubers which are harvested two months later.

Since 1962 investigations have been carried out on the distribution of weevils attacking this crop in the French West Indies. The main insect pests found belong to three genera of the Curculionidae, viz : *Euscepes, Parisacalles,* and *Cylas*. Taxonomically *Cylas formicarius* (Sub-family Apioninae) is easily distinguished from *Euscepes* and *Parisacalles* both of which belong to the Cryptorhynchinae.

These weevils have similar bionomics. Eggs are deposited on parts of the plant near ground level. The larvae develop in galleries which they bore into the plant. The insects pupate, the adults emerge from the pupae and continue to feed within the larval galleries. As a result the complete life-cycle may be spent within the tuber and the adults are difficult to find outside the plant. *Cylas formicarius* (Fab.) and *Euscepes post-fasciatus* (Fair.) bear functional wings though they rarely use them (4, 5). Species of *Parisacalles* from Guadeloupe are however, apterous. These are transferred to new areas in vine cuttings used as planting material.

EUSCEPES

Euscepes post-fasciatus is of American origin. It has now spread to Tropical Asia and Australasia but has not reached the African continent. It is widespread in the Caribbean islands. There are only two known hosts, viz., *Ipomoea batatas* and I. *pes-caprae,* but further investigation may reveal more. The species is found on cultivated sweet potato in Guadeloupe and Martinique, and the authors have collected it at 60 stations, all at an elevation of less than 200m. In parts of the Windward coast of Guadeloupe where the annual rainfall exceeds 3m, this pest is not found. This confirms Fennah's (1) opinion that the insect is seldom a pest in very wet regions.

Seasonal fluctuations in population density are little understood. Although the insect may be found in all its developmental stages the year around, it seems that populations are larger during the dry season. The insect is very resistant to adverse conditions and can survive in crop residues.

A second species, *E. porcellus* (Bohem), has been reported as collected by Vitrac in Guadeloupe (2). The present authors were unable to collect any specimens and feel that this record may be erroneous.

PARISACALLES

This genus and the genus *Palaeopus* were described by Faust in 1896 in the same paper. They resemble so closely that it would be desirable to recheck the prototypes.

The genus *Parisacalles* includes three previously known species. Two have been described from Venezuela and *P. guadelupensis* (Hust.) from Guadeloupe. The authors collected the latter at more than 12 stations where the average annual rainfall was below 2m. The insect is sometimes found together with *E. post-fasciatus* in the same tuber. It is likely that this species also develops in wild *Ipomoea* spp. because it is sometimes collected by "sweeping" natural vegetation. The species is not kown outside Guadeloupe. In St. Martin the writers collected about 100 individuals of what they consider to be a new species. It differs from the above species by being larger and darker, and having a dorso-ventrally flattened body which is rarely pubescent. A complete description of it will be published elsewhere.

Parisacalles n. sp. is found only in the sweet potato tuber and it is sometimes present with *E. post-fasciatus* and *C. formicarius* in the same tuber. Myers (3) never observed these last two species together in the same tuber.

CYLAS FORMICARIUS

The geographical distribution of *C. formicarius* is extensive, including nearly all tropical regions, Africa and some sub-tropical areas. It is noteworthy, therefore, that this species is not found in the Windward Islands.

The authors did not find it in Guadeloupe or in Martinique but found it on the island of St. Martin. Fennah lists this pest as serious in the Greater Antilles and notes that sporadic outbreaks occur in St. Kitts and Nevis. The host range is small, the main host being sweet potato. However, specimens have been found on wild *Ipomoea* spp. and some closely related plants (Risbec, 5).

DISCUSSION

These surveys of sweet potato weevils in the French West Indies establish the occurrence of *E. post-fasciatus* in this part of the Caribbean and allow us to state precisely their local distribution. The records confirm the occurrence in Guadeloupe of the genus *Parisacalles* which is present in St. Martin as well, though as a seemingly new species. They also establish the occurrence of *Cylas* in St. Martin and confirm its absence from Guadeloupe and Martinique.

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DISCUSSION

G. Williams (Trinidad):

There are no points arising directly from this paper that I want to discuss but, I should like to thank the speaker for this paper because it is harder to get information on Caribbean insects than on insects in any other part of the world. To remedy this there is a plan conceived by the Zoology Department of this Faculty of Agriculture. We are producing a check list of insects attacking crops and stored products throughout the Caribbean region. We have started with funds from the Regional Research Centre and from Shell and we are using the Review of Applied Entomology as our basis. We propose to circularize all Entomologists in the Caribbean region to ask them (1) for unpublished information on the insect pests in their area and (2) to inform us whether they have reference collections. The project started three months ago and we have set the time limit of two years for submitting the list for publication. I therefore ask all Entomologists here to contact the Zoology Department if they would be willing to contribute to this venture.

VASCULAR STREAKING OF STORED CASSAVA ROOTS*

— *by* —

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Cassava, manioc, or yuca *(Manihot utilissima* Pohl. *(Manihot esculenta* Crantz)), is an important fresh vegetable and commercial source of starch in the tropics. It has been grown in the Southern United States and Florida for many years (9), but sustained interest in this crop never developed until the recent immigration of Cuban refugees to Dade County. It is grown on approximately 200 acres in Dade County and is sold largely in the Miami area. However, shipments of cassava to New York have been rejected because of decay and dark discoloration in the fleshy roots. Shipping was in wooden boxes with moist sawdust and took approximately four days.

It appeared that in storage fresh cassava roots were affected by two disorders — a soft rot that was caused by fungi and bacteria, and a dark bluish discoloration of vascular bundles. This vascular discoloration usually started from cut surfaces and progressed rapidly inward, so that, within four days, roots twelve inches long were completely affected. Vascular streaking was more common toward the periphery of the root. In some cases the parenchymatous tissue between the vessels near the cambium was slightly discoloured with a light bluish cast.

The purpose of this study was to find the cause, conditions for development, and methods of control of vascular streaking.

REVIEW OF LITERATURE

Storage of cassava for more than a few days has been a continuing problem (2 and 7). There is a considerable amount of work reported on the botany, culture, and utilization of cassava, as well as chemical aspects of toxicity of the roots; but there have been no detailed studies on storage problems of fresh roots.

Most reports state that the cassava roots must be used within one to a few days of harvest because of rapid deterioration after harvest (3, 4, 5, 6, 7 and 9). However, neither the cause of the streaks nor the factors that contribute to the streaks were understood. Successful storage procedures reported include : slicing the roots, drying in the sun, and storing in a dry place (7 and 8); burying the roots in a cool place (7); refrigerating the roots at 0°—2.5°C and 85—90 per cent relative humidity (4 and 7); and desiccating the roots to 10—12 per cent moisture (7). Normancha and Pereira (7) suggested that harvested roots should receive a minimum of sun.

The cause of the discoloration is believed by a number of workers to be enzymatic. For example, Normancha and Pereira (7) state that enzymes acting

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on the carbohydrate cause the discoloration. Akinreile (1) stated that the brownish discoloration during fermentation of the cassava was due to the oxidation of leucoanthocyanins and that deeper layers under anaerobic conditions were not discoloured. He concluded that contact of the root with air and iron should be avoided. It was not clear, however, if this discoloration was the same as the vascular streaking problem.

METHODS AND RESULTS

Attempts to isolate fungi and bacteria from the leading edge of discoloured vascular tissues were negative. The following culture media were used : potato dextrose agar, corn meal agar, V-8 juice agar, and nutrient agar. Microscopic examination of wet sections from discoloured tissue did not reveal the presence of a microorganism.

Because of the absence of microorganisms and the rapidity of the development of the streaking, it was concluded that the disorder was solely physiological. Five storage tests were conducted with mature roots. In each case mature roots were selected and were thoroughly washed in tap water and dried before starting the tests.

Test 1. The roots were dug 24 hours before starting the test and were held at room temperature until used. The duration of the test was one week. Neither surface sterilization of the roots in a 10 per cent solution of Clorox (5.25 per cent sodium hypochlorite) for 10 minutes with storage at room temperature, nor storage in moist or dry sawdust at room temperature resulted in severe rot. However, storage at 5°C or at 35°C avoided the problem.

Test 2. Roots were obtained as in Test 1. The treatments and results are presented in Table 1. Roots with slight discoloration would probably have been acceptable on the market. The commercial practice of storage in moist sawdust at room temperature was ineffective and also resulted in severe rot.

Table 1.—Effect of 60-minute ice water dip and packaging on vascular streaking of cassava roots stored for five days at different temperatures.

Treatment description				No. roots discoloured		
No.	Hydrocooled	Packaging	Storage Temp. (°C)	Severe	Slight	None
1	No	Open crate	22	5	0	0
2	No	Moist sawdust	22	5	0	0
3	Yes	Open crate	22	4	1	0
4	Yes	Open crate	7	0	0	5
5	Yes	Moist sawdust	7	0	1	4

Test 3. The roots were obtained as in Test 1; in addition they were surface sterilized in a Clorox solution before starting the test. The treatments and results are presented in Table 2. The internal temperature of the roots was taken by removing a core with a cork borer and inserting a thermometer. The results indicated that dipping in water of 60°C for 45 minutes was effective in inactivating

the cause of the streaking. The data suggest that longer dips at lower temperatures may also be effective. Storage at 40°C was also effective.

Table 2. Effect of high and low temperature water dips on vascular streaking of cassava roots stored five days at different temperatures.

	Treatment description				No. of roots discoloured		
No.	Water dip Temp (°C)	Water dip Time (Min.)	Root internal temp. (°C)	Storage temp. (°C)	Severe	Slight	None
1	Not dipped		21	21	4	0	0
2	Not dipped		21	40	0	0	4
3	43	23	38	21	4	0	0
4	52	10	31	21	4	0	0
5	52	33	45	21	1	2	1
6	54	10	32	21	4	0	0
7	54	30	49	21	1	2	1
8	60	10	53	21	0	2	2
9	60	45	53	21	0	0	4

Test 4. The roots were freshly dug and immediately taken to the laboratory and prepared as in Test 3. The roots were then wrapped in moist paper towelling and placed in polyethylene bags. Storage time was eight days. Roots stored at 25°C developed slight vascular streaking. Vascular streaking did not develop at 10°C or at 40°C. Unbagged roots kept submerged in tap water did not develop streaking in this time; however, a severe slimy bacterial rot developed. This test was of interest because of the mild development of streaks at 25°C. Since the roots were placed in plastic bags it was speculated that perhaps the storage atmosphere may have had an effect on the streaking. Possibly the freshness of the roots at the time of storage avoided some of the streaking.

Test 5. Roots of the variety San Diego were freshly dug, cleaned, kept moist, and refrigerated overnight. The following day sections six inches long were cut and placed under various storage conditions for seven days. Roots were submerged in water containing 200 ppm streptomycin sulphate for seven days at 24°—27°C and were in perfect condition after this storage time. The antibiotic was added to avoid bacterial soft rot. The rest of the treatments and results are given in Table 3.

Table 3. Effects of various root treatments on vascular streaking of cassava roots stored seven days under various conditions.

No.	Treatment description	Storage Temp. (°C)	No. roots discoloured Severe	Slight	None
1	Open air	24–27	4	0	0
2	Polyethylene bag	18	0	0	4
3	Moist chamber	2–10	0	1	3
4	Moist chamber	24–27	0	2	2
5	Moist chamber	40	0	0	4
6	Ends dipped in hot paraffin	24–27	0	1	3

The roots that were frozen in polyethylene bags were "spongy" when thawed, but the eating qualities were acceptable. Thawed roots did not develop streaks in four days at room temperature. The roots that were maintained at 40°C for seven days in a moist chamber developed streaking in four days when exposed to the air at room temperature. However, streaking did not develop in these roots when left for the same period of time in the moist chamber at room temperature. Vascular streaking developed rapidly in samples previously stored between 2°C and 10°C when these were placed at room temperature.

Discussion

The results obtained do not explain the cause of vascular streaking of cassava, but do suggest that its nature is enzymatic. The evidence for this is (1) absence of microorganisms from discoloured tissue, (2) inactivation of the mechanism when kept at 53°C for 45 minutes, (3) lack of full development of discoloration in roots under anaerobic conditions, and (4) complete lack of development of streaking in roots submerged in water.

Inconsistent results were obtained in development of vascular streaking at room temperature. Variables included varieties, maturity of crop, time of harvest, and drying of roots before and during the tests. The final test indicated that drying of roots may have been a major factor inducing vascular streaking.

These tests confirmed the previous report that post-harvest losses of cassava roots can be avoided by refrigeration (4). The tests further indicated that vascular streaking can be avoided by using a pre-storage hot water dip; by storing roots submerged in water at room temperature; or by storing roots at high temperature or at freezing temperature. It is possible that a number of these procedures could be developed for commercial storage of fresh cassava roots. In the meantime, however, fresh roots should probably be kept moist and removed quickly from the field after digging. The roots should be cooled, packed in moist material, and maintained under refrigeration until sold.

Grateful acknowledgment is given to Mrs. J. F. Morton, of the Morton Collectanea, University of Miami, for obtaining some pertinent literature.

C. W. AVERRE

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CONTENTS

THE SIGNIFICANCE OF ROOT CROPS IN THE TROPICS

— *by* —

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Numerous reports have told of malnutrition, undernourishment and even starvation occuring in widespread tropical areas. Today, the tropics is perhaps the world's principal food deficit region. This current situation represents one of the striking paradoxes of our times, for in the tropics, perhaps as much as 80 per cent of the inhabitants are engaged in agriculture. By contrast, in many developed temperate countries, with less than 20 per cent of their population engaged in agriculture, their peoples are reportedly overfed, and surpluses of basic food accumulate. These contrasts emphasise at once the primitive technology, and low agricultural productivity of tropical agriculture, as well as the low nutritional values of many tropical foods.

Yet, only in recent years have the quality and quantity values of tropical food supplies become subjects of serious study. In these circumstances it is not surprising that such limited agreement exists as to the nature and magnitude of tropical food deficiencies. The supplies of domestic foods have never been satisfactorily assessed.

The present paper will no doubt throw some light on the supply situation for it deals with the significance of a group of foods which have for centuries been basic in the diets of millions of tropical peoples. In particular, the paper reviews the relative importance of tropical root crops and in terms of food-supply, resource allocation, national product and in trade, both domestic and international. It seems appropriate to set this analysis against the background of tropical food deficiency.

FOOD SUPPLY

Root crops are important suppliers of calories and in the tropics they contribute substantially to the daily calorie intake. In some areas, notably in Africa and South America (see Tables I and Ia), they contribute nearly as much to the calorie supply as do cereals. Indeed, in some Nigerian villages, for example, their contribution is likely to be greatly in excess of the national average.

Table 1. Comparison of Starchy Roots with Cereals, in terms of Calorie Intake for Selected Countries, 1959—61 (Av.)

Country	Starchy Roots	Rice	Wheat	Other Grains	Total
	(................calories per day................)				
Argentina	160	40	1,100	—	2,900
Brazil	430	400	250	40	2,700
Ceylon	90	1,060	200	20	2,100
Chile	120	90	1,170	20	2,500
China (Taiwan)	190	1,350	210	10	2,400
Colombia	230	170	120	310	2,200
Cuba	220	480	280	190	2,600
Ecuador	90	200	160	300	1,900
Indonesia	390	880	10	220	2,100
Japan	90	1,070	240	90	2,300
Korea	120	970	190	470	2,000
Malaysia	110	1,220	210	10	2,300
Nigeria	740	30	20	930	2,200
Paraguay	670	70	300	450	2,500
Peru	290	190	320	350	2,000
Philippines	110	890	100	220	1,900
Venezuela	140	80	370	460	2,400
West Africa	590	230	30	1,100	2,400

Source: Abstracted from F.A.O., 'The Economic Relationships Between Grains and Rice', *Commodity Bulletin Series No. 39,* Rome, 1965.

Table Ia. Percentage Contribution of Starchy Roots and Cereals to Total Calorie Intake, Selected Countries, 1959—61 (Av.)

Country	Starchy Roots	Rice	Wheat	Other Grains	All Cereals and Roots
	(..........per cent of total calorie intake........)				
Argentina	6	1	38	–	45
Brazil	16	15	9	1	41
Ceylon	4	50	10	1	65
Chile	5	4	47	1	57
China (Taiwan)	8	56	9	–	73
Colombia	10	8	5	14	37
Cuba	8	18	11	7	44
Ecuador	5	11	8	16	40
Indonesia	19	42	–	10	71
Japan	4	47	10	4	65
Korea	6	49	9	23	65
Malaysia	5	53	9	–	67
Nigeria	34	1	1	42	78
Paraguay	27	3	12	18	60
Peru	15	9	16	17	57
Philippines	6	47	5	12	70
Venezuela	6	3	15	19	43
West Africa	25	10	1	46	82

Source: Derived from F.A.O. 'The Economic Relationships Between Grains and Rice', *Commodity Bulletin Series No. 39,* Rome, 1965.

But although root crops may furnish a sufficient number of calories to sustain life, they are insufficiently balanced to prevent malnutrition. Typically, root crops are deficient in vitamins, protein and fat. The unbalanced nature of their food supply becomes at once apparent when they are compared with other sources of carbohydrate, for example, the cereals, or when measured against some recognised dietary standards.

Typically, as can be seen in Table 2, water accounts for over 65 per cent of the weight of a fresh tuber, carbohydrate for between 18.9 to 34.7 per cent

Table 2. Food Composition of Irish potatoes, Sweet potatoes, Manioc, Yams and Taro, Per 100 Grams (Edible Portion)

Item	Unit	Irish potatoes	Sweet potatoes	Manioc	Yams	Taro
Food energy	calories	82	117	146	105	104
Water	g	78	70	62.5	72.4	72.5
Carbohydrate	g	18.9	27.3	34.7	24.1	24.2
Protein	g	2.0	1.3	1.2	2.4	1.9
Fat	g	0.1	0.4	0.3	0.2	0.2
Calcium	mg	8	34	33	22	23
Iron	mg	0.7	0.1	0.7	0.8	1.1
Vitamin A	I.U.	traces	500	traces	traces	traces
Thiamine, B_1	mg	0.10	0.10	0.06	0.09	0.15
Niacin (nicotinic acid)	mg	1.4	0.6	0.6	0.5	0.9
Riboflavin, B_2	mg	0.03	0.05	0.03	0.03	0.03
Vitamin C	mg	10	23	36	10	5

Source : 'Tropical Root Crops', *Green Bulletin*, No. 19, Germany, 1965.

Table 3. Food Composition of Maize, Wheat and Rice Per 100 Grams (Edible Portion)

Item	Unit	MAIZE		WHEAT (medium)		RICE	
		Whole Meal	Fine Meal 85% Extractions	Whole Meal	White Flour 72% Extractions	Husked 80% Extractions	Milled 65% Extractions
Water	g	12.0	12.0	12.0	12.0	13.0	13.0
Protein	g	9.5	8.4	12.2	10.9	7.5	6.7
Fat	g	4.3	1.21	2.3	1.1	1.8	0.7
Carbohydrate	g	72.9	77.3	71.8	75.5	76.7	78.9
Fibre	g	2.1	0.5	2.1	0.3	0.8	0.4
Ash	g	1.3	0.6	1.7	0.5	1.0	0.7
Calcium	mg	21(a)	5	36.0	16.0	15.0	10.0
Iron	mg	2.3	1.2	4.0	1.0	1.4	0.9
Vitamin A	I.U.	450(b)	300.6	0.0	0.0	0.0	0.0
Thiamine	mg	0.45	0.18	0.41	0.13	0.33	0.08
Riboflavin	mg	0.11	0.08	0.10	0.04	0.45	0.03
Niacin	mg	2.0	4.6	4.6	1.1	4.6	1.6

a For Maize from the U.S.A. and South Africa; for Latin America 7 mg; and for other areas 10 mg.
b For yellow varieties; white maize contains only little Vitamin A.

Source : Y. R. Chadha, 'Maize', *Tropical Science*, Vol. 4, No. 1, 1962.

and protein, for less than 3 per cent. By contrast (see Table 3) the water content of cereals stands at less than 12 per cent, with their carbohydrate and protein contents being two and four times respectively the equivalent weights for the starchy tubers.

Comparisons of the food-supply of root crops with a given dietary standard are likely to invite some dispute, for few are agreed on nutritional standards. Yet even allowing for possible differences, it seems clear from Table 4 that a daily diet consisting of about 1,000 grams of any of the starchy staples would show deficiency in important food elements — the magnitude of the deficiency varying from one root to another.

Table 4. Food Composition of a diet of 1,000 grams of one of five starchy roots[a] compared with estimated nutritional requirements for Adult Male

Item	Unit	Irish potatoes	Sweet potatoes	Manioc	Yams	Taro	Adult Male daily requirements
Food energy	Calories	820	1170	1460	1050	1040	2500
Water	g	780	700	625	724	725	
Carbohydrate	g	189	273	347	241	242	
Protein	g	20	13	12	24	19	65
Fat	g	1.0	4	3	2	2	
Calcium	mg	80	340	330	220	230	500
Iron	mg	7	1	7	8	11	8
Vitamin A	I.U.	traces	5000	traces	traces	traces	2500
Thiamine, B_1	mg	1	1	0.6	0.9	1.5	1.2
Riboflavin, B_2	mg	0.3	.5	0.3	0.3	0.3	1.2
Niacin (nicotinic acid)	mg	14	6	6	5	9	15
Vitamin C	mg	100	230	360	100	50	25

a Food values for the roots are calculated from Table I.

Source: Derived from data presented in 'Tropical Root Crops', *Green Bulletin*, No. 19, Germany, 1965.

But obviously, the significance of these deficiencies to the nutrition and health of tropical man is dependent, among other things, on the foods which complete his diet. While the statistics might not be available, the evidence would suggest that necessary supplementary foods are often consumed in inadequate quantities. For this, there would seem to be great need to breed improved varieties of the starchy staples in an effort to alleviate, if not remove, tropical nutritional problems.

This, however, is not to say that improved varieties are entirely the answer to the nutritional problem. For, taking protein requirements for example, it is certainly a much debated question whether satisfactory nutrition does not require a sizeable percentage of animal protein. Perhaps the more promising avenue might well be to develop some processing and to enhance the nutritional value of roots by adding then, the necessary food elements.

RESOURCE ALLOCATION

It has been possible to illustrate the food-supply of root crops with a few relevant statistics. But a discussion on resource allocation will necessarily involve a heavy reliance on qualitative evidence, for the data on factor-inputs for root crop production are extremely sketchy.

Table 5. Area under Irish Potatoes, Cassava, Sweet Potatoes and Yams in Selected Tropical Countries, 1963/64,

Continent and Country	Irish potatoes	Cassava	Yam and Sweet potatoes
	(..............	'000 acres	............)
North & South America			
Bolivia	282.5b	10.0a	10.0a
Brazil	500.0	4,042.5	380.0
Colombia	252.5a	202.5a	n.a.
Costa Rica	5.0a	—	—
Cuba	20.0b	137.5a	157.5b
Ecuador	80.0	60.0	10.0
Jamaica	2.5c	10.0b	92.5
Mexico	125.0	—	35.0
Paraguay	5.0	230.0	22.5
Peru	575.0c	70c	40.0c
Venezuela	37.5	62.5	30.0
Asia			
Burma	37.5	—	—
Ceylon	—	167.5	40.0
India	995.0	627.5	340.0
Indonesia	—	3,730.0	1,115.0
Japan	520.0	—	782.5
Korea	115.0	—	230.0
Pakistan	175.0	—	—
Philippines	7.5	235.0	380.0
Taiwan	2.5	42.5	567.5
Thailand		347.5	65.0c
Africa			
Cameroon	5.0b	145.0c	152.5
Central African Rep.	—	500.0	40.0
Dahomey	—	570.0	177.5
Ivory Coast	—	525.0	687.5
Madagascar	40.0	792.5c	150.0c
Malawi	n.a.	15.0	50.0
Mali	—	25.0	12.5
Mozambique	5.0a	2.5a	—
Niger	—	40.0	5.0
Rvanda-Urundi	32.5a	250.0b	362.5b
Rwanda	65.0	117.5	205.0c
Senegal	—	85.0	5.0
Sierra Leone	—	50.0	7.5c
Togo	—	345.0	125.0a
Uganda	5.0	715.0	592.5
Upper Volta	—	12.5	80.0
Zambia	—	100.0a	5.0a
Oceania	150.0	25.0c	50.0b

a Average for 1948/49 and 1952/53; b Average for 1961/62; c Average for 1962/63.

Source: F.A.O., *Production Yearbook 1964* Vol. 18, Rome, 1965.

Of the 16.8 million square miles of land reportedly capable of producing major food crops in the tropics,[1] roughly seven thousand square miles are under root crops.[2] The area estimates presented in Table 5, reveal that a high proportion of this acreage is devoted to cassava production, with the acreages in Irish potatoes being least in importance. Further, it is evident that the relative importance of individual crops varies widely among the various countries.

The relative importance of a crop in a country is dependent on a number of factors. While topography, soil and climate place certain agronomic limitations on production, economic and social factors often determine the extent to which potential for production will be exploited. Yet in not a few instances, the continued dominance of a food crop particularly in a tropical country, reflects not so much an economic choice as it does reflect the conservatism of food habits, for usually a high proportion of domestic production is geared to meet family requirements.

Characteristically, the production of root crops has almost exclusively been the concern of the local peasantry. The situation in Jamaica, for example (see Table 6), may not represent an extreme case.

Table 6. Acreage of Cocoe (Tannia), Yam Hills, Sweet Potatoes, Badhoo & Dasheen by size Group; Jamaica, 1961

Farms by Size Group	Cocoe (acres)	Yam (hills)	Cassava (hills)	Sweet potatoes (acres)	Badhoo & Dasheen (acres)
0 to under 5 acres	6,031	10,505,483	4,093,376	9,019	2,299
5 to under 25 acres	4,392	7,158,358	3,399,934	7,595	1,761
25 to under 100 acres	811	780,132	724,421	922	431
100 to under 500 acres	67	111,329	118,511	145	20
500 acres and over	10	15,355	213,195	4	—
All Farms	11,311	18,570,657	8,549,477	17,658	4,511

Source: *Survey of Agriculture 1961–62*, Department of Statistics, Jamaica, *1966.*

In terms of resource allocation the dominance of peasant production has meant that possibly apart from the primary factors in production — land, labour and planting material — supplies of such supplementary factors as are usually associated with scientific farming do not in general play an important part in the production process. Thus irrigation, disease and pest control and fertilizer applications are oft-times unknown, with shifting cultivation and intercropping assuming great importance.

A second factor in root crop production which is related to the dominance of peasant production is the small scale of individual production units. In general,

1 See D. T. Edwards, and A. M. Morgan Rees, 'The Agricultural Economist and Peasant Farming in Tropical Conditions', **International Explorations of Agricultural Economics**, Iowa, U.S.A., 1964.

2 Approximate calculation based on area statistics in **Production Yearbook 1964**, Vol. 18, F.A.O., Rome, 1965.

root crops require large quantities of labour[3] and clearly there are early limits to the size of farm a peasant can cultivate when his main tools are the fork, the hoe and the cutlass.

A striking fact which, therefore, emerges from a study of the resource allocation for root crops is the limited usage of certain production factors. This is part and parcel of the problems of peasant production and they are not relieved by the virtual indifference with which the cultivation of the starchy roots has been regarded in many official circles.

THE NATIONAL PRODUCT

Traditionally, tropical agriculture has emphasised the production of crops for export. The value of export crops has thus tended to overshadow the contributions of food crops to local economies, and the situation may not infrequently be exaggerated because of rather poor statistical coverage of food crop production.

While trade statistics usually provide a reasonably good basis for assessing the production of export crops, estimates of production of root crops must invariably rest on less reliable sources for few relevant records are kept either by the farmer or public bodies. This, as Edwards and Rees[4] point out, places the burden of providing information on the farmers' judgment and on their recollections, and on what the investigators can see for themselves, and although the farmer may remember fairly well the amount of crops he sold in the last season, his memory of the amount harvested for family consumption is likely to be hazy. Further, the units in which quantities of produce are harvested and marketed are apt to be in measures that cannot be easily translated into standard ones. Then too, from the point of view of the investigators, the system of intercropping and successional farming, and of irregular and incomplete harvesting, present serious problems in estimating food crop production.

In spite of these hazards, the F.A.O. of the U.N. has been able to collate some statistics on production, and in Table 7 data for selected tropical countries are presented. Some striking limitations of the statistics are seen in the combination of yam and sweet potato production, and the large number of countries for which production statistics are not available.

It would not be convenient, even if it were possible, to show the contribution of root crop production to the Domestic Product of 'individual' tropical countries. Therefore it is proposed to illustrate the importance of root crops by reference to their place in the Jamaican economy.

In 1961 the contribution of agriculture to the Gross Domestic Product of Jamaica was just under 13 per cent, the proportion of total working population engaged in agriculture approximately 40 per cent.[5] Over the last seven years (see

3 The labour requirements for the cultivation and preparing for consumption of a crop of cassava in the Belgian Congo, for example, are reported to be between 121 — 124 man days per acre. See Gordon Wrigley, **Tropical Agriculture**, Cambridge, 1961.

4 Edwards and Rees, **op. cit.**

5 **A Digest of West Indian Agricultural Statistics,** Occasional Series No. 2, Department of Agricultural Economics and Farm Management, University of the West Indies, St. Augustine, Trinidad, 1965.

Table 7. Production of Yams and Sweet Potatoes, Cassava, and Potatoes in Selected Tropical Countries, 1961—1964 (Av.)

Continent and Country	Yams and Sweet potatoes	Cassava	Irish potatoes
	(............	'000 metric tons	............)
North & Central America			
Cuba	240[a]	n.a.	113[a]
Jamaica	576	22[b]	17[b]
Mexico	279	n.a.	1,058
Brazil	4,356	60,150	3,382
Paraguay	230	3,279	n.a.
Venezuela	257	965	n.a.
Colombia	n.a.	1,532[b]	1,422[b]
Dominican Republic	n.a.	288[b]	n.a.
Honduras	n.a.	46	n.a.
Peru	n.a.	n.a.	2,476[b]
Asia			
India	2,980	5,665	8,354
Indonesia	9,138	33,917	n.a.
Philippines	2,200	1,549	41
Thailand	355[b]	5,914	n.a.
Burma	n.a.	n.a.	164
Pakistan	n.a.	n.a.	1,386
Ceylon	n.a.	871	n.a.
Africa			
Dahomey	1,732	3,510	n.a.
Ivory Coast	5,467	2,600	n.a.
Madagascar	873	2,503	190
Nigeria	n.a.	n.a.	n.a.
Ethiopia	n.a.	n.a.	262[b]
Rwanda	n.a.	n.a.	206
Ghana	n.a.	1,982[c]	

a 1961/1962.
b 1961/62 — 1962/63.
c 1962/63 — 1963/64.

Source: F.A.O., *Production Yearbook 1964*, Vol. 18, Rome, 1965.

Tables 8, 8[a], and 8[b]), the contribution of root crops to the total agricultural product was generally in excess of 11 per cent, and the contribution to product for home consumption in excess of 34 per cent.

These statistics may invite some generalization but here one must be careful, for among other things, the ratio of price levels between root crops on the one hand and the rest of the agriculture on the other, is likely to be dissimilar, and so too the ratio of production. Any generalization must therefore take due cognizance of these factors.

Yet, judging from fragmentary data and general comments, the relative importance of the roots in the economies of some tropical countries, particularly in Africa, would seem to be of even greater importance than it does in the Jamaican economy.

Table 8. Contribution of Export and Domestic Agriculture to total Agricultural Product[a], Jamaica, 1959—1965

Type of Agriculture	1959	1960	1961	1962	1963	1964	1965
	(.................			£ J '000			.................)
Export Agriculture							
Sugar Cane	6,884	7,333	7,999	8,394	12,814	11,669	9,258
Other Main Exports	4,644	3,830	3,922	4,048	4,533	4,506	4,503
Domestic Agriculture							
Root Crops	3,849	3,087	2,855	3,139	3,048	3,330	3,783
Other Products	4,848	5,059	5,374	5,471	6,123	6,383	7,302
Total Agriculture	20,225	19,309	20,150	21,052	26,518	25,888	24,851

a Excludes livestock and hunting, fishing, and forestry and logging.

Sources: *National Income and Product of Jamaica,* Dept. of Statistics, Kingston, Jamaica, 1965; and *Economic Survey of Jamaica, 1965,* Central Planning Unit, Gov't. of Jamaica, 1965.

Table 8a. Percentage Contribution of Export and Domestic Agriculture to total Agricultural Product, Jamaica 1959—1965

Type of Agriculture	1959	1960	1961	1962	1963	1964	1965
Export Agriculture							
Sugar Cane	34.0	38.0	39.7	39.9	48.3	45.1	37.3
Other Main Exports	23.0	19.8	19.4	19.4	17.1	17.4	18.1
Domestic Agriculture							
Root Crops	19.0	16.0	14.2	14.9	11.5	12.9	15.2
Other Products	24.0	26.2	26.7	26.0	23.1	24.6	29.4
Total Agriculture	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Table 8b. Value of Root Crops as Percentage of Value of Total Domestic Agriculture, Jamaica, 1959—1965

Type of Agriculture	1959	1960	1961	1962	1963	1964	1965
Domestic Agriculture							
Root Crops	44.3	37.9	34.7	36.4	33.2	34.3	34.2
Other Products	55.7	62.1	65.3	63.6	66.8	65.7	65.8
Total Domestic Agr.	100.0	100.0	100.0	100.0	100.0	100.0	100.0

TRADE

Tropical root crops have never assumed much significance in international trade. While the F.A.O. trade yearbooks do record some trade in potatoes, it is for the 'Irish' variety which is relatively unimportant in the tropics.

An important limitation on a sizeable export trade in root crops is associated with the high water content of fresh tubers. This, apart from making them extremely vulnerable to bruising and hence decaying, makes the cost of transport, in relation to their food values, extremely high. Trade is therefore limited to nearby foreign markets and to the producer's domestic market. Further, the high water content of the fresh tuber also means that the storage of roots presents serious problems which in turn affect the regulation of trade. And, in the absence of any really advanced processing periods of gluts must continue to alternate with periods of scarcity and give rise to wide price variations.

Another factor limiting any sizeable international trade in roots is related to the generally low productivity of root crops. In Sierra Leone, for example, the yield per acre of sweet potatoes may be as low as .5 tons per acre (Table 9).

Table 9. Average Yields of Sweet Potatoes in Selected Tropical Countries

Country	Yield (tons per acre)
Ceylon	7 — 9
Congo	10 — 20
India	3.6 — 10.8
Malaya	4 — 5
Sierra Leone	0.5 — 2
Trinidad	1 — 7
Uganda	7 — 20
Zanzibar	3 — 4

Source: Y.R. Chadha, and J. Dakshinanurthy, 'Sweet Potatoes', *Tropical Science* Vol. 8, No. 2, 1965.

For cassava, the yield sometimes drops as low as two tons per acre in Northern Nigeria (Table 10). These low yields mean that production is often just sufficient to supply local needs (see Table 11).

Table 10. Average Yields of Cassava in Selected Tropical Countries

Country	Yield (tons per acre)
Ghana	5
Eastern Nigeria	3 — 5
Northern Nigeria	2 — 3
Northern Kenya	3 — 4
Southern Kenya	4 — 5
Mauritius	4 — 5
Malaya (on good soil)	4 — 5
Indonesia (on good soil)	10 — 25
Brazil	15 — 19
India	5

Source: Y.R. Chadha, 'Cassava', *Tropical Science,* Vol No. 3, 1961.

Table 11. Estimated Production and Consumption of Sweet Potatoes and Yams, Cassava, and Potatoes in Selected Tropical Countries, 1959—1961 (Av.)

Country	Sweet Potatoes and Yams			Cassava			Potatoes		
	Prod.	Cons.	Bal.	Prod.	Cons.	Bal.	Prod.	Cons.	Bal.
	(..........				'000 tons				..........)
Argentina	372	290	82+	251	60	191+	1,966	1,140	826+
Brazil	1,234	1,150	84+	17,175	n.a.	n.a.	1,060	—	1,060+
Ceylon	36	40	4—	204	210	6—	n.a.	50	n.a.
Chile	n.a.	—	n.a.	n.a.	470	470—	760	—	760+
China (Taiwan)	2,937	700	2,237+	153	10	143+	6	10	4—
Colombia	n.a.	—	n.a.	n.a.	520	n.a.	685	310	375+
Cuba	212	250	38—	n.a.	190	n.a.	103	120	17—
Ecuador	41	20	21+	232	30	202+	287	120	167+
Indonesia	2,793	2,890	97—	11,920	9,650	2,270+	n.a.	30	n.a.
Japan	6,629	1,630	4,999+	n.a.	—	n.a.	3,423	1,620	1,803+
Korea	422	370	52+	n.a.	—	n.a.	303	250	53+
Malaysia	n.a.	100	n.a.	n.a.	270	n.a.	n.a.	30	n.a.
Nigeria	n.a.	6,900	n.a.	n.a.	3,500	n.a.	n.a.	n.a.	n.a.
Peru	76	140	64—	319	310	9+	1,217	950	267+
Philippines	783	690	93+	495	380	115+	9	10	1—
Venezuela	68	20	48+	279	250	29+	97	100	3—
West Africa	n.a.	2,260	n.a.	n.a.	2,390	n.a.	n.a.	10	n.a.

Sources: Derived from F.A.O., *Production Yearbook, 1961*, Rome, 1962 and F.A.O., 'The Economic Relationships Between Grains and Rice', *Commodity Bulletin Series, No. 39*, Rome 1965.

A striking feature of the domestic marketing of root crops is the unorganised nature of the marketing process. In the West Indies and in West Africa, the 'higglers' and the 'mammies' respectively, are the major handlers of domestic foods. Of these there are usually thousands. Some higglers are farmers or farmers' wives, who market their own produce plus that of their neighbours; others purchase their entire supply. These latter, in particular, usually assemble small diverse lots from remotely-located farms using trucks, carts, donkeys, or sometimes even carrying their supplies on their heads, and distribute their products to numerous small and large markets. Their system of distribution has often been described as inefficient. In recent times in the West Indies, many State-operated marketing agencies, designed to improve the marketing of food crops (including the starchy roots) have come into being. This is in recognition of the fact that the failure of many small farmers to respond to efforts made to increase productivity and production has been in large measure due to the absence of assured markets and an efficient marketing system. Yet the problems of storage and processing have not yet been adequately tackled and wide price variations still obtain.

CONCLUDING OBSERVATIONS

The significance of root crops in terms of food-supply, resource allocation, national product and in trade, has been briefly presented. It now remains to make a few concluding observations.

Against a background of widespread consumption of roots and of tropical food deficiency, three problem areas are of particular interest. The first, that root crops are deficient in important food elements; the second, that yields are low; and the third, that in the absence of proper processing and storage arrangements, periods of glut and scarcity alternate depending on the 'in' and 'out' season of the crop.

None of these problems allows an easy solution. They involve technical as well as economic, social and political issues. For instance, raising the nutritional level of roots — either by breeding new varieties or by enriching during processing — presents certain technical problems, but that is not all. There are also the likely problems of consumer acceptance. Or again, attempts at raising yields might in some areas involve land reform with its financial and political implications.

What needs to be done seems clear; what is still vague is how it should or indeed, may be done.

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DISCUSSION

Chairman :

I would like to suggest that we adopt the following practice, that we should first of all direct comments and questions to Mr. Leslie on his paper, and if there is still time, we could have questions and comments raised about Mr. Rees' paper, if it seems useful to do so, and then anyone who feels capable of making a useful contribution in relation to this is welcome to do so.

Dr. Jones :

I should like to comment briefly on one of the smaller parts of Mr. Leslie's paper. It refers to a rather important aspect of the economies of the tropical roots. In speaking of trade and commerce on tropical roots, he refers to the West African marketing system as being 'inefficient and disorganised'. We currently have four teams studying West African marketing systems, and it is our impression that they are efficient, well-organised, and capable of handling a very large volume of produce. After I read that section I tried to recall figures I had seen on the quantity of yams present in some of the Eastern Nigerian markets. As best as I can reconstruct it, they run in order of two to three hundred thousand pounds of yams present in the market at any one time. These are very large markets indeed, and some of the markets also serve as major distribution centres. In an area where the roots are as important in the dietary as they are in West African countries, there has to be an efficient marketing system to go along with it.

One other point, having to do with the position of the tropical roots in international trade, I suspect, though I am not sure, that one of the reasons they have not figured particularly in the post World War II period is because of increasing demand at home for the product which pushed prices up, and also interfered with the flow in the international trade, in such a way to cause them to lose foreign markets.

Dr. Rogers :

One interesting thing, in terms of international marketing in cassava, is the recent importation of very significant quantities of cassava roots into eastern cities of the United States due largely to the influx of Spanish American folks. In New York and all the big cities now, we find a very large market for almost all of the tropical root crops, in spite of the fact that they are inefficient to be shipped because of their high water content.

Mr. Courcey :

I would just like to confirm from my personal experience in Nigeria and Ghana, the comment of Professor Jones, on the efficiency of yam marketing, and also to mention the study of Dr. Hill, late of Ghana University, which is confined to the Ghanaian marketing, but is nevertheless a worthwhile study. In fact, when you consider the local conditions of shortage of capital, and compare the available labour, the marketing systems are extremely efficient.

The other point which was taken also was in interfering factors in international trade. It is very significant in this context, that the Untied Kingdom yams are traditionally supplied by Nigeria—a matter of eight or ten thousand tons a year. This was stopped suddenly by the decision of the Nigerian Military Government in February or March last year to prohibit the exportation of foodstuffs, including yams, owing to local shortages.

Mr. Pilgrim :

Just two minor points in connection with firstly, the efficiency of marketing systems of tropical roots. I do not know the situation in Africa, but certainly in the West Indies, the marketing systems for tropical root crops are relatively inefficient, when compared with the marketing systems for sugar, cotton, banana. With these crops which I just mentioned, you know before-hand what the yields are going to be; you know, usually before planting what prices you are going to get for these crops; you do not have to market them yourself, in that the farmer can grow the crop and leave some other organisation to market the crop, and he is assured of a basic minimum price. This situation does not obtain for our tropical root crops in the West Indies, and I would say that as far as we are concerned, the marketing of these crops is relatively inefficient when compared with others.

On the matter of international trade for tropical root crops, I do not know the situation in Africa, but certainly in the West Indies the amount of this type of crop which is marketed abroad is very, very small compared with the value and quantity grown and consumed locally.

Mr. Yankey :

Mr. Chairman, I too am in no position to comment on the efficiency of the marketing systems in Africa for food crops, but what we know in this part of the world—the Caribbean—is that the pricing system on the domestic markets, which are concerned largely with food crops is not that effective, since the prices, particularly in the day, may vary from one point in time to another.

The second point is that the measures are very arbitrary. In fact, you would have a heap of dasheens sold in one spot for $1, and in another area for 75c. It also depends on the knowledge between the buyer and seller, because in these markets you may find that certain sellers are well-known, and that certain buyers would prefer to patronise them rather than go to others. This makes the pricing system inefficient, because what you have here is an uncertain price throughout the day and sellers might be very reluctant in spending that time at the market, to know at the end of the day that they have got very little for the produce. In this part of the world, I think that the domestic market for food crops is very inefficient, and I would like probably someone to comment on the system in Africa relative to the pricing system.

Mr. Ferrer :

Mr. Chairman, let us not be too rash in condemning the inefficient system. The higglers, trafficcers, etc., tend to be crucified by people who speak about an efficient marketing system. But one has to consider the pattern in which these crops are grown. You have small units scattered over a wide area, and I can tell you that I have personal experience in the collection of these parcels of commodities scattered over a wide area, and the cost of collection is extremely high. An investigator in Jamaica, some years ago, raised the same question, and he was rather doubtful whether with the pattern of production in these small territories, you can really organise an efficient marketing system which could really be a great substantial improvement on the system that exists at the present moment.

Dr. Johnston :

With regard to the contrasts that have been mentioned several times between the efficiency of marketing starchy root crops in Africa and the West Indies, I strongly suspect that the point that Mr. Pilgrim made the other day is very relevant here, namely the fact that for many years (basis of one doctoral thesis I'm familiar with) going back at least sixty years, in the case of Jamaica, there has been continuing substitution of imported rice, and wheat flour for the starchy roots, reflecting a situation in which the growth of demand for the purchased staple foods has been mainly met by imported supplies, so that the stimulus for developing a more efficient domestic marketing system for the starchy roots has been relatively weak.

The question I would like to put to Mr. Leslie is, to what extent there has been, or there is the use of a processed starchy root product here in the West Indies ? In West Africa, manioc meal, as it is known there, or farina de manioca, as it is known in Brazil, is of very considerable importance in the urban areas, and unlike the fresh roots has an ease of transportation, storage and handling, very much like the cereals and it is therefore not subject to anything like the same degree of the special problems of distribution that affect the bulky starchy root crops, and I would like to ask whether any consideration has been given to the possibility that it might be introduced.

Mr. Leslie :

There is not, as far as I know, any significant processed form of the roots, except perhaps for cassava, farina. But there is no significant trade and no regular supply.

Dr. Sidrak :

I would just like to make a small comment on Mr. Leslie's paper, concerning Tables 1 and 2. In fact, the food composition of the root crops is not as bad as it appears here. It is simply because the calculations which are made in Tables 1 and 2 were not strictly made on dry weight basis, and if we calculate this on a dry weight basis, all the figures in Table 1 should be multiplied by a factor of 2.5 to 3, which brings about the food composition of these root crops to a bit more comparable values —to more or less comparable values—to what is found in maize and wheat and rice. If we really want to compare we have to compare in a particular and comparable basis, and this should be on a dry weight basis.

Mr. Leslie :

I took it, when I was compiling the statistics, that in most instances the tubers were consumed fresh, particularly in the West Indies, where I have the basis of my experience. With maize and wheat, the normal form is to have them in the dry, and this was the reason why I considered the basis of comparison did not necessarily exaggerate the picture.

Mr. Williams :

I would like to draw some evidence from the literature, because it seems to endorse Mr. Leslie's suggestion that breeding may not be the answer to the supplementing of additional nutrients supplied by the root crops. The evidence seems fairly clear. Time and again in the literature you can see exhaustive references by economists that breeding may be the answer. Dr. Jones from Stanford has spoken against the point, and I wish to endorse it. Most crops plants have evolved biochemical pathways towards the elaboration of products which might be carbohydrates primarily, or protein primarily, or oil primarily, but the significant thing is that there are other smaller levels of nutrients, other than the major nutrient elaborated.

About the turn of this century in Illinois Experiment Station, a team of geneticists showed that if you selected maize for high protein from the mean level of about 10.9 per cent, after fifty years, they were able to double it, but this is in about 50 years, so with the sophistication of extension methods nowadays, it would seem that the real answer could well be instead of trying to improve these things by breeding, to encourage people to change their food habits.

Mr. Doku :

Mr. Leslie, you stated that yields of root crops are low. I wish to inform you that in West Africa compared with the cereals, the yield of root crops is certainly higher than the cereals. You could easily get about 5 tons per acre for most of the root crops, whereas for two crops per year of cereals you might get something less than that.

Mr. Leslie :

I do appreciate that there are variations from one country to another, but in general, I think that yields are low.

Mr. Francis :

Mr. Chairman, I thought it unfortunate that Mr. Leslie did not point out the fact that temperate agriculture has emphasised traditionally the production of cereals. and foods for people in temperate climates, whereas, in tropical agriculture we have to emphasise the production of raw materials and export commodities. I thought that this was particularly important, in view of the fact that he made an observation in his first paragraph, to the effect that these contrasts emphasise that once the primitive technology and low agricultural productivity of tropical agriculture which certainly is not the case, we point to productions like sugar, rubber, cocoa, coffee, and a wide variety of products, which we produce primarily for export. I think if even a small proportion of our agriculture and investment in these paticular areas were devoted to production of root crops, and if the research in our institution here was devoted to a larger extent to the production of root crops, productivity in agriculture would be considerably increased.

Dr. Edwards :

I am tempted to ask the Dean to comment on this, but I think I'll allow someone else to.

Mr. Ferrer :

The question I would like to ask is whether the market for starchy root crops is likely to expand or to grow in time. I asked the question because not so long ago I happened to be in England and I had a few discussions with some of the people who handle tropical products in the United Kingdom and a number of them expressed apprehension about the growth of the market in that the sons and daughters of people who now eat starchy root crops in the U.K. are growing up in a new environment, they are eating in the canteen with other English people, and they are losing taste for things like yams, tannias, and even things like pigeon peas. They are growing up on Irish potatoes and cabbages and cauliflower and such products and on the whole, the younger generation of these people are moving away from these root crops.

Mr. Persaud :

Mr. Chairman, I wonder if the problem of root crops in tropical countries is not one of demand, in the sense that demand for them is not really responsive to changes in incomes. This means that over time, you have a circular decline in prices, or the terms of trade are adverse to the people producing them. It may lead to this. Also we have an inelastic demand for these products, which means that with any increase in supply, prices tend to fall. These tend to discourage the production of these crops and probably leads to this problem of low productivity.

Dr. Edwards :

We have time for one last question or comment.

Mr. Hendrick :

We in the Solomons appear to be rather fortunate in view of what has been said, and what is said in this paper. We have no land shortage, we have no food shortage, but we do, however, have one thing in common — we have a tremendous marketing difficulty mainly due to the widespread nature of the country (a large number of islands and very poor communications). In an attempt to get over this, we have been forming a large number of co-operative societies, producer societies and marketing societies, and to date I think it is fair to say that they have been working reasonably well. In our producer societies we are attempting to bypass the one-man one-acre system which is predominant in the tropics, and this allows use to mechanise more easily and makes the extension work easier too.

SOME ECONOMIC ASPECTS OF ROOT CROP PRODUCTION

WITH PARTICULAR REFERENCE TO THE ECONOMICS OF PRODUCING CARBOHYDRATES FROM ROOTS AS COMPARED WITH OTHER SOURCES IN PRIMITIVE, DEVELOPING AND ADVANCED ECONOMIES

— by —

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Both in the tropics and in the temperate regions of the world much dependdence is placed on root crops as a source of starchy food. The sweet potato, yams and cassava are the most important of the tropical root crops, but in certain areas, eddoes, dasheen, cocoyams, taros and tania are also of importance. The Irish potato is the major root crop grown for human consumption in the temperate regions, but it is also found in certain tropical environments, particularly where cool periods occur or where favourable locations exist at higher altitudes.[1] Sugar beet is of considerable importance in some temperate countries, but this crop will be dismissed from the coverage of this paper on the grounds that it is grown for its sugar content and is therefore hardly comparable with the other starchy roots. Fodder roots, such as mangolds and turnips, which are grown for feeding to ruminant livestock and not for direct human consumption, play an important role in the farming systems of some temperate countries and must be considered in any discussion on the economics of root crops. Again, in some of the developed countries root crops have some part to play as a source of supply of raw material for industrial purposes such as alcohol production. There are a host of other root crops including carrots, beetroot and arrowroot, but except in specific areas these can be relegated to the category of minor crops.

THE PATTERN OF WORLD CROPPING

A rough indication of the area occupied by major world crops, together with yield and production estimates, is available from the Food and Agriculture Organisation of the United Nations.

Table I. Summary of Area, Yield and Production of Major World Crops, 1961/62

Crop	Area (million hectares)	Yield (100 Kg. per hectare)	Production (million metric tons)
Wheat	202.8	11.7	236.7
Rye	28.5	12.5	35.5
Barley	62.5	13.7	85.7
Oats	39.6	13.6	51.4
Maize	103.1	20.8	214.0
Millet & Sorghum	99.1	6.9	68.3
Rice, paddy	119.4	20.3	242.2
Total Cereals	**655.0**	—	**933.8**
Potatoes	25.0	112.2	280.8
Sweet Potatoes & Yams	16.2	70.0	113.5
Cassava*	8.0	93.0	74.8
Total Pulses	**46.3**	—	**28.7**
Total Oilseeds	**104.8**	—	**81.3**
Cotton	34.9	3.1	10.9

Source: F.A.O., *Production Yearbook*, Vol. 16, Rome, 1963.

* Not listed as a major crop.

1 An example of a favourable environment of this character is the Christiana area in the central uplands of Jamaica.

Potatoes, sweet potatoes, yams and cassava occupy only 7.5 per cent of the area taken up by cereal crops; nevertheless, their total production in terms of weight represents 50 per cent of total grain production. But the starchy root crops have moisture contents ranging from 63 per cent for fresh cassava to 78 per cent for potatoes, whereas typical moisture contents for grain crops would range from 10 – 13 per cent.

The bulkiness of root crops and their relatively low value per unit of weight, pose problems in relation to their movement. These features of the starchy root crops to a large extent explain their lack of importance in the international trade in agricultural commodities. They are essentially food crops produced for local consumption on domestic markets, but it would be erroneous to classify them simply as subsistence crops. In addition to production for subsistence they are also produced for sale on domestic markets, and in small quantities, may enter into the export trade. Thus the root crops are not only subsistence crops, but are also cash crops being sold or exchanged mainly for local consumption. The extent to which crops are grown for subsistence as opposed to their production for sale will vary considerably depending on the region, the season and the type of crop in question, but fairly complete figures are available for the Congo to show the percentage of African production of certain crops that were marketed in the period 1955-59.

The proportion of production marketed ranged from 11 per cent for millets and sorghums and sweet potatoes to 65 per cent for rice, with cassava holding an intermediate position. Much of the demand for marketed food crops stems from the population of the urban centres and this is often expressed in the form of a preference for the higher-grade cereals such as rice, maize and imported wheat rather than the starchy roots.

Table 2. Sales as Proportion of Estimated Total African Production of Selected Crops : Congo (former Belgian), Average 1955/59.

Crops	Percentage
Maize	32
Millet & Sorghum	11
Plantains	65
Groundnuts	11
Rice	21
Sweet Potatoes	22
Cassava	55
Bananas	33
Peas & Beans	28

Source: K.C. Abercrombie, 'The Transition from Subsistence to Market Agriculture in Africa South of the Sahara', *Monthly Bulletin of Agricultural Economics & Statistics,* F.A.O., Vol. 10, No. 2, 1961.

DIETARY PATTERNS

Dietary habits vary markedly from country to country, and in fact, also exhibit considerable regional and group differences within a country. The dietary pattern may reflect the agricultural production that predominates in the area, but this itself may be determined by the physical environmental conditions as well as by other factors such as tradition, the extent of technical knowledge, the man-land ratio and other forces. Again, apart from being influenced by considerations arising on the supply side, the dietary pattern may be moulded by demand conditions. The price of foodstuffs, price differentials between different foods on the market, the purchasing power of the consumer and custom and tradition all have marked influences. This paper is concerned primarily with production rather than consumption, but the two topics are closely interwoven and are virtually inseparable segments of a single problem.

The diet of the mass of the population of the tropics depends essentially on the foodstuffs that are produced locally, and at early stages of development, little reliance is placed on food importations except in respect of a fairly narrow range of items. With a locally based food economy considerable importance attaches to the question of whether restrictions exist in relation to the range of crops that can be grown successfully in a particular environment. Difficulties arising from physical causes such as soils or climatic conditions can therefore be important determinants of the pattern of production and of the pattern of diet. Starchy foods represent the major items in the dietary of the subsistence and less developed economies, but the degree to which different communities rely on grain or on roots as their staple food crop varies considerably. Some economies are almost entirely grain orientated, others rely basically on root crops as their source of starch, while some fall into an intermediate category relying on both sources of supply. Root crops can be grown in the tropics in a variety of soil types where rainfall is adequate. Their production is widespread, but they are associated particularly with the tropical rain forest zone. Grain production, on the other hand, is favoured in drier areas of lower rainfall. In Africa, for example, as one moves from the drier areas towards the tropical rain forest, the importance of cereals in the diet declines steadily and there is a tendency for them to be replaced by the starchy roots and plantains. Table 3 illustrates this point by reference to the consumption of selected foodstuffs in savanna and tropical forest areas.

Table 3. Consumption of Selected Foodstuffs in Savanna and Tropical Forest Areas

Geographical Zone	Latitude (North)	Cereals	Roots & Tubers (including plantains)	Legumes
		(Kilograms per person per year)		
Sudanian Zone (Mali)	15°	229.1	1.2	9.9
Sudanian Zone (Togo)	11°	108.3	25.6	32.5
Guinean Zone (Togo)	8°	70.2	349.8	7.5
Guinean Equatorial Zone (Togo)	6°30′	52.5	432.6	7.6
Guinean Equatorial Zone (Ivory Coast)	6°30′	9.8	766.1	1.8

Source: F.A.O., *Africa Survey,* Rome, 1962.

The same source has shown that farmers in the Warri Province of Southern Nigeria derive 75.5 per cent of their total calorie intake from roots and tubers (cassava, yam, sweet potatoes) and only 2.5 per cent from cereals (millet and Guinea corn). In the case of farmers in the Niger Province of Northern Nigeria, however, the importance of starchy roots and cereals is reversed. Here only 1.7 per cent of total calorie intake is derived from roots and tubers, while 91.6 per cent comes from cereals.

As one moves from a country where the economy is based on subsistence agriculture to one possessing a more diversified economy with a broader based commercial agriculture, one finds that diets become more varied and more nutritious. Wright[2] has illustrated this point by reference to the pre-war patterns of food consumption in different European countries at varying levels of development. As one moves from Eastern and South-Eastern Europe, through the Mediterranean and Southern European countries, to Central and Western Europe and on to Scandinavia and finally to the United Kingdom, the percentage of total calories supplied by grain and potatoes declines from 75 per cent to 34 per cent, while the contribution of animal products, oils and fats, sugar and other foods (including fruit and vegetables) increases. Again, as national income rises and industrial development takes place, food imports may become of increasing importance and these allow for further diversification of food consumption. The marked change that has occurred in the pattern of diet in the United Kingdom over the period 1880-1955 can be used to illustrate this trend towards improvement in the balance of diet.

Table 4: Estimated Percentage Distribution of United Kingdom Calorie Supplies, 1880 and 1955

Kind of Food	1880	1955
Grain and Potatoes	55	32
Animal Products	21	27
Oils and Fats	5	18
Sugar	13	16
Other Foods (including fruit and vegetables)	6	7
ALL FOOD	100	100

Source: N.C. Wright, *Proceedings of Conference 'Agriculture in the British Economy'*, Imperial Chemical Industries Ltd., London, 1957.

The type of change that occurs with economic development is one involving a decrease in dependence on the starchy foods in the form of cereals and root crops and an increase in reliance on animal products, fats and oils, sugar and other miscellaneous foods. From a nutritional viewpoint these dietary changes are to be welcomed and they also provide for increased palatability of the food intake as opposed to a dull and monotonous diet based primarily on the more starchy foods.

2 N. C. Wright, **Proceedings of Conference 'Agriculture in the British Economy'**, Imperial Chemical Industries Ltd., London, 1957.

Nevertheless, starchy foods still represent an important constituent of food supplies in the developed countries while remaining major items in the dietary of primitive and developing ones. Data for certain selected countries to show the net food supply per caput and the proportion of total calories derived from cereals and from potatoes and other starchy foods are given in the Appendix Table.

A CASE STUDY OF FOOD CONSUMPTION IN JAMAICA

Food balance sheets for Jamaica have been prepared for the years 1942 and 1958 and these provide indicators of per capita food consumption and of changes in the availability of locally produced and imported foods in the West Indies environment. Inevitably, the degree of accuracy of these estimates will depend upon the soundness of the data relating to the volume of local food production, but despite certain limitations, they at least provide information which allows for generalisations.

A radical change in consumer habits occurred between 1942 and 1958. The per capita intake of cereals increased by 101 per cent while there was also a notable increase of 87 per cent in the figure for animal products. On the other hand, the per capita intake of roots, tubers and other starchy foods declined by 48 per cent. Reduced consumption of pulses and nuts also occurred, but considerable increases were shown in the per capita intake of fats and oils, sugars and syrups, and vegetables and fruits. Although the per capita increase in total calories consumed per day was relatively small there was a striking increase of approximately 28 per cent in protein intake and in all probability the quality of the protein consumed had also improved. It was concluded that on average the population was better fed in 1958 than in 1942.

In 1958, 78 per cent of the total food consumed was supplied from local production. But almost all the cereals (94.5 per cent of total supplies) were imported, compared with only 1.6 per cent of the total in the case of the roots, tubers and other starchy foods. These two groups, cereals and roots etc., provided more than one-half of the bulk of the Island's food supply, but twice as many calories were supplied by the cereals as by the starchy roots. This latter group, for example, provided 38 per cent of the total food in terms of kilograms per capita, but provided only 17 per cent of the total calories and 11 per cent of the protein. Corresponding figures for cereals were 16 per cent of the bulk, 34 per cent of the total calories and 40 per cent of the total protein. In the West Indian context, however, breadfruit, banana and plantains provide a considerable proportion of the total intake falling in the category roots, tubers and other starchy foods and when these items are excluded the contribution of roots and tubers to the food supply becomes correspondingly less.

Table 5. The Consumption of Starchy Foods and their Contribution in Terms of Calories and Protein, Jamaica, 1958

Food Item or Group	Kilograms per year	Calories per day	Protein per day (grams)
	(.......... Per Caput	Consumption	..........)
Potatoes - Irish	5.74	11.01	0.27
Potatoes - Sweet	6.69	17.78	0.20
Cassava	3.06	9.15	0.08
Cocoes (Taro)	6.66	15.70	0.27
Yams	37.78	93.17	2.17
Yampies	0.09	0.22	0.01
Total Roots and Tubers	*60.02*	*147.03*	*3.00*
Breadfruit, Banana, Plantains	130.13	236.91	3.34
Total Roots, Tubers & Other Starchy Foods	*190.15*	*383.94*	*6.34*
Cereals	81.35	790.62	23.06
Total Roots, Tubers Other Starchy Foods & Cereals	*271.50*	*1,174.56*	*29.40*
ALL FOODS	*505.91*	*2,292.01*	*58.02*

Source: Based on data contained in '*Food Consumption in Jamaica*', Division of Economics & Statistics, Ministry of Agriculture and Lands, Kingston, Jamaica, 1962.

CROP YIELDS AND PRODUCTIVITY

In any economy where a large part of the agricultural output is retained for subsistence consumption, problems inevitably arise in relation to the valuation of the products consumed. To overcome problems of this type and to assist in the measurement of output of different crops under circumstances where only a small portion is traded for money, there has been a tendency to apply as a unit of measurement the kilogram of grain rather than the money value. The outputs of different crops can be converted to their grain equivalents at the rate at which they exchange against grain in local markets for the purpose of making comparisons. F.A.O. has adopted a weighting system based on regional wheat relative price weights, and food consumption data or agricultural output for different products can then be expressed in terms of their wheat equivalents. Under such a system of weights, Irish potatoes have been given a weight of 0.65, sweet potatoes 0.30, cassava 0.23, and maize 0.75, – compared with the unit weight of 1.00 attaching to wheat. Clark and Haswell have applied the wheat equivalent system to yield data for different crops derived from various sources.

Table 6. Cereals and Root Crops in terms of Kg. Wheat Equivalents/per hectare

Crop	General Estimate for All Africa		Ghana	
	Crop Kg./ha.	Kg. Wheat equivalent/ha.	Crop Kg./ha.	Kg. Wheat equivalent/ha.
Maize	1,790	1,340	712	533
Eleusine millet	953	650		
Cassava	14,280	3,285		
Sweet potato	6,080	1,824		
Yams	9,790		9,850	4,660
Rice (rough)	795	646		

Source: Colin Clark and M.R. Haswell, *The Economics of Subsistence Agriculture*, MacMillan, London, 1964.

Thus, on the basis of productivity per area of land expressed in kilograms of wheat equivalent per hectare, the root crops compare very favourably with the cereal crops. Calculations of this type depend heavily on the levels of yield which are capable of being achieved for different crops in the same locality. There is evidence to show that crop yields fluctuate considerably and this fluctuation applies both to roots and to cereals. But the root crops can form a valuable food reserve at times when other crops have failed or have been attacked by pests and diseases. They can be harvested over a period of time, and in some instances, can be stored best in the ground and drawn upon as required or in times of famine.

The yield factor is a decisive one in relation to the economics of crop production and this applies both to cereals and to root crops. A certain breakeven level of yield has to be achieved before the fixed inputs are covered but these fixed inputs are generally higher in the case of root crops than cereals. The investment of inputs (whether in the form of unpaid labour or cash labour, in fertilisers and planting material), tends to be greater and hence the elements of risk is a factor to be taken into account.

Research into the problems of food crop production in the tropics has lagged in comparison with work on the export commodity crops. The impact of modern technology has hardly made its appearance and there is a natural reluctance to incur cash outlays on the purchase of inputs such as fertilisers, for crops that are destined for consumption rather than for sale. There are likely to be fairly spectacular improvements in relation to the levels of yield of all food crops, cereals and roots included, as research and technological breakthroughs are achieved and the results are disseminated and applied. Even in the developed countries advances are still taking place in relation to crop yields and some figures from the United Kingdom can be used to illustrate this continuing upward trend.

Table 7. Crop Yields per Acre, United Kingdom, 1950 – 1964 (Av.)

Period	Wheat	Barley	Oats	Potatoes	Turnips
	(cwt.)	(cwt.)	(cwt.)	(tons)	(tons)
Average 1950-59	24.2	22.6	19.3	7.7	16.5
Average 1960-64	31.1	27.5	22.2	8.8	18.9

In countries, such as the West Indies, where land resources are limited, one of the principal ways of raising production to keep pace with expanding population, is by raising yields per acre. This applies particularly in the case of developing countries which have to rely largely on their own resources for food and can ill-afford foreign exchange for heavy food importations. Increasing the productivity of land, however, need not imply only the raising of crop yields, but may also embrace changes in the pattern of farming and a switch towards high-value crops as opposed to low-value crops. Here it is important to bear in mind the distinction between increases in land productivity in terms of calories or other measurements of food values and its measurement in money values. Increasing the acreage devoted to roots at the expense of cereals, for example, may increase the output of calories per acre, but productivity measured in money values may go up or down depending on the relative prices of roots and cereals.

LABOUR REQUIREMENTS AND LABOUR PRODUCTIVITY

In many subsistence and developing economies the main limiting factor to increased agricultural output is not the lack of available land, but the availability of labour to undertake the essential seasonal tasks. Mechanisation is in its infancy in these economics and the digging stick and the hoe are still the main tools in the hands of the peasant. What he is able to produce depends essentially on the amount of labour that he is able to apply to the land and the extent of his cultivation will depend on the quantum of labour that he is able to deploy, particularly during the busy seasons. The average investment of labour to land is high in peasant farming, and root crops in particular, tend to be labour-demanding: their labour requirements per acre are greater than those of cereals. Raeburn, Kerkham and Higgs have provided some data relating to labour requirements and their distribution for the main tropical savanna crops in Africa. They have also related these labour-requirements to the yields per acre to arrive at the yield per man day.

Table 8. Labour Requirements of Selected Tropical Crops

Crop	Preparation of land	Establishment of crop	After Cultivation	Harvesting, threshing, store work, etc.	Total	Yield Per Acre	Yield Per man day
	(............ man-days per acre				............)	(lb.)	(lb.)
Maize	15	9	13	19	56	16,00	27
Sweet Potatoes	16	19	16	21	72	5,430	75
Yams	27	17	61	39	144	8,750	67
Cassava	6	19	63	38	126	12,650	109
Large Millets	6	3	11	11	31	852	27

Source: J. R. Raeburn, R. K. Kerkham, J.W.Y. Higgs, *Report of a Survey of Problems in the Mechanisation of Native Agriculture in Tropical African Colonies,* H.M.S.O. London, 1950.

Notes: (a) Costs of opening land from bush or grass are not included.

(b) Yields are expressed in terms of threshed grain, seed cotton, shelled nuts and fresh roots per acre.

The total labour requirements per acre for the starchy root crops are considerably higher than those for maize and millet. Much of the difference arises due to the heavy demands that the root crops make in after-planting cultivation such as weeding, and also in harvesting the bulkier crops. In terms of yield of product per man day expended, the root crops produce a larger bulk per unit of labour, but this takes no account of value either in money or nutritional units. Clark and Haswell, however, have converted these and other data from African sources to kilograms of wheat equivalent per man hour.

Table 9. Productivity of Labour in terms of Kg. Wheat Equivalent per Man Hour for Selected Crops - Africa

Crop	General estimate for all Africa	Nyasaland (1938) Hill Village	Nyasaland (1938) Foothill Village	Nyasaland (1938) Lake Village	Ghana
	(..........Kg. wheat equivalent per man-hour..........)				
Maize	1.49	1.19	0.86		0.81
Eleusine millet	1.30	0.08	0.28		
Cassava	1.75			3.39	
Yams	1.58				2.96
Rice (rough)			0.45		

Source: Colin Clark and M.R. Haswell, *The Economics of Subsistence Agriculture,* MacMillan, London, 1964.

These and other similar data suggest that the starchy root crops, despite their heavy labour requirements per unit of land, represent a sound form of land use as a food crop under a wide range of African conditions and that a unit of labour devoted to their cultivation produces a higher quantum of product, measured in terms of Kg. wheat equivalent, than cereals. Where climatic and soil conditions are less or more favourable the results obtained may differ considerably from those shown in Table 9. In most countries labour is the most important cost item in agricultural production, and to a very large extent, differences in labour requirements for different products are reflected in their relative prices, except insofar as this tendency may be offset by the forces of demand.

Wide differences exist in the number of man-hours required to produce 100 kilograms of crop product in countries at different stages of economic development. For example, F.A.O.[4] has published figures to show the range in the man-hours required, on a national average basis, to produce 100 kilograms of wheat, barley or rice. In the United States and Argentina, under conditions of extensive cultivation, the labour requirement was 1-2 man-hours compared with 4-5 man hours in most Western European countries and 30-50 man-hours in the less developed countries. For potatoes the corresponding man-hour requirements were 1,2-5 and 6-16 for these different countries at different stages of development. Where lower productivity of labour exists this is often compensated for by its lower cost, but the wide differences in labour productivity reflect differences in levels of yield, intensity of farming and the extent to which labour is aided by mechanisations. The extent to which different agricultural products and different

4 **The State of Food and Agriculture,** F.A.O., Rome, 1963.

tasks in relation to these products lend themselves to the application of mechanisation will obviously vary. In similar fashion, the complexity of applying mechanisation and its costs, will also vary. Raeburn, Kerkham and Higgs have examined some of the problems associated with mechanisation of African agriculture and their findings indicate that greater scope exists for mechanising the production of cereals than starchy roots.

Table 10. Proportions of various Labour Tasks that could be accomplished with the aid of mechanised equipment : Selected Tropical Crops, Africa

Crop	Preparation of land	Establishment of crop	After Cultivations	Harvesting, threshing, etc.	Total for all Operations
	(..............	Per cent of	man-days per acre	....	)
Maize	100	100	60	50	73
Sweet potatoes	100	60	40	30	57
Yams	100	80	40	30	54
Cassava	100	Nil	60	Nil	33
Large millets	100	100	60	100	85

Source: J.R. Raeburn, R.K. Kerkham, J.W.Y. Higgs, *Report of a Survey of Problems in the Mechanisation of Native Agriculture in Tropical African Colonies,* H.M.S.O., London, 1950.

Under United Kingdom conditions the same conclusion has been reached by Nix who has drawn attention to the relatively poorer economies in labour that have been achieved for potatoes compared with certain other crops. But looking ahead to 1970 he anticipates the labour demand for potatoes to change more markedly with the application of further mechanisation and new husbandry methods.

Table 11. Labour Requirements for Cash Crops, United Kingdom 1930–70

Crop	1930	1950	1960	1970(?)
			hours per acre	
Potatoes	215	195	140	60
Sugar Beet	235	180	120	20
Wheat	53	33	17½	6½
Barley	54	23	12½	6

Source: J.S. Nix, 'Labour for Cash Crops, 1930–70' *Agriculture* Vol. 68, No. 3, 1961.

Spectacular reductions in labour requirements can be achieved in agriculture by the application of mechanisation. The benefits accruing stem not only from the substantial reduction in the amount of labour required to carry out various farm tasks, and from the lessening of drudgery, but also from the ability to undertake cultivations quickly and at the proper time. Many of these potential benefits, at the present time, are beyond the reach of the mass of producers of cereals and starchy roots in the developing countries, but scope still exists in these countries for increasing labour productivity by other means. Much benefit can result from the application of farm planning methods to maximise the returns from resource use, particularly from the scarce resource – labour, and to iron out the peaks in seasonal labour requirements. The work of Edwards[5] in Jamaica and Collinson[6] in Tanganyika has highlighted some of the seasonal variations in labour requirements for different tasks on peasant farms. The application of such data for the derivation of model farm systems for peasant farming areas has also been developed by various workers including Clayton[7] in Kenya.

SOME ECONOMIC ASPECTS OF ROOT CROP PRODUCTION IN THE UNITED KINGDOM

Certain broad generalisations can be made in relation to the economics of crop production. Firstly, the profit per acre depends on the relationship between the cost per acre and the value of the product. But the cost per acre is itself the resultant of a number of highly variable factors such as the individual cost of seed, fertilisers and other inputs. Again, the value of the product itself depends on the yield per acre and on the selling price realised per unit, together with the value of any by-product. Thus one can say that the profit per acre is determined largely by the relationship between the cost per acre, the yield per acre and the selling price per unit. Broadly speaking, the price of the product is beyond the control of the farmer, except insofar as it may be influenced by quality or by the time at which it is marketed. On the other hand, both the cost and the yield per acre are, at least partly, under the farmer's control. Yields, of course, will vary considerably from one geographic area to another depending on the environmental conditions under which the crop is grown, but they will also vary from year to year on the same farm due to differences in seasonal conditions. It is one of the aims of good management to prevent undue fluctuations in the level of crop yields and to maintain them at a high level compatible with other considerations.

Looking at costs of production of potatoes and cereals in the United Kingdom on the basis of data derived from enterprise costs studies, one is struck immediately by the far greater outlay that is involved in respect of potato production.

Total costs for potato production averaged nearly £115 per acre compared with average figures of from £17 to £24 for cereals. In arriving at enterprise costs of this type a good deal of purely arbitrary allocation of items of an overhead nature has been involved, and today, farm costs are normally looked at on the basis of whether they are variable or fixed cost items. This division of costs into these two categories recognises the fact that the farm as a production unit is an integrated business and not merely a collection of independent enterprises. Variable costs are those costs that are readily allocatable, are clearly specific to the particular enterprise and vary with the scale of production, while fixed costs are those costs which are part-and-parcel of the system of farming as a whole, not readily attri-

5 D. T. Edwards, **An Economic Study of Small Farming in Jamaica**, University College of the West Indies, 1961.

6 M. P. Collinson. **Farm Management Survey, Report No. 3**, Ministry of Agriculture, Tanganyika, 1964.

7 E. S. Clayton. 'Economic and Technical Optima in Peasant Agriculture', **Journal of Agricultural Economics**, Vol. XIV, No. 3, 1961.

Table 12. Crop Costs Per Acre, United Kingdom

Crop	Potatoes(1)			Cereals(2) (Harvesetd by binder)			Cereals(2) (Harvested by Combine)		
	(£	s.)	(%)	(£	s.)	(%)	(£	s.)	(%)
Variable Costs									
Seed	22	5	19.0	2	2	8.5	2	4	12.5
Fertiliser	9	8	8.5	3	5	13.5	3	4	18.5
Casual Labour	11	3	10.0	0	8	1.5			
Contract Work	7	11	7.0	1	8	6.0			
Sundries	5	14	4.5	0	17	3.5	0	4	1.0
Total Variable Costs	**56**	**1**	**49 0**	**8**	**0**	**33 0**	**5**	**12**	**32 0**
Fixed Costs									
Regular Labour	20	2	17.5	5	5	22.0	2	2	12.0
Tractor Costs	6	6	5.0	2	2	8.5	1	8	8.0
Specialised Equipment	5	12	5.0				1	9	8.5
Rent	5	6	4.5	4	0	16.5	4	0	23.0
Overheads	21	6	19.0	4	16	20.0	2	18	16.5
Total Fixed Costs	**58**	**12**	**51 0**	**16**	**3**	**67 0**	**11**	**17**	**68 0**
Total All Costs	114	13	100.0	24	3	100.0	17.9		100.0

Sources: (1) *Potato Costs*, 1965 Crop, North of Scotland College of Agriculture.
(2) Unpublished Crop Costs data, North of Scotland College of Agriculture.

butable to any particular enterprise and not avoidable in the short-run. This concept of variable and fixed costs is used increasingly today in the gross margin system for farm analysis and planning, the gross margin for an enterprise being the difference between the output of a crop and its variable costs, and representing that enterprise's contribution towards covering the fixed costs of the farm and profit. Some idea of the relative level of current gross margins for different crops under Scottish conditions is provided in Table 13.

In the United Kingdom context, potatoes are a cash crop whereas cereals may be grown either for sale or for consumption by livestock on the farm. Irrespective of the utilisation of the crop, however, the farmer is seeking to equalise his returns from the last acre of land, the hour of labour or the last £1 of capital invested in his various enterprises. If we apply as our criterion of selection the yardstick gross margin per acre, then in relation to cereals, his returns are maximised by growing as many acres of potatoes as the various constraints allow. However, these constraints in the shape of rotational considerations, basic potato acreage allotment, labour availability at peak periods, capital uncertainty and an unwillingness to over-invest in a relatively risky crop, result in early limits being placed on the acreage of potatoes that can be grown on most farms. Generally,

Table 13. Gross Margins Per Acre, Scotland (current values)

Crops	Yield	Price	Gross Output	Variable Costs	Gross Margin
	(tons per acre)	(per ton)	(£)	(£)	(£)
Potatoes :					
Earlies	6	£22	132.00	81.20	50.80
Maincrop Ware	9	£13	117.00	71.25	45.75
Maincrop Seed	5 seed; 3 ware	£27 seed; £11 ware	168.00	86.20	81.80
	(Cwt. per acre)	(Per Cwt.)			
Oats :					
Crop on High Ground Bindered	22	18.6s.	27.55	6.85	20.70
Crop on Low Ground Combined	28	18.6s.	33.14	5.40	27.70
Barley:					
Combined & Sold Sept. to Oct.	32	18.00s.	34.60	6.55	28.05
Combined, dried, stored and sold Jan. to Feb.	32	19.25s.	39.40	6.55	32.85
Wheat :					
Combined & Sold, Oct.	40	18.0s.	43.05	9.20	33.85
Combined, dried, stored and sold Mar. to Apr.	39	20.5s.	53.10	9.20	43.90

acreage constraints on the area of cereals that can be grown on arable farms do not operate at such an early point as they do with potatoes, and thus there is a tendency on farms endeavouring to maximise their total gross output to expand their cereal acreage very considerably. In fact one of the features of arable farming today, particularly where efforts are being made to take advantage of economies of scale by spreading fixed costs over a large output, is to plant an increasingly larger proportion of farm acreage to cereals and to follow a trend towards continuous cereal growing. However, profitable production of cereals and of potatoes, as with other farm enterprises, depends essentially on the manner in which the various enterprises fit into the economy of the farm as a whole.

Because of the high costs of potato growing a high output is essential for profitable production. But fairly violent fluctuations in yield take place and these cause unstable supply conditions. On the other hand, in the short-run, consumer demand is stable and is relatively unresponsive to changes in price. Thus the value of output per acre of potatoes shows a high degree of variability, but nevertheless there is a close relationship between the level of the yield and the level of gross margin per acre.

Fodder roots such as turnips and swedes still play an important part in the economy of British livestock farms even though the acreage grown has decreased considerably over recent years. In Scotland, for example, the acreage devoted to turnips declined by nearly 38 per cent between 1945 and 1963. Prior to the 1939/45 war, turnips supplemented by hay were the main foods fed to cattle, but more recently on many farms they have been displaced by silage. One of the main factors behind this trend has been the difference in labour requirements between the two crops. Figures from recent surveys in the North of Scotland show the average man-hours required per acre for turnips to be 56 compared with only 11 for silage. But with the introduction of pre-emergence spraying techniques and more efficient mechanised harvesters there could well be a resurgence of interest in growing of roots for fodder. On farms where turnips were harvested by hand the total labour requirements per acre averaged 96 man-hours, but this total dropped to 57 when turnips were harvested by puller and to 50 when the crop was mechanically harvested. One of the ways in which turnips and silage can be compared is on the basis of the cost per ton of starch equivalent. This calculation will depend heavily on the relative level of yield per acre, and the costs per acre – chosen as the basis of comparison. Some figures based on data from the North of Scotland attempt to make this comparison. They indicate that if only poor to moderate yields of poor quality silage are achieved (i.e. under 7 tons at below 10 per cent S.E.) and high yields of turnips (i.e. over 30 tons) are obtained, the cost per ton of starch equivalent would be less in the case of turnips.

CONCLUSIONS

The data presented in this paper, although not conclusive and very patchy, suggest that root crops as a source of carbohydrates compare favourably with other sources. The exact relationships in terms of economics will vary with the environment and with local conditions, but irrespective of the level of development of the economy, the root crops appear to have an important role to play in terms of both their food and monetary values. As development takes place the importance of starchy roots in the dietary may well decline, but with the aid of modern technology to raise the level of yields and the application of mechanisation to offset the inherently high costs of production per acre, there is little reason to assume that the returns from growing these crops will not remain at a satisfactory level. One of the key factors contributing towards success is the achievement of high levels of yield over which to spread the high levels of input costs. This requirement is likely to call for an increasing degree of specialisation in production as development takes place. In the West Indies this might well result in the production of increasing quantities of ground provisions (apart from Irish potatoes) in the plains where conditions would allow for mechanisation as a means of increasing the productivity of labour. Traditional methods of production are likely to become less remunerative as time goes on due to their heavy labour demands and relatively low yields, and the root crops, like any other form of agricultural production, will have to adapt to changing circumstances. If adjustments in outlook, methods and location of production occur, then the starchy roots can make a very valuable contribution to the economy of the West Indies where land is limited in supply and a high man/land ratio exists.

APPENDIX TABLE I

Net Food Supply Per Caput and Proportion of Total Calories derived from cereals and from Potatoes and Other Starchy Foods, Selected Countries

		Kilograms Per Caput Per Year		Per cent of Total Calories Derived from:		
Country	Period	Cereals	Potatoes and other starchy foods	Cereals	Potatoes and other starchy foods	Cereals, Potatoes and other starchy foods
United States	1961	66	47	21.4	3.0	24.4
Australia	1960/61	86	40	27.2	2.5	29.7
New Zealand	1961	87	61	24.7	3.4	28.1
United Kingdom	1961/62	81	97	24.7	5.8	30.5
Germany, Fed. Rep.	1961/62	79	128	26.8	8.5	35.3
Ireland	1961	107	140	31.0	7.8	38.8
Italy	1961/62	136	55	47.0	3.8	50.8
Greece	1960	163	36	53.1	2.4	55.5
Ecuador	1960	69	96	31.7	8.5	40.2
Mexico	1960	123	9	47.6	0.8	48.4
Brazil	1960	106	123	38.3	13.3	51.6
Honduras	1954/55	118	9	52.1	1.1	53.2
Paraguay	1957/59	84	229	33.2	26.7	59.9
Mauritius	1961	126	12	53.4	1.0	54.4
South Africa	1959/60	138	21	52.7	1.6	54.3
Japan	1960	150	68	62.6	6.8	69.4
India	1960/61	140	11	66.5	1.4	67.9
Pakistan	1960/61	158	4	78.3	0.4	78.7

Source: Based on data contained in F.A.O., *Production Yearbook*, Vol 16, Rome, 1963.

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STARCHY ROOTS IN THE DIETARIES OF DEVELOPING TROPICAL COUNTRIES

— *by* —

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The Food and Agricultural Organization of the United Nations regularly publishes food balance sheets for about 65 countries. In 38 of these, starchy roots and tubers and starchy fruits provided more than 100 calories per person per day in 1964/65 ; in Poland and Colombia they provided more than 400 calories, in Paraguay more than 700, and in Uganda almost 1,000 calories. Not included in the set of food balance sheets are many of the countries of Africa and southeast Asia, for the very good reason that statistics of production and disposition (even statistics of populations for some countries) are so poor that the FAO statisticians have been unwilling to attempt to construct food balance sheets from them. The United States Department of Agriculture, which does not operate under the same proscription from adjusting official estimates that FAO must observe, has published estimated food balances for 90 countries. In 65 of these more than 100 calories per person per day are believed to come from the starchy roots and fruits, and in 18 countries of tropical Africa and the tropical Americas, more than 400 calories.[1] The Department estimates that in 6 of the 14 countries of tropical Africa for which it has published food balances, starchy roots, tubers, and fruits contribute more than 1,000 calories per day. Food balance sheets for geographically large countries with a wide range of climates may obscure the importance of the starchy roots over extensive areas if they include in one national total such different climatological areas as southern and northern Nigeria, or north eastern and south eastern Brazil.

In Western Europe the starchy roots are more clearly supplementary foods than staples, although they are an essential item in most menus. In Ireland, where potatoes were once the preeminent staple, they now contribute only 265 calories to the daily diet and records of the past three decades show consumption declining there, as it has been in all of the western countries except Spain and Portugal.

M. K. Bennett has demonstrated that declining consumption of the cereals, starchy roots and tubers, and starchy fruits — the starchy staples — typically accompanies an increase in per capita income, and that the starchy staple ratio may be used as an indirect measure of relative income levels. Declining con-

Countries for which the Department finds values of 400 or more calories per person per day are : Angola, 661 ; Cameroun, 1,094 ; Congo (Kinshasha), 1,506 ; Ghana, 1,297; Guinea, 646; Ivory Coast, 1,537; Liberia, 756; Malagasy Republic, 506; Nigeria, 1,219 ; Sierra Leone 583 ; Tanganyika, 1,389 ; Togo 1,063 ; Brazil 568 ; Dominican Republic, 555 ; Ecuador, 553 ; Haiti, 439 ; Panama, 447 ; Paraguay, 704. Estimates were not published for Uganda. The very tentative character of many of these estimates is illustrated by the figure for Nigeria, which implies that 50 per cent of all food calories come from yams and manioc. This figure seems reasonable, or even a little low, for the Southern Regions, but more than half of the country's population lives in the Northern Region, where the roots are a minor element in the diet.

sumption of starchy roots appears to be an aspect of the declining starchy staple ratio. Records for the United States, however, show the rate of decline in potato consumption to have been less than for the cereals over the period 1880 to 1960. Perhaps this is not surprising given the much greater importance of cereals at the beginning of the period when wheat flour contributed 1,000 calories a day and cornmeal 652 calories against 168 from white and sweet potatoes. By 1910 wheat flour consumption was unchanged, but maize products and potatoes were about equal at 229 and 189 calories. By 1959, consumption of wheat flour had declined nearly 50 per cent from this level, as had potatoes, but maize products were off 85 per cent and provided only about one-third as many calories for human consumption as did potatoes.[2]

II

The great prominence of root crops in tropical diets results essentially from the large amount of food calories they yield per unit of cleared land, in agricultures where a major cost of food production is the physical effort of claiming land for cultivation. Long-fallow agriculture — shifting cultivation — today is most widespread in tropical Africa of all the continents, and estimates of yields there clearly demonstrate this superiority. For West Africa, B. F. Johnston reports yields of sweet potatoes, cocoyams, yams, and manioc of from 1.25 to 4.20 times those of the millets and sorghums in net food calories per hectare, or from slightly more than (cocoyams) to 3.5 times (manioc) those of maize and rice. In Congo (Kinshasha) manioc yields are approximately 4 times, and yields of sweet potatoes and plaintains about double, those of rice and maize.[3] Comparison of yields of manioc and other staples province by province in Congo shows manioc to outproduce maize and rice in all provinces except the high country of North Kivu, with an advantage ranging from about 10 per cent in Maniema to nearly 400 per cent in Lac Leopold II.[4] Similar comparisons for Nigeria show manioc and yam yields about the same as the cereals in the drier northern provinces but exceeding cereal yields in the south by 100 to 250 per cent. Statistics of crop yields elsewhere in the tropics reveal this same superiority of the roots, particularly of manioc, over the cereals when growing conditions are similar, a superiority frequently enjoyed also by the plantain. The high yields of manioc are less impressive where seasonal rainfall distribution permits two growing seasons. Then yield per acre per year may be little more than can be obtained by double-cropping maize or rice because of the long period the manioc crop must occupy the field. Manioc's yield advantage is most dramatic on soils so poor as to make other crops uneconomic, or in areas subject to frequent drought that may periodically make seasonal cultures a total failure.

There is something of a paradox here. The roots, and especially manioc, are highly productive of food calories in terms of natural resources utilized. But they enjoy their greatest popularity in tropical Africa where land, in the sense of

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2 M. K. Bennett and Rosamond H. Peirce, "Change in the American National Diet, 1879 — 1959", **Food Research Institute Studies, II, 2, 1961.**

3 B. F. Johnston, **Staple Food Economies of Western Tropical Africa,** 1958, pp. 126—27

4 W. O. Jones, **Manioc in Africa,** 1959, p. 259.

unoccupied geographical space, was until recent years essentially a free good and even today the space available for cultivation is still relatively plentiful in most places. If the popularity of manioc — and let us speak only of this root crop for a bit — is to be explained by the cheapness of the calories it provides, it is not enough to say that it gives high yields per acre on relatively costless land. How cheap is it in terms of the limiting factor, the amount of labour that can be employed? How many calories does manioc yield per man-day?

Statistics of labour costs of growing and harvesting the tropical starchy staples under comparable conditions are fragmentary and confusing. In general, however, they suggest that the time required to plant and to cultivate an acre of maize and an acre of manioc are roughly the same, varying with how the field is prepared for planting and how many times the growing crop is weeded. If more careful preparation of the soil is thought to be necessary for maize, this cost may be offset by the longer time required to prepare the manioc stakes for planting. Although manioc occupies the land much longer than does maize, it may be necessary to weed it no more or even less often than maize if the leafy tops establish a good canopy early. The major difference is the labour required for harvesting, but it is so because of the difference in yields, and is probably not as great as that difference even when yields are measured in calories. Moreover, because timing of the manioc harvest is not as critical as for most other crops, the opportunity cost of labour used in harvesting may be much less, an advantage enjoyed in part by maize only in colder regions. The productivity of labour up to harvest is therefore greater for the crop that yields more per acre, and the advantage may be increased when harvesting costs are added. Increased yield per acre may be taken to imply increased yield per man-day.

That this must be true — that both land and labour costs of growing manioc are low — is confirmed for Africa at least by comparison with market prices of the starchy staples. At nearly every place where manioc is available in significant quantities, some one of its products costs the consumer substantially less in caloric terms than any of its competitors. This can only be so if total production costs are less.

In comparison with starchy staple prices, the qualification that manioc *in one of its forms* will be cheapest, is necessary. In urban markets, fresh roots are frequently much more expensive than dried ones; and manioc meal (gari or farinha) may sell for quite a bit more than less highly processed forms of the dried root. That the price of a prepared foodstuff like manioc meal should reflect the additional labour costs involved in its manufacture is not surprising, nor is it unreasonable that the high perishable and bulky fresh roots should command a price sufficient to repay the transport costs and the risk of sending them into urban markets some distance from the farms where they are grown. It is a bit surprising, however, to find urban consumers willing to pay the high fresh root prices asked for what is generally regarded as an inferior good. The answer here may be that fresh manioc roots enter the diet more as vegetable than as starchy staple in the pure sense, that is, they occupy a place in the dietaries of tropical cities similar to that of potatoes in European cities. That dual character of potatoes, too, may explain their persistence in European and American diets at a low but significant level. (It is not uncommon in American restaurants to be offered a choice of two out of three "vegetables", one of which is potatoes.) In European-type diets the potato's position in menu planning reinforces its place in consumption. For manioc, the use in Brazil of farinha as a general dressing for other dishes is the nearest analogy.

It is not, however, because they are preferred as vegetables that potatoes, yams, manioc and taro have served as major providers of food calories, but rather because they have been the cheapest sources of these calories, just as in other places and in other circumstances the great cereals have supplied the cheapest food calories. That cost, not taste, is the primary determinant of the dominant position of the starchy staples is confirmed by the negative correlation between starchy-staple ratio and income. In general, we may expect that as the low income countries succeed in efforts to raise consumer incomes, effective demand for the roots and tubers, as for the cereals, should fall. As between these two major groups, we might expect that rising incomes would be accompanied by a shift from roots to cereals, followed by a decline in consumption of the cereals themselves, for there is evidence of a general preference for cereal products over root products as staple foods. But this evidence is not conclusive, and the tendency it implies may take decades to manifest itself. For useful prediction of the future position of the roots, more detailed examination of the development process and of its implications for the root crops is required.

III

The long-run goal of economic development is to increase net output per capita. Most often this means to increase consumer income, although occasionally this objective may be subordinated to that of increasing the economic power of the state. The principal means to achieve this objective is through increased specialization in production, made possible by improving productive skills and expanding the nation's resources through saving and investment.[5] Specialization and increased use of productive capital result in transfer to urban industrial centres of a large number of economic functions previously performed in the rural area; economic growth is accompanied by a relative growth in manufacturing and in services provided by transport and communication agencies, by public utilities, and by government. An increasing proportion of the population comes to live in cities, and eventually, even though total population may continue to grow, the number of people living in the countryside declines. The essential characteristics of developing countries that may be expected to affect demand for the starchy root crops are rising consumer incomes and increasing urbanization. Independently of these consequences of development, however, demand will also be influenced by continuing growth of total population, and by continuing growth of the rural population in the early period of development, a period that may extend over a number of decades. The quantitative information needed in order to make firm predictions of the effect of each of these influences on the competitive position of the root crops is lacking, but a considerable body of evidencesupports the reasonableness of speculations about their direction and sequence, even though estimation of the magnitude of the changes they may induce is beyond our grasp.

5 Specialization in itself, of course, tends to improve productive skills, and increased reliance on the market for allocation of resources and products tends to bring the members of the society who are potentially most productive into control of the productive and distributive process. Over and beyond this, however, is the contribution made by new knowledge and new skills to specialization and to productivity.

Where uncultivated lands still remain, as they do in some parts of the tropical world, larger rural populations can be fed simply by bringing more land under cultivation with the increased labour force they provide. But this cannot go on for long without forcing farmers to alter their cultivation practices. As open land becomes less available, fallows will shorten and yields decline. If there is no other change in technology,[6] the decline in nutrient content of the soils may be expected to bias production in the direction of the crops yielding more calories per acre, even though their labour costs may be relatively high. This would seem to favour the entire set of starchy roots. In fact, as land becomes dearer the relative cost advantage of manioc over yams may decline, despite, or rather because of, the greater amount of labour required in yam production. Manioc would continue to be cheaper to grow, in terms of labour and land, but the difference would be relatively less than when the cost of land was less, i.e., when the ratio of wages to economic rent was higher. Possibly the response to increasing population in Southern Nigeria was something like this in the early decades of this century. The evidence is not clear, and other changes in the economic environment were taking place at the same time. Various observers have reported, however, that southern farmers were producing yams for sale to the cities and growing manioc to feed to their families, and it may be that this represented a more rapid expansion of yam than of manioc production. If the only change is growth of population such a tendency cannot go on for long.

Increasing land scarcity must inevitably lead to declining rural incomes until farmers can no longer employ land in ways that contribute less than they might to the supply of food calories. Absolute yield advantage now takes over from relative advantage, and just as yams may have displaced competing maize, now manioc replaces yams. This shift to a less preferred staple represents a decline in consumer satisfaction, that is to say, in consumer income. It need not, however, result in nutritional deterioration of the diet if advantage is taken of the superior productivity of manioc to grow food crops with high protein content on some of the land once devoted to yams. If economic growth has progressed far enough so that farmers have market outlets for their products, some of the increased production of food calories in the form of manioc may be sold and the proceeds used to buy supplementary foods.

When the commercial economy is still more highly developed, and farmers can rely on the market for their basic food supply, relative yields may again become important, with the consequences that yam or even cereal production takes over where these crops yield best, even though manioc might yield well too, and manioc production is concentrated in areas where its competitors do very poorly. Overall, the relative contribution of manioc to rural food supply should still be expected to increase because of declining wage income in farming and rising land values. This change has in fact been observed in various parts of tropical Africa and in Indonesia, perhaps elsewhere.

Eventually, if development is carried through successfully, the time will come when rural population begins to decline. Greatly increased productivity of labour in the industrialized sector will long since have influenced wages in the farming sector too, and this, combined with the shrinking agricultural labour supply,

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6 A shortening of the fallow period is itself a technical change.

will reverse the relative importance of wages and rent in determining comparative costs of the staples. If capital can be substituted for labour equally well in the production of all starchy staples, their comparative costs will be altered less by this change in factor costs, but experience to date has been that mechanization of cereal culture is much easier to achieve than mechanization of root culture. Here the potatoes appear to fare best, the yams least well. Mechanization of manioc culture lacks only the solution of the problem of harvesting and even here appreciable reductions in labour cost can be achieved by mechanical topping and by cross-ploughing before lifting. But digging of the roots continues to require a major labour input.[7] Even when mechanical harvesting of root crops is possible, however, the cereals, because of their lesser weight per thousand calories, will tend to benefit more than the bulky roots. Mechanization achieves large savings in labour costs in the processing of the cereals and of manioc flour and meal ; it is of little importance for the other roots. Mechanization of field operations and mechanization of processing have somewhat different implications, depending upon the stage of economic growth. (These are explored tentatively in the last section of this paper.)

Economic development, however, implies that consumer incomes are rising ; for those parts of the population enjoying an increase in income, cost considerations may be expected to play a lesser part, and taste considerations a greater, in the composition of food consumption. It will probably be the city dwellers who enjoy these first fruits of increasing national productivity. Building the specialized manufacturing and processing industries to take over the functions once performed by rural populations requires that a greater part of the nation's capital stock and labour force be placed at the disposal of the manufacturing sector. Whether in a socialistic or a capitalistic state this implies relatively higher economic rewards for those engaged in the favoured urban industries than for those still employed in rural occupations. It is a persistent characteristic of the developing countries, however, that although average incomes may be higher in the city, greater poverty may be found there too. The chance for better wages in the town serves to lure the countryman in greater numbers than the new industries can absorb. As a consequence, a certain number of the migrants find themselves less well off than before.[8] On the whole, however, the urban population may be expected to enjoy a relatively higher income, and a rising one.

The revolution in effective demand for staple foodstuffs that comes with a move from country to town is fairly complex. Income, food costs and availability, and tastes as well are likely to alter. Those who experience rising income may be expected to buy more of the higher priced foodstuffs previously denied to them and total expenditure on food should increase. Engel's law says that it will increase less than income ; availability of a wide range of non-food commodities not to be found in the country will make the increase in food expenditures even less. Nevertheless, relatively high income elasticities of demand are likely to prevail in these populations for which expenditure on food accounts for such a large part of total

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7 A. Krochmal, "Labour Input and Mechanization of Cassava," **World Crops**, September, 1966.

8 Increasing population alone may produce a similar migration to the cities where poverty-stricken rural workers seek some relief from government and wealthy townsmen. The movement to the cities is a familiar aspect of the great famines.

income. This implies a decline in consumption, or at least in upgrading, of the starchy staples in terms of consumer perference.[9] Typically, upgrading takes the form of substituting rice or wheat flour for manioc and sweet potatoes, probably for taro and yams. The income effect alone for this part of the population should reduce consumption of the starchy roots as staples, although they may continue to occupy a position as vegetables at a much lower level of consumption. For the poorer city dwellers the effect might be expected to be the reverse.

Other forces alter the effect of changing incomes. Growing city populations draw their supplies from ever-widening areas, and as the supply hinterland increases, so does the cost of transport. Because of their higher moisture content, the urban prices of fresh root crops, in terms of food calories, rise much more rapidly than prices of cereals, and prices of highly perishable fresh manioc roots rise more rapidly still. The end result may be that the root crops are no longer the cheapest sources of food calories in the cities, despite their lower costs of production. But here we must again single out manioc for special attention, for it alone yields a widely accepted product in the form of manioc meal or flour which enjoys the low cost of transport of the cereals and approximates their keeping quality. Increased transportability and storability are not achieved without cost, and manioc meal is more expensive in rural markets, in calorie terms, than are fresh roots, although the relationship is typically reversed in town. At the same time, the cost embodied in the processed product yields a service to the consumer in the form of much greater ease of preparation for the plate, a matter apt to be of more significance to the townsman than to the rural householder. Higher wages mean higher opportunity cost of labour, and more rigid work schedules plus the distractions of city life mean less time for the kitchen. In much the same way that ready-baked bread and rolls make wheat flour more attractive, so does gari or farinha increase the appeal of manioc.[10]

In general, then, the competitive position of most root crops in urban diets may be expected to decline, both because of higher cost of marketing and because of higher incomes. Demand for manioc in the form of meal, however — although affected adversely by income — may be heightened by consideration of cost and convenience. For that part of the city population that is unable to find regular remunerative employment it will have an additional appeal.

IV

Let us consider what might be expected to happen in a country with a growing population and rising per capita income. Let us assume that the increase in population has already created a sufficient shortage of land so that it is being brought into higher uses and the demand for food calories is provoking a shift

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9 Household expenditure studies in tropical Africa show more evidence of upgrading than of decline in the starchy-staple ratio (cf. Poleman, Kaneda and Johnston, Jones, 1960).

10 In many African cities, where men without families make up a large part of the working force, the ease of preparation of manioc meal is of even greater importance.

toward staple foods with higher calorie yield, but without other changes in farming practices.

In the early stages of development farm population will continue to rise and the pressure for food calories will intensify. In those parts of the rural sector with few and unremunerative market outlets, the drive to higher calorie yielding crops will intensify and the kinds of shifts in cropping patterns that have been reported in many parts of tropical Africa may be expected to occur. To other farming areas, however, economic development will bring improved market opportunities, and acreage formerly devoted to subsistence crops will be planted to those bringing a higher cash return per acre and per hour. If the density of rural populations is very high and labour costs low, the shift may be in the direction of more labour-intensive crops including double-cropping when rainfall or irrigation makes this possible. In either event the area available for staples may be expected to decline. The consequent shortfall in supplies of food calories can be made good by substituting crops with higher calorie yields for those with lower yields, e.g., by growing manioc instead of yams, or it can be met by purchasing part or all of the staple food supply with proceeds from the cash crops.

Urban population rises more rapidly. Recent migrants are compelled by low incomes, changed relative prices of foodstuffs, and the opportunity for new kinds of expenditures to save on maintenance cost by consuming the cheapest staple. Earlier migrants who have found the economic advancement they sought will consume increasing quantities of the dearer, preferred staples — rice and wheat flour when they are available. For the country as a whole demand for the high-yielding roots and their products will continue to increase until development has progressed far enough so that increased purchasing power of the cities begins to offset the income-depressing effects of rising rural population. This may be a very long time indeed.[11]

If significant increases in consumer income are to be achieved, sole reliance cannot be placed on expanding the urban population and raising its productivity. In a country where city employments occupy 20 per cent of the working populations, for example, and, with urban and rural incomes equal, to increase income 2 per cent per capita per annum assuming no change in total population would require a 10 per cent annual increase in urban productivity. If town workers are already twice as productive as rural workers, it would nevertheless require a 6 per cent annual rise in urban productivity or a 12 per cent increase in urban employment. If rural productivity can be increased at a rate of only 1 per cent per year, required increases in urban productivity become 6 per cent, and 4 per cent without migration.

Increased productivity in agriculture comes about first because expansion of market economy permits specialized production of crops for which comparative advantage is high. In these early stages the export market tends to dominate all

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[11] B. F. Johnston has calculated how long it would take, at varying growth rates, for populations one-fifth urban and four-fifths rural at the outset to reach the point where urban and rural populations are equal and the point where rural population begins to decline. If total population grows at 2 per cent per annum, and the non-farm labour force at the very high rate of 4.5 per cent per annum, the farm labour force would begin to decline after about 35 years and would equal the non-farm labour force after 40 years. (Johnston, 1966.)

farming investment and research. As commercial activities in the producing country expand, however, the local market for food, and later for feed, becomes increasingly important, and specialization in production of food crops for market profitable. Many parts of the tropical world are in this stage now, and are far from exhausting the rewards that specialization can bring. As they do, new investments in food crop production become necessary if agricultural productivity is to continue to increase, investments that may take four principal forms — alteration of production methods without increased inputs of the productive factors ; improvement in planting material ; expanded use of purchased inputs such as fertilizer, pesticides, and herbicides ; and capital investment either in machines or in the farm itself. The major need for fixed capital in the industrial sector argues against similar investment in agriculture except when capital can be formed primarily by labour, as in ditching, building and levelling. The large working population in the rural areas argues against labour-saving mechanization. The indicated strategy appears to call for improving farming practices, improving varieties, and increasing the use of purchased inputs.

Productivity of the tropical starchy roots can undoubtedly be raised significantly by the use of improved varieties, as it has been for potatoes. It is not clear that changes in farm practices can significantly alter return per acre or per man day ; at least the large amount of agronomic research on manioc culture seems not to have resulted in economically important advances. It seems unlikely that economic returns from the roots will justify extensive use of scarce and costly fertilizers on a crop like manioc, although it may be profitable for roots that enter the diet as vegetables.

For manioc, but not for the other roots, there may eventually be great advantages in mechanization, especially because of the market open to this crop in its dried form. If it is to become a staple foodstuff for low income city populations, regular and large supplies of a standardized product must be obtained. It is extremely difficult to assure such supplies from a multitude of small processors. It is being done in some of the cities of West Africa, but the low returns per man hour afforded by this production suggest that output will decline as labour productivity elsewhere rises, and the highly differentiated product results in high and increasing market costs as volume of sales rises.[12] Regularity of supply is a strong argument for mechanized processing ; it is reinforced by the large labour savings that can be effected. Manioc processing by hand methods requires as much or more labour than growing and harvesting the crop, labour performed usually by women. Labour saved by mechanization cannot make much of a contribution to field operations, but it will permit the women of the household to devote more time to domestic duties and care of their children and may enable the girls in the household to obtain more formal education.

Fully mechanized processing plants have nearly always had difficulty in obtaining a regular supply of fresh roots and have most often found it necessary or desirable to establish their own plantations. On manioc plantations of any size the arguments for as complete mechanization as possible are again compelling if costs are at all comparable, for mechanical ploughing, stake preparation, planting, cultivating, cutting, and lifting could greatly reduce reliance on less dependable

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12 R. Galletti, K.D.S. Baldwin, and I.O. Dina, **Nigerian Cocoa Farmers: An Economic Survey of Yoruba Cocoa Farming Families**, Nigeria Cocoa Marketing Board, 1956.

labour supplies. For the long-term development of manioc as an economic crop, efforts should continue to achieve complete mechanization of the harvest. This will probably require the development of new varieties with roots more amenable in shape, size and number to machine-harvesting as well as research on the machines themselves.

The market for manioc products in the immediate future is probably to be found in supplying calorie requirements of lower income populations of growing cities. Its longer-term market is undoubtedly as a feedstuff. Rising incomes will both increase the demand for meat and the demand for cereal foods. If manioc producers can devise ways of reducing their requirements for labour, which will become increasingly costly in this final stage of economic development, manioc should be able to realize a continuing competitive position as principal element in animal rations.

Dried manioc roots are presently imported in quantity for animal feeding in Western Germany, but there must be some skepticism about potential growth of this market so long as manioc products are widely consumed as human food in the producing countries. One of the problems in the international market for cassava starch has been the way in which exportable supplies have been reduced when economic reversals or shortage of other foodstuffs caused roots to be diverted to human consumption in the producing countries. Steadily rising incomes should eventually reduce the possibility of such diversion, while the improved marketing system accompanying economic progress eases the flow of roots to the processor.

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SOME FACTORS AFFECTING THE DEMAND FOR STARCHY ROOTS AND TUBERS IN TRINIDAD

— by —

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The agricultural development programme of the Second Five Year Plan 1964–1968 of Trinidad and Tobago has been designed "to bring about sustained increases in agricultural production" to meet the "dominant objective of policy", that of reducing the share of imports in total food consumption.[1] "The aim over the plan period is, therefore, to establish the basis for a productive small and medium farm system geared to produce increasing quantities of milk, eggs, poultry, green vegetables, root crops" and so on.[2] The plan continues that "it is important that growers be educated to realize that their income rests upon high yields, reduced costs, and a satisfactory *average price* and not upon the maintenance of high prices for small outputs.[3] What has not been emphasized by the planners however, is that income and the satisfactory price to root crop farmers depend, in the face of a concerted effort to increase root crop production, to a large degree, on the nature and level of the demand for root crops.

In Trinidad, starchy roots and tubers are generally called ground provisions while white potatoes are called Irish potatoes. The starchy roots and tubers or ground provisions that are commonly used as food in Trinidad are dasheen, yams including cush-cush, tannias, eddoes, sweet potatoes and cassava. These are referred to in this paper as starchy roots.

Analysis of the demand for starchy roots has been handicapped by the dearth of statistics. Information on domestic disappearance of starchy roots in Trinidad is not available, while estimates of root crop production are available for some years but their accuracy and reliability are suspect. Another very serious handicap is that records or copies of very valuable studies that would provide the basis for future work have not been kept, thereby requiring an expensive duplication of past efforts. The magnitude of the efforts expended to promote agricultural development has somehow vitiated avoidance of analyses of the demand for starchy roots under the pretext that adequate information is not available.

II

The theory of consumer behaviour postulates that a consumer is generally willing to take more of a commodity at lower prices than at higher prices.

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1 Government of Trinidad and Tobago, **Draft Second Five Year Plan 1964–1968**, 1965, p. 174.

2 Government of Trinidad and Tobago, **op. cit.**, p. 173.

3 Government of Trinidad and Tobago, **op. cit.**, p. 175.

On this basis, economists generalize that the individual consumer demand curve for a commodity slopes downward and to the right. The demand curve for starchy roots represents the functional relationship between price and the quantity or amount demanded. It shows for each price how much of a given starchy root the consumer would buy at the price. It should be noted that each point on the demand curve or schedule represents an alternative market possible for the period of time under consideration. The individual consumer's demand curve must rest on at least the following premises : (1) given tastes ; (2) given money incomes ; and (3) given other prices or their mode of variation. The market demand curve for starchy roots then becomes the aggregate of the demand curves of individual consumers, actual and potential.

The general characteristic of the demand curve for a commodity is for the amount of the commodity demanded to increase as its price falls or decrease as its price rises. The amount of the commodity demanded or purchased, therefore, responds to price changes. The concept of elasticity of demand is used to measure or describe the degree of responsiveness of changes in the quantity demanded to price change.

This concept of elasticity refers to movement along the demand curve in question. The elasticity of demand is defined as the ratio of the proportionate change in the quantity wanted to the proportionate change in price. Price elasticities of demand for individual starchy roots largely reflect the degree of substitution for starchy roots. Where the elasticity of demand is greater than one, that is, demand is elastic, the total outlay of consumers on the good rises in response to a fall in price. When the elasticity of demand is less than one, an inelastic demand, total consumers' outlay on the commodity falls as its price is reduced. But where the elasticity of demand equals one, outlay by consumers on the commodity is constant whatever the price of the commodity.

The entire demand curve can shift up and down, or to the left or right. This is referred to as a "shift" in demand or a change in its level. The level of the demand for starchy roots is mainly influenced by the size of the population, consumer income, supplies and prices of competing commodities, and consumer tastes and preferences.

III

The demand for starchy roots is predicated on a given taste and preference pattern of consumers. Tastes and preferences may have as important an influence on the demand for starchy roots as prices and incomes. Changes in consumer tastes and dietary patterns tend to be a gradual process. Studies of consumer preferences, nevertheless, may aid in the understanding of the market for starchy roots and may also suggest ways for influencing demand.

A consumer preference survey conducted in March 1967 indicated, as is shown in Table I, a preference for Irish potatoes over the starchy roots.

Sweet potatoes, dasheen, cassava, yams and cush-cush were preferred in the order listed. Tannias were the least preferred of all the starchy roots. The United States Inter-departmental Committee on Nutrition also found that "in the matter of roots and tubers it was quite apparent that the Trinidad population generally likes white potatoes".[4]

The preference pattern of the families surveyed closely paralleled their average weekly purchases of starchy roots. This is shown in Table 1. Average weekly purchases of starchy roots per family ranged from 3·6 pounds for Irish potatoes to 0.5 pounds for tannias. The order of magnitude of the average weekly purchases of starchy roots by households should not be regarded, however, as an indication of consumer preference as it reflects, in addition to consumer tastes and preferences, the influence of other forces affecting demand.

Table 1. Preference, Quantity Purchased, and Expenditure Per Week on the Average of 116 Households, Trinidad, March 1967

Commodity	Rank Score[1]	Average purchases per week (pounds)	Weighted average price per pound (cents)	Expenditure per household (cents)
Irish Potatoes	85.4	3.6	12.0	43·9
Sweet Potatoes	83.8	1.9	11.9	23.7
Dasheen	81.5	2.4	9.6	23.1
Cassava	75.4	1.1	10.6	12.1
Yams	73.5	1.6	13.3	21.4
Cush-cush	70.0	0.8	19.5	5.7
Eddoes	65.0	1.0	11.7	1·6
Tannias	44.1	0.5	14.8	7.1

1 Rank score is in terms of first place votes. 8 points were alloted for a first place vote and 1 for a last place vote or no rating. The total points accumulated for each starchy root was then divided by 8 to obtain the rank score in terms of first place votes. Irish potatoes, obtaining the highest rank score, was taken as the most preferred. A low rank score is regarded as being down on the scale of preferences.

The reasons most frequently advanced for preferring Irish potatoes to the starchy roots were (1) variety in preparation ; (2) availability ; (3) taste ; and (4) because it is economical. Some of the reasons advanced for preferring the respective starchy root to all others were :

Dasheen	*Yams*	*Sweet Potatoes*	*Irish Potatoes*
Taste	Taste	Taste	Variety in preparation
Starchy texture	Variety in preparation	Sweetness	Taste
Ease of preparation	—	Availability	Availability
—	—	—	Economical

In many instances, a clearly stated preference for a given starchy root was not accompanied by any regular purchases of the root in question. Further exam-

4 U.S. Inter-departmental Committee on Nutrition for National Defense, **A Report of Nutrition on Survey of Trinidad and Tobago, St. Lucia, St. Christopher, Nevis and Anguilla**, June 1962, p. 109.

ination indicated that the demand for starchy roots may be indirectly affected by (1) the limited ways of preparation ; (2) method of marketing and merchandising ; (3) uncertainty about product quality ; and (4) high wastage in preparation.

These four factors indirectly affect the demand for starchy roots since they tend to influence adversely consumer tastes and preferences for starchy roots. A frequently voiced criticism of starchy roots, on the whole, is the limited ways in which these starchy roots can be prepared. Starchy roots such as dasheen, yams, and sweet potatoes are boiled, peeled and served plain. Variations to the traditional method of preparation are few. The growing sophistication of the population and the desire to add variety often result in irregular or no purchases of starchy roots and the gradual omission of starchy roots from the diets.

There is no processing and grading of starchy roots before marketing. Starchy roots enter the market place just as they leave the farmers' fields, unwashed, varying in size and shape, and with varying degrees of damaged and unsaleable tubers. The increasing importance of super-markets and selfservice and the declining importance of public markets have resulted in some discrimination against starchy roots as the modern housewife is reluctant to handle the unwashed product. In addition, these unwashed starchy roots generally leave the kitchen sink in a very messy state. This problem is not encountered with plantains and bananas.

The gradual exclusion of starchy roots among the urban population has sometimes been explained away by the desire of the population to ape the dietary habits of Europeans. A more logical explanation, however, is the adverse reaction of consumers to the inherent short-comings of starchy roots now that they are in a better position to choose. The effects of uncertain product quality and high wastage are discussed later under relative prices.

The self-evident solution to wash the starchy roots before marketing is not as simple and straight-forward as may appear. Experience with sweet potatoes indicated that some dirt on the sweet potato tuber was desirable. There was the tendency for skin blemishes and scars to show up on the washed sweet potato tuber. Even though these skin blemishes did not affect the quality of the tuber in any way. consumers none-the-less regarded these blemishes as indicative of damaged and unsound tubers. Further, the washed tubers had very poor eye-appeal, even poorer than the unwashed tubers, and a shorter shelf life.

The major outlet for starchy roots is food consumption. Industrial uses, except for cassava to a limited degree, are virtually non-existent. Very small quantities of starchy roots have sometimes been used as livestock feed. Except for normal waste and losses in marketing, the supply that reaches the consumer is exactly equal to that marketed by farmers. Imports from the neighbouring islands constitute a significant portion of the total supply of sweet potatoes available as food.

Per capita consumption of yams, sweet potatoes, eddoes and tannias, has shown a marked downward trend for the period 1954 to 1963. Per capita consumption of cassava and dasheen has demonstrated for the same period a slight upward trend. Per capita consumption of Irish potatoes, however, has remained stable at a relatively high level. In 1963, consumption per person of Irish potatoes was 366 per cent greater than that of yams and almost 300 per cent greater than that of sweet potatoes.

The high per capita consumption of Irish potatoes, the clearly indicated preference for Irish potatoes over starchy roots and the declining per capita consumption of starchy roots (dasheen and cassava excepted) have led to the conclusion that the demand for starchy roots is declining and that efforts should be redirected towards stimulating production of Irish potatoes. A low per capita consumption *per se* is not conclusive evidence of low or declining demand for a commodity, especially when domestic consumption represents the major outlet for the product. A declining per capita consumption may also reflect the influence of changes in supply.

Table 2. Per Capita Consumption of Yams, Dasheen, Sweet Potatoes, Cassava, Eddoes, Tannias, and Irish Potatoes, Trinidad, 1954–1963

Year	Yams	Dasheen	Sweet Potatoes	Cassava	Eddoes	Tannias	Irish Potatoes
	(pounds)						
1954	11.6	8.0	15.4	7.5	4.5	—	28.7
1955	11.1	8.3	17.1	7.8	3.7	—	33.3
1956	12.7	7.7	19.7	11.2	3.7	7.0	30.2
1957	9.5	6.2	15.5	6.9	3.7	7.1	29.9
1958	9.6	6.2	14.7	6.9	3.7	7.0	29.9
1959	9.3	6.0	14.9	6.8	3.0	7.0	28.6
1960	9.5	6.2	14.4	6.9	1.0	6.7	26.8
1961	8.5	8.5	8.5	8.2	1.1	8.6	26.9
1962	5.2	8.7	6.5	7.4	1.9	7.1	29.8
1963	5.9	9.7	6.9	8.9	1.8	4.5	27.5

Source : Based on data obtained from the Ministry of Agriculture, Trinidad.

The availability of Irish potatoes in relation to the availability of starchy roots may be one of the factors responsible for its relatively high per capita consumption. Yams, dasheen, sweet potatoes, eddoes and tannias are not as readily available to consumers as are Irish potatoes because of inadequate storage, limited channels of distribution, and limited distributive outlets. Irish potatoes can be purchased at super-markets, groceries, small shops and public markets in every part of Trinidad throughout the year. Starchy roots are sold in super-markets and in public markets in the urban areas, but only in the public markets in the rural areas. Small quantities may sometimes be sold by vendors in front of shops on a Saturday morning in rural areas where there are no public markets. Groceries and small shops do not handle starchy roots at all.

The adverse effect of the limited availability of starchy roots on their per capita consumption is magnified by the fact that there is a general tendency for most families to patronize the grocer daily. "Only a few foods such as sugar, flour, rice and condiments are stored in the home."[5] There is therefore little or no cost involved in getting supplies of Irish potatoes and rice as needed from the corner grocery.

5 U. S. Inter-departmental Committee on Nutrition, op. cit., p. 114.

Supplies of starchy roots require a special trip to the public market. The pattern of diet may largely be dictated by the food available.

IV

Prices of substitutes tend to affect the demand for starchy roots. Yams, dasheen, sweet potatoes, cassava and tannias compete amongst themselves and with rice, plantains, green bananas, Irish potatoes and wheat (flour, bread, macaroni) as sources of carbohydrate in the diet. In Trinidad, rice is commonly the principal food, while "roots and starchy vegetables are consumed in relatively small quantities".[6] In 1958, per capita consumption in Trinidad of total cereals was 285.5 pounds, of rice 103 pounds, and of roots and starchy vegetables including plantains 146.3 pounds.[7]

The dietary pattern in Trinidad is such that though starchy roots, Irish potatoes, and the other bulky perishables such as plantains and bananas compete in a general way with rice, the tendency is for these carbohydrate foods to be regarded as vegetables to supplement rice and add variety to the diet.

Starchy roots, Irish potatoes, and bulky perishables (plantains and bananas) compete with each other in the lesser role of vegetables in the Trinidad diet. A high degree of responsiveness of the quantity of the individual starchy root purchased to changes in price is therefore to be expected. Consumers, given their preference pattern, tend to substitute the relatively cheaper starchy vegetable.

Estimates of the price elasticity of demand at the retail for sweet potatoes and yams were obtained for the period 1954 to 1963 from the regression of price on per capita consumption. The average price elasticity of demand for sweet potatoes of 1.13 and for yams of .99 were obtained from the following demand equation[8] :

Yams : P_y — 20.76 — 1.12 q_y (r^2 — .81)

Sweet potatoes : P_s — 19.61 — .689 q_s (r^2 — .77)

Where : P_y — price per pound of yams (undeflated)

P_s — price per pound of sweet potatoes (undeflated)

q_y — per capita consumption of yams

q_s — per capita consumption of sweet potatoes

6 U. S. D. A., **Projected Levels of Demand, Supply and Imports of Agricultural Products to 1975**, ERS Foreign 94, p. 68.

7 U. S. D. A., **op. cit.**, p. 69.

8 Average price for yams was 10.34 cents ; for sweet potatoes 10.4 cents ; and the average per capita consumption of yams was 9.29 pounds and of sweet potatoes 13.36 pounds.

Analysis of the price relationships of bulky perishable staples may be handicapped by lack of comparable price data. The same difficulty in the market price tends to limit the influence of price changes on consumer behaviour. Mere price ratio comparisons may be misleading as choice indicators. Uncertainty with regard to product quality, particularly in the case of dasheen and cassava, makes market price comparisons difficult. Both dasheen and cassava tend to "turn", that is, become inedible when cooked. This characteristic is more pronounced at certain times of the year than at others and has the effect of transforming the given market price per pound to a price per pound of infinity. Consumers develop a reluctance to purchase dasheen or cassava. They tend to substitute dasheen or cassava for other starchy vegetables only when the price ratios are very much in favour of dasheen or cassava. Small changes in the price of both dasheen and cassava may have little influence on the quantity purchased. A linear regression of retail price on per capita consumption of dasheen for the period 1954 to 1963 yielded a coefficient of determination of .112. Only 11.2 per cent of the variation in the retail price of dasheen was accounted for by variation in per capita consumption.

Differences in edible yield of the competing carbohydrate foods influence the effects of price changes on consumer behaviour and also tend to make actual market price comparisons misleading. Starchy roots have comparatively thick skins which have to be removed by peeling before they can be used as food. The extreme head ends are unpalatable and are therefore rejected. A pound of starchy root yields somewhat less than a pound of edible material. The percentage of edible material from a pound of starchy root or carbohydrate food is called the edible yield. Edible yield ranged from 60 per cent of market weight for green bananas to 90 per cent for Irish potatoes. Losses in preparation have the effect of raising the real price per pound of starchy roots and of altering the price relationship of the competing carbohydrate foods in favour of those with high edible yields. On the basis of actual market prices prevailing at the Tunapuna public market in June 1966, consumers would normally substitute rice for only tannias and plantains since their prices were 7 per cent higher than the price of rice. When edible yield was considered, only dasheen, Irish potatoes and bananas were cheaper than rice (Table 3).

Table 3. Edible Yield, Actual and Adjusted Prices and Price Relatives of Carbohydrate Food at Tunapuna Market, June 1966

Commodity	Edible Yield[a] (per cent)	Actual Price (cents)	Adjusted Price[b] (cents)	Actual Relative[c] (per cent)	Adjusted Relative[d] (per cent)
Rice	100.0	15	15.0	100	100
Dasheen	77.5	8	10.3	53	69
Yams	78.3	12	15.3	80	102
Sweet Potatoes	78.1	14	17.9	93	119
Tannias	78.1	16	20.5	107	137
Cassava	63.1	10	15.8	67	105
Irish Potatoes	90.0	12	13.3	80	89
Bananas	60.0	6	10.0	40	66
Plantains	61.1	16	26.2	107	175

Source : *Weekly Market Report, Tunapuna Market, June 1966.*

a Edible yield is the percentage of edible matter per pound of actual weight.

b Adjusted prices equal actual prices divided by the respective edible yield.

c Actual price relative is the actual price of the commodity as a percentage of the price of rice.

d Adjusted price relative is the adjusted price as a percentage of the price of rice.

Actual and adjusted price relatives for the bulky perishables using the price of Irish potatoes as the base are shown in Tables 4 and 5 respectively. Actual market price comparisons indicate that while bananas have been relatively cheaper than Irish potatoes, plantains have generally been more expensive. Yams and sweet potatoes, once cheaper than Irish potatoes, have become more expensive.

Table 4. Prices of Starchy Staples as a Percentage of Irish Potato Price, 1954–1963

Year	Irish Potato Prices	Irish Potatoes	Dasheen	Yams	Sweet Potatoes	Plantains	Bananas
	(cents)	(...................			price relatives	....	)
1954	8.2	100	73	68	66	160	60
1955	9.7	100	98	73	84	157	59
1956	9.5	100	87	86	84	167	56
1957	9.6	100	96	96	86	167	58
1958	10.2	100	125	101	84	180	59
1959	10.3	100	108	103	109	178	62
1960	11.2	100	102	99	82	161	62
1961	9.7	100	100	132	162	173	67
1962	12.3	100	77	115	117	134	48
1963	12.5	100	81	115	121	134	46

Source : Based on data from Government of Trinidad & Tobago, Central Statistical Office, *Annual Statistical Digest.*

Table 5. Prices of Starchy Roots as a Percentage of Adjusted Irish Potato Prices, 1954–1963[a]

Year	Irish Potato Prices	Irish Potatoes	Dasheen	Yams	Sweet Potatoes	Plantains	Bananas
	(cents)	(...................			price relatives	....	)
1954	9.11	100	85	79	76	235	90
1955	10.78	100	114	84	96	231	88
1956	10.56	100	101	99	97	246	84
1957	10.67	100	111	110	99	245	87
1958	11.33	100	146	116	97	266	88
1959	11.44	100	125	118	125	262	93
1960	12.44	100	118	114	95	237	92
1961	10.78	100	116	152	186	255	101
1962	13.67	100	90	132	135	196	72
1963	13.89	100	94	132	139	198	70

Source : Based on data published from Government of Trinidad and Tobago Central Statistical Office, *Annual Statistical Digest.*

[a] Adjusted prices obtained by dividing actual market prices by edible yield in Table 3.

When edible yields are taken into consideration (Table 5), with the exception of bananas, price ratio comparisons generally favoured Irish potatoes. When price relationships favoured starchy roots the relative availability of Irish potatoes in terms of time and transport cost tended to minimize any tendency towards substituting starchy roots for Irish potatoes.

There is every reason to believe that consumers take edible yield into consideration in adjusting their behaviour to price changes. One of the reasons advanced for preferring Irish potatoes to the other starchy roots was because it was more economical. In addition, many of the respondents to the survey were concerned with being able to provide their family with sufficient food for the outlay that the family could afford to devote to food. It is important to note also that price relationships are generally less favourable to starchy roots in the super-markets than in public markets.

The characteristic pattern of distribution of agricultural produce in Trinidad is for produce to move from areas of production to the terminal markets in Port-of-Spain and San Fernando and to be redistributed from these terminal markets, through a network of vendors, handling relatively small quantities, back to the rural areas. Starchy roots follow this pattern of distribution. The transportation component from this two-way haul is twice as great in the rural prices as in the urban prices of starchy roots. In addition, these vendors usually have fairly high mark-ups. These high margins are needed to allow for product losses in transit due to poor packing and handling and, in the absence of grading, to compensate for quantity purchased but not received because of unsaleable tubers and foreign matter. In contrast, rice, other cereals and Irish potatoes move one-way from urban to rural. Losses in transit are negligible and the urban-rural transportation differentials are normally small, about ½ to 2 cents per pound. Prices of starchy roots are generally higher than prices of rice and Irish potatoes in the rural areas.

Small scale farming in Trinidad is characterized by the dominance of plantation crops and part time farmers. Farm family food supplies, because of the part time nature of farming come mainly from plantations and bananas, which require less labour to cultivate and harvest than the majority of areas. Family incomes are lower in rural areas than in urban areas while price levels are generally higher. Given the lower income and the higher price levels in rural areas, a lower level of satisfaction is attained and hence a lower level of demand. The tendency for plantains, bananas, or rice to provide home-grown food, the lower the real income, and the adverse price ratios of starchy roots suggest a low level of demand for starchy roots in the rural areas.

V

The level of income is an important factor influencing the pattern of food consumption in the longer run. For individual foods, however, the response of consumption to changes in income depends on the per capita level of consumption. At very high levels of consumption, the demand for an individual food may show very little response to changes in income even though consumers may be relatively poor.

Average weekly purchase of Irish potatoes was approximately the same for the different income groups in the households surveyed, ranging from 3.47 pounds in the low income group to 3.70 pounds in the high income. The quantity of Irish potatoes purchased displayed a positive correlation with income (Table 6). From the other starchy roots, average weekly purchases declined as incomes increased. Weekly household purchases of yams dropped from 1.79 pounds among the low income group to .93 pounds among the high income group, while purchases of sweet potatoes dropped from 2.25 pounds per household to 1.0 pounds per household among the high income group. Purchases of starchy roots tended to decrease as incomes increased.

Table 6. Weekly Purchases per Household of Starchy Roots and Tubers by Income Groups, One Week, March 1967 in Pounds for 116 Households, Trinidad

Commodity	Average annual family income		
	$2,500	$8,500	$17,500
	(....................	pounds	..................)
Dasheen	3.09	1.12	1.71
Yams	1.79	1.38	.93
Eddoes	1.26	.64	0.0
Tannias	.63	.19	.43
Sweet Potatoes	2.25	1.31	1.0
Cassava	1.35	.65	.57
Cush-cush	1.11	.35	0.0
Irish Potatoes	3.47	3.83	3.7
No. of respondents	73	36	7

Evidence of the effect of income on demand for starchy roots is inconclusive as the income elasticity of demand in terms of quantity for sweet potatoes has been estimated at .40, for other roots and starchy vegetables at .25, and for Irish potatoes at .40. A negative income elasticity of demand for sweet potatoes of – .3 has been estimated for Jamaica.[9] The positive correlation of Irish potatoes to income is in agreement with the survey result. Changes in taste, relative prices and the competition from substitute carbohydrate foods may well be the dominant factors in determining the demand for individual starchy roots.

If the sample of households surveyed is representative of the population and the pattern of purchases for the week typical, then increasing per capita income over time may lead to a lowering of the demand for starchy roots. A linear regression of quantity purchased to income yielded an average income elasticity of demand of – .29 per cent in the quantity of sweet potatoes purchased.

VI

The demand for starchy roots may also be adversely affected by the increased number of wives in the labour force (resulting in the trend towards easily prepared staples) and the changing composition of the population. With the increased share of the retail grocery trade captured by super-markets and the declining importance of public markets, the uncertainty about the quality of starchy roots, the primitive

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9 U. S. D. A. ERS Foreign 94, op. cit., p. 160.

manner in which starchy roots are marketed and the increasingly adverse price ratio for starchy roots all point to a declining demand for starchy roots. Growth of demand associated with population increases may for a time offset the trend toward declining per capita consumption of starchy roots.

This stable per capita consumption of Irish potatoes over time and the uniformity of purchases among income groups suggest that Irish potatoes have assumed the role of a minor staple providing much needed variety to rice. This role of a minor staple can be attributed to its high edible yield, its availability, and above all to the fact that it can be prepared in several ways.

The present state of knowledge precludes any definitive statements about the level of demand for starchy roots in Trinidad. Economic models of the root crop industry are needed in order to estimate price and cross elasticities of demand and to assess fully the impact of changes on the supply and prices of substitutes of the demand for root crops. Consumer acceptance studies are also needed in order to tailor starchy roots to meet consumer requirements. What is clear is that unless drastic changes in taste occur there is little likelihood of starchy roots replacing rice or Irish potatoes as the staples in the Trinidad diet. The important consideration at this stage revolves around the measures that are necessary in order for starchy roots to maintain their position and not decline any further in relative importance as carbohydrate foods.

A very vital and basic requirement is an improved product. Product improvement should take the form of increases in edible yield which will result in a more favourable price relationship, uniformity in shape and size of tubers to facilitate packing and merchandizing, an improved appearance, and a greater degree of reliability in product quantity. Improvement in product quality will bring about improvement in marketing and distribution.

New and improved ways of using starchy roots must also be developed. At present, starchy roots and other bulky perishables are being promoted and marketed as snack foods. Increased demand for starchy roots as raw materials in preparing snack foods depends on the competitive position of starchy roots and on consumer acceptance of the final product. Development of new uses and of new ways of using starchy roots are necessary to increase their demand. New ways must include the potentials of starchy roots as raw materials in livestock feed formulations.

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AN ECONOMIC VIEW OF THE DEVELOPMENT OF NEW PRODUCTION SYSTEMS

WITH PARTICULAR REFERENCE TO ROOT CROPS IN THE WEST INDIES

— *by* —

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Root crops comprise an important element in the West Indian diet. The dependence on root crops varies from territory to territory and the kind of root crop consumed also varies appreciably, not only between territories but also within some of the territories. Sweet Potatoes and Yams are the most widespread of locally grown root crops : Cassava (Manioc) tends to be restricted to drier conditions and Cocoes to more humid conditions. Irish Potatoes (*S. tuberosum*) are grown, in any quantity, only in Jamaica — which has become virtually self-sufficient for this crop[1] — and are imported from outside the Area to a growing extent, even when measured in per capita terms.[2]

The traditional West Indian root crops are characteristically grown on a small scale, by farmers using fairly primitive techniques.

The yields per acre tend to be low (even allowing for an appreciable extent of mixed cropping), and the use of labour per acre high, since most of the cultivation is undertaken with simple hand tools often under difficult natural conditions.[3]

Most of the root crops produced in the West Indies are consumed in the Area, mainly within the producing territory and to an appreciable extent by the producers and their families. Montserrat and St. Vincent do, however, export substantial quantities of sweet potatoes to Antigua and Trinidad and Tobago, while virtually all Arrowroot is exported as starch to North America and Europe.[4]

The roots are commonly consumed in a narrow range of dishes which do not exploit the range of possible forms. Persons unaccustomed to local roots often find them unattractive in customary dishes. Any 'storage' which occurs is due almost entirely to delayed reaping, except in the case of Irish Potatoes in Jamaica ;

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1 I. Johnson, **Development of the Irish Potato Industry in Jamaica**, (a paper presented at the Tropical Root Crop Symposium, St. Augustine, April 1967), 1967.

2 D. T. Edwards, and J. Cropper, **Agricultural Research in the West Indies : the economic background to programmes of livestock and crop investigations**, Department of Agricultural Economics and Farm Management, U. W. I., St. Augustine, Trinidad, 1967.

3 D.T. Edwards, **An Economic Study of Small Farming in Jamaica**, I.S.E.R., Kingston, Jamaica, 1961.

4 C. I. Martin, **The Arrowroot Industry in St. Vincent**, (a paper presented at the Tropical Root Crop Symposium, April 1967), 1967.

while virtually no large-scale processing is undertaken of the traditional root crops grown for local consumption. (Arrowroot is, of course processed and stored locally prior to export.)

As a consequence of the pattern of production (which tends to be highly seasonal), the pattern of consumption, and the largely unorganised marketing system, scarcity alternates with gluts in the local market. Indeed, scarcity may co-exist with surpluses even in a small territory, due to market imperfections.

In view of the circumstances outlined, it is not to be expected that the prevailing, traditional systems of root crop production will continue to be viable. They do not have the capacity to provide adequate remuneration to the small farming community with its growing aspirations, even were the market to be developed and the marketing system highly organised.

This paper is particularly concerned to point to the need for formulating new and improved systems of production which can be widely applied with benefit to the nation's economy., It seems appropriate to discuss this problem in relation to the conditions obtaining in the West Indies.

AN APPROACH TO DEVELOPING A NEW SYSTEM OF PRODUCTION

In the West Indies, as elsewhere in the Tropics, data on the economics of producing the traditional root crops are scarce. Those available do, however, illustrate the high labour requirements and low yields achieved.

Thus in Jamaica – which produces a substantial proportion of the root crops grown in the (British) West Indies – the following estimates were presented in 1943 by an official committee of inquiry.[5]

	Labour requirement per acre of crop (in eight-hour working days)
White Yams	151 – 247
Other Yams	122 – 136[a]
Sweet Potatoes	53 – 67[b]
Cassava	32 – 37

a In 1954-55 a small number of small farms in Jamaica producing mainly Yams, used the equivalent of more than 160 days of labour per acre of Yams and other food crops. (Derived from Edwards, D.T., 1961).

b An estimate presented in 1957 for one of the main Sweet Potato Producing islands, St. Vincent, was 56 days per acre, assuming an eight-hour working day. (See Team of Experts, **Report and Recommendations for the Development of St. Vincent**, Barbados, Advocate Printer, 1957.)

More estimates are available for yields than for labour requirements but these are possibly even less reliable. It would seem, however, that the yields of the

5 Cost of Production of Food Crop Committee, **Report of Committee on the Cost of Production of Certain Local Food Crops**, Jamaica, The Government Printer, 1946.

common root crops for the various territories generally average no more than two tons per acre.[6]

Given an unsatisfactory existing or projected system of production, various means suggest themselves for improving the profitability of the system. The more significant of these may be summarised as follows.

I *Reducing cost of production, by* :

(a) omitting unnecessary practices,

(b) eliminating the use of excessive inputs,

(c) replacing more costly by less costly methods of production.

II *Raising marketable yield, by* :

(a) using superior varieties,

(b) making optimum use of seasons,

(c) using improved disease and pest control,

(d) reducing damage in reaping and handling,

(e) using other improved technology.

III *Increasing prices, by* :

(a) using varieties preferred by consumers,

(b) improving quality,

(c) finding more lucrative market outlets,

(d) timing production for seasons of high prices.

These means have simply been stated, so as to indicate the range of decisions open to the person responsible for making a system of production more profitable. But even this brief statement indicates the large number of possibilities to be considered. The choice of method is further complicated by the incomplete state of knowledge of the effect of techniques and of their interactions with each other. Thus some of the means by which marketable yields and product prices may be increased, involve increasing the cost of production : on the other hand, lowering the costs of production may, in turn, reduce the marketable yield or the product price.

A few examples of the application of these means are drawn from the experience of the Texaco Food Crops Demonstration Farm during the first three years of its operation, 1964–66.

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See, for instance, the data collated from large-scale sample surveys, Department of Agricultural Economics and Farm Management, U.W.I., **A Digest of West Indian Agricultural Statistics**, (Occasional Series No. 2) St. Augustine, Trinidad, 1965. The few estimates available from intensive field surveys also indicate very low levels of yields. See, for instance, Edwards, D.T., and Ministry of Agriculture, (Division of Economics and Statistics), Jamaica, **The Economic Organisation of Small Scale Farming in the Brokenhurst Area of Southern Manchester, 1959–1960, Jamaica**, The Government Printer, 1962.

Experience at the Texaco Food Crops Demonstration Farm

The Texaco Food Crops Demonstration Farm was established on the Field Station of the University of the West Indies, to formulate, test and demonstrate systems of production for individual crops, on scale comparable to prevailing commercial conditions. The approach employed falls between the highly controlled technical experiments which are concerned mainly with a single or small number of practices, and the 'Unit' farm approach, which is intended to combine enterprises ('systems of production') into an integrated 'system of farming'.[7]

When a crop is grown for the first time the best technical practices are combined to form a system of production. The results of this first crop and successive crops are recorded and analysed, and changes made to the system in the light of the analysis.[8] The experience with the first crops of Yams and Sweet Potatoes, and some of the changes made to the initial production systems, are discussed below.

The first crops of Yam and Sweet Potatoes grown and costed on the Texaco Food Crops Demonstration Farm differed in important respects from the customary pattern, as the figures below reveal. Thus the labour used in producing Yams was 90 days per acre, as compared with over 120 days using traditional methods ; the yield also was far higher than was reported for farms in the Area. But in the case of Sweet Potatoes neither the labour used nor the (marketable) yield per acre were different from the general levels prevailing.

The Yam crop cleared the total variable expenditure, giving an appreciable surplus or Gross Margin, while the Sweet Potato crop failed to cover even the variable expenditure.[a]

Table I. Economic Observations of Yam and Sweet Potato Crops : Texaco Food Crops Demonstration Farm, 1964

	Yams (Per Acre)	Sweet Potatoes (Per Acre)
Marketable Yield	4.5 tons	1.7 tons
(Gross Yield)	(8.3 tons)	(3.1 tons)
Total returns	$1,374	$310
Total variable expenditure	$ 669	$412
Gross Margin	$ 705	– $102
Labour – used (eight-hour man days)	91 days	59 days
– expenditure	$ 358	$237
– expenditure, as a proportion of total expenditure	54%	58%

a Labour is costed at the local commercial rate (of 50c. per hour), rather than at the substantially higher Government rate which has to be paid at the Texaco Food Crop Demonstration Farm.

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7 A. L. Jolly, 'The Unit Farm as a Tool in Farm Management Research', **Journal of Farm Economics**, 39, 3, 1957.

8 D. T. Edwards, **The Economics of Food Crop Production** (mimeo.), 1965.

Examples of Reducing Cost of Production

Since payment for labour accounted for a substantial proportion of the cost of growing the first crops of Yams and Sweet Potatoes – see Table 1 – it was to be expected that attempts would be made to reduce costs by mechanising some of the practices using appreciable labour.

Planting Yams.[9] The use of a ridging plough and 48 hours of hand labour to plant an acre of Yams, was replaced in the next crop by a tractor-mounted potato planter and only 10 hours of labour per acre. (The extent of the net saving in cost would depend on the change in cost for machinery as well as for labour.)

Weed Control in Sweet Potatoes[10] In the first crop a contact spray was applied by a knapsack sprayer at a cost of $28 for materials and $32.50 for 65 hours of labour. But in the next crop pre-emergence weedicides were applied from a tractor mounted sprayer immediately after the crop was planted, and supplemented later by a limited amount of 'spot' applications of contact weedicides. The cost of both materials and labour was reduced to $14.50 for materials and $9.50 for labour.

Examples of Raising Marketable Yields.[11]

Various methods may be used to raise yields. One adopted was to concentrate future production on the variety which emerged with the highest yields in the first crop. To avoid the complications caused by comparing crops over time, it may be pointed out that the highest yielding variety in the first crop gave 4.2 tons of marketable Sweet Potatoes, as compared with the average for all five varieties of 1.7 tons. Given the conditions obtaining for the first crop, the use of only the highest yielding variety could have provided a Gross Margin of $237, rather than the negative Gross Margin of $102.

Example of Increasing Prices.[12]

The approach adopted for increasing the price for the product was to produce 'out of season' crops, to be sold during a period when prices were appreciably higher than during the normal reaping season. Thus the 'out of season' Sweet Potato crop realised (on average) 8.4 c. rather than 6.9 c. per pound, while the 'out of season' Yam crop was sold for 12c. rather than 8c. per pound. In the case of Yams the total variable costs per acre were far higher for the crop which received the higher price, so much higher in fact that a smaller Gross Margin was made. However, in the case of Sweet Potatoes not only were prices higher, but

9 P. H. Haynes, 'The Development of a Commercial System of Yam (**Dioscorea alata** L.) Production, **Trop. Agric. 44**, (3) **215–221, 1967.**

10 J. Cropper. **The Prospects for Commercial Production of Irish and Sweet Potatoes** (D.T.A. Project Report Series, No. 2) Department of Agricultural Economics and Farm Management, U.W.I., St. Augustine, Trinidad, 1967.

11 H. V. Walker, and P. H. Haynes, 'Prospects for Sweet Potatoes in Trinidad and Tobago', **Texaco in Agriculture**, 1965.

12 J. Cropper, **op. cit.**

the cost was substantially reduced and a larger Gross Margin was earned for the 'out of season' crop.

In due course means of increasing profitability, other than those already employed, will, no doubt, be introduced into the systems of production now being evolved.

APPLICABILITY OF A NEW SYSTEM OF PRODUCTION

Given that a new system of producing a root crop is evolved locally : can it be reasonably assumed that the present producers in the West Indies will adopt a new system in a substantially unchanged form ? There are, commonly, problems of introducing innovations in agriculture, but is there any reason to believe that new systems of root crop production may involve unusually severe problems ? These questions may be approached by considering the salient differences in the characteristics of new systems in relation to the features of the environment under which root crop production now occurs.

It may be anticipated that new systems of production will make considerably greater use of chemicals, both for the supply of nutrients and to provide plant protection (against weeds, pests and diseases), and will involve a high degree of mechanisation. These characteristics require a greatly increased cash outlay per acre, (with the concomitant demand for increased finance), and a quality of management with knowledge and skills adequate to the new, far more complex, systems of production. We shall limit discussion to the problems posed by a mechanised system of production since this is the feature which seems least compatible with the existing system.

Two aspects of a mechanised system are worth distinguishing : spraying, and mechanical cultivation (including planting and reaping). Much of the root crop production in the West Indies takes place on steep slopes. Such slopes need not prevent spraying of crops, as the banana industry illustrates,[13] but they do seriously prejudice mechanised planting and reaping. The typically small acreage controlled by the individual root producer compounds the difficulty of cultivating the land mechanically. This is especially true if medium and large tractors – which comprise most of the tractor force in the Area – were to be used, but there is little reason why appropriate small power units should not be used more widely. The problem may also be tackled by the provision of mechanical equipment through contract services, and by the formation of machinery co-operatives amongst small producers. In such ways the problem of the 'lumpiness' of investment for the individual producer may be overcome ; other problems posed by numerous small, scattered holdings would not, however, be entirely solved.

It is quite probable that the conclusion reached would be that the needs of the mass of traditional producers for a more competitive system of production are not likely to be met by a system which depends to a great extent on mechanical cultivation. Such a conclusion would, however, not imply that all the elements

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13 G. Ordish, and R. Houghton, **Disease Control in Bananas – Windward Islands, West Indies**, London, Ministry of Overseas Development, 1965.

of a new system would be totally inapplicable to the conditions of the typical producer. For example, the use of improved varieties, appropriate fertilisers and plant protection methods are all feasible and could well result in increased profitability.

But under what conditions could a new system be most fully applied : on large scale, well financed and well managed units, with land suitable for mechanical cultivation ? The question seems to answer itself, although the decision to produce root crops on a large scale would also require satisfactory conditions in the market. It would be necessary to have either a guaranteed market with an acceptable price or, at least, a far more highly organised marketing system than has generally obtained hitherto.

Discussion above, of the conditions under which a new system of production can be applied, raises issues of national policy. Which is the primary purpose, to produce root crops cheaply or to try to maintain small scale producers ? If large scale, low cost producers meet the market needs, how is the future of the traditional producers to be provided for ? It is not intended to deal with these problems here, but raising them serves to draw attention to the link between the attempt to provide production systems for general adoption and the consequences of their widespread use in an economy.

THE AGGREGATE EFFECTS OF WIDESPREAD INTRODUCTION OF A NEW SYSTEM

The primary interest of those concerned with the development of a new production system is its commercial attractiveness to the individual producer. Persons concerned with national economic policy must, however, be alert to the more remote but equally important impact of the widespread introduction of a new system on the whole economy.

It is common for attention to be focussed on the effect of increased output on price and income. In countries with substantial unemployment (such as the West Indies) the effect of extensive mechanisation on employment must also be considered. (Since this latter topic is the subject of the following paper the treatment here will be particularly brief.[14])

Mechanisation and employment

Increased unemployment under conditions where unemployment is substantial, and is costly and difficult to reduce, must necessarily be considered a threat to the society : though there may be cases where decreased employment has to be accepted. An example is provided by a case where the cost of producing a crop is so uncompetitive that the alternative to reduce employment, consequent on the increased mechanisation of the system, could be no employment – due to the collapse of the industry.

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14 See B.F. Johnston, **The Discrepancy between Social and Private Returns to Mechanisation in the Early Phase of Economic Development, (T.R.C.S., April 1967), 1967.**

The outcome of the calculations of political economy are, however, clear-cut and simple. Thus the economist has to provide in his analysis for the possible conflict between the individual producer's gain from reduced costs (by increasing unemployment), and the society's loss by having to provide for the unemployed. While it is conceivable that if the competitive position of the industry is improved sufficiently, production might increase to such an extent that employment in the production of the crop could have increased despite the lower labour requirement per acre. Greater employment would also tend to be generated in supplying increased goods and services to the industry, in the marketing and production processes. Against these sources of increased employment would have to be set any decreases in employment due to withdrawal of resources from other industries.

Mechanisation is not simply 'good' or 'bad' : desirable or undesirable. The involved effects of an increased degree of mechanisation have to be traced carefully in the particular circumstances to arrive at a judgement consistent with national objectives.

Output, Price and Income

If production is increased by the general introduction of improved systems, the consequence could be a substantial decrease in price – sufficiently great to result in lower gross revenue and even net revenue. As an alternative to simply allowing producers to respond by decreasing production, through diversion of land and other resources to the production of other products, an attempt to expand the market for the product might well be more desirable in the first instance.

The market might be expanded in several ways within the country of production, as well as by opening up export markets. Hitherto, the traditional root crops have been used in a few, conventional ways. They have been confined largely to home use — often in excessive quantities in relation to nutritional standards — by the poor members of the population, and served in a very limited range of dishes. Surpluses and inferior products have been fed to pigs kept, generally, under poor systems of management. If the supply of roots could be made less seasonal, by reducing the seasonality of production or by storing the crop for longer periods than hitherto, a substantial increase in consumption could be provided for, either in the natural or in a processed form.

The low prestige accorded to the traditional root crops is not without some justification by any objective standards, as they are generally :

(i) inconvenient to use in their prevailing forms – being irregular in shape, difficult to peel, and often excessively large ;

(ii) not cheap per pound of usable material, in relation to some other sources of carbohydrates ; and

(iii) served in a few, unimaginative forms.

This appraisal, if sound, points the way to increasing the attractiveness of these crops for human consumption. An attempt to improve their natural form should be considered. It is not a matter of coincidence that the Hawaiian pineapple fits into a standard sized can, any more than it is that modern turkeys fit into small modern ovens. The production of small, regular and conveniently shaped yams, for instance, would seem attractive not only for marketing but would also facilitate harvesting. It must be admitted that knowledge of consumer preferences in this field is so limited that even establishment of appropriate grades for buying and selling existing varieties cannot yet be undertaken with any confidence.

Other avenues of investigation might seek new uses for root crops. Three uses seem particularly worth consideration : replacing cereal flour in part, by incorporating root crop flour ; using locally produced roots in natural or processed form as a substantial ingredient in rations for the expanding livestock industries ; and seeking industrial uses for root crop starches.

Explorations of the market are significant for the development of systems of production of root crops, because the nature and extent of the market should influence the system of production devised. Thus a system of production to provide a very cheap and, by human standards, poor quality animal feed, may need to be very different from one geared to a discriminating and distant export market.

It is conceivable that the conclusion might be reached that the prospects for the expansion of root crop production are poor, because of the severe limitations of demand. This possibility indicates, more clearly than any other, the importance of exploring all the conditions under which a system of production would be operating, before committing substantial resources to formulating such a system.

CONCLUSIONS

This paper has dealt with a problem which is not peculiar to root crops or to the West Indies, though it is certainly important for root crops, and there is advantage in discussing it in relation to a particular area, such as the West Indies. The problem concerns the basis on which a system of production is to be formulated.

Increasing the profitability of an isolated 'pilot' system of production seems at first sight to be quite reasonable. But when account is taken of the farming conditions as they relate to the application of a system, and the national economic conditions as they will influence and be influenced by the effects of the widespread employment of a system, it becomes apparent that informed views about these conditions need to be arrived at before devising a new system of production. In short, the process commonly followed needs to be reversed. In as far as it is intended that systems should be put to widespread use, they should be devised to have characteristics that render them applicable to the farming conditions they can realistically be expected to serve, and they should be geared to a pattern of resource use and demand that are in the national interest.

If this view is accepted, there are important implications for the approach to be adopted. The problem is not just how technically superior practices can be modified and combined to produce a profitable system of production for the kind of conditions under which the system is being evolved. But rather, what farming conditions should they be created for : those prevailing for the mass of producers, or those – which may be very different – under which the bulk of production may necessarily take place in the future ? What system will meet the needs of the prospective markets ? Is it possible to produce a profitable system which uses the resource combinations appropriate to the resource endowment of the economy and to national policy ?

These questions imply a council of perfection. However, while it is not possible to anticipate with certainty all the relevant circumstances which will prevail when a system is ready for general application, lack of certainty about the future is not sufficient reason to avoid making and using informed judgements about prospective conditions. For unless adequate regard is paid to the conditions likely to obtain when a system is ready for distribution it may not find general application or, if applied, may create more problems than it solves.

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THE DISCREPANCY BETWEEN SOCIAL AND PRIVATE RETURNS TO MECHANIZATION IN THE EARLY PHASE OF ECONOMIC DEVELOPMENT

— *by* —

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The technical problems that are encountered in the mechanized production of tropical root crops are likely to divert attention from certain economic considerations that cast doubt on the wisdom of applying scarce resources of capital to the mechanization of root crop production. Increasing attention is being given, perhaps most vociferously in the United States, to a "world food crisis" resulting from rapid growth of demand for food which in a number of less developed countries is not being matched by equally rapid growth of domestic production. Although unprecedentedly rapid growth of population is the major component of this growth of demand, the increase in demand for food associated with rising per capita incomes is also an important factor.

The other conspicuous feature of the attention being given to the world food crisis is the growing recognition that expansion of agricultural output "depends predominantly," in Schultz's terminology, "upon the availability and price of modern (nontraditional) agricultural factors".[1] Closely associated with this emphasis on the need for farmers to make use of "a profitable new set of factors" is the conviction that agriculture has been assigned too low a priority in developing countries with resulting underinvestment and inadequate price incentives for farmers. Heady has even suggested that it would be a good policy to maintain "producer prices which favor growth and output but subsidize consumers at lower prices. ."[2]

Although neglect of measures to foster increased agricultural production can unquestionably have serious consequences, there is also a danger in focusing too exclusively on the food supply implications of rapid population growth. The purpose of the present paper is, first of all, to emphasize that rapid growth also has important implications with respect to the process of economic transformation whereby the overwhelming importance of agriculture in an underdeveloped economy is modified by growth of the nonfarm sectors. The interrelationships between the transformation of the productive structure of an economy and the development of the agricultural sector is stressed because the possibility of creating a highly productive agricultural economy is so heavily dependent upon the process of economic transformation. And finally, it will be suggested that the degree of structural transformation that has taken place in a national economy has strong influence in determining *which* "modern agricultural factors" are most appropriate for achieving expanded production. Although farm machinery is often regarded as the hall-

1 W. T. Schultz, **Transforming Traditional Agriculture**, New Haven, Connecticut, 1964 p. 145.

2 E. O. Heady, **A Recipe For Meeting The World Food Crisis**, Iowa State University, Report 28, Ames, 1966. p. 7.

mark of a modern agriculture it will be argued that investment in mechanization is likely to be uneconomic from a social point of view until considerable structural transformation has taken place.

Just as tractors are commonly regarded as the symbol of a modern agriculture, industrialization is often viewed as an overriding goal because it symbolizes a modern economy. Excess zeal in pursuing the goal of industrialization has often been self-defeating, particularly when a high and unbalanced tariff structure has fostered the creation of high-cost domestic industries and resulted in such distorted price relationships that "import substitution" has actually resulted in increased dependence on imports.[3] Nevertheless, sound industrial development is an essential component of economic growth ; agricultural and industrial development are goals that must be pursued simultaneously.

Three aspects of the interaction between agricultural and industrial development are of critical importance to the modernization of agriculture and raising the productivity of a nation's farmers. First of all, the expansion of the market for cash sales of agricultural products as a growing percentage of the population comes to depend on purchased food is of profound importance to the agricultural sector. Secondly, the enlarged use of purchased inputs, a fundamental characteristic of a progressive agriculture, depends to a considerable extent on increased local production of new and improved inputs — higher yielding plant material, fertilizers, insecticides, improved tools, equipment for drying or grating, etc. — as well as the enlarged money income that makes such purchases possible. And finally, the growth of nonfarm employment is a critical requirement for increasing labour productivity in agriculture since it is the availability of alternative job opportunities that initially slows the increase in the size of the farm labour force and eventually makes possible a reduction in its absolute size. Moreover, the growth of nonfarm employment provides the income base for the nonfarm population dependent on purchased food that increases both in absolute size and in relation to the size of the farm labour force.

The bearing of international trade on these interactions must be noted. The possibilities that exist for exporting agricultural products obviously represent an additional means whereby farm cash incomes can be increased, a possibility that is particularly significant in the early phase of development. And imports of certain types of farm inputs are likely to be highly beneficial to developing countries. Domestic production of farm requisites such as nitrogen fertilizers and heavy farm machinery is likely to be much more costly because the local market is too small to realize economies of scale, and the lack of capital, professional and technical personnel, and complementary industrial activities also increase the cost of local manufacture. For most developing countries the possibilities opened up by international trade qualify but do not by any means nullify the dependence of agricultural development on the process of structural transformation.

The nature of these interactions between agriculture and the rest of the economy clearly depends upon the degree of structural transformation that has taken

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For discussion of this problem and additional references, see R. I. McKinnon, "Intermediate Products and Differential Tariffs : A Generalization of Lerner's Symmetry Theorem," **The Quarterly Journal of Economics**, November 1966.

place, measured most simply by agriculture's share in the total population and labour force. Agriculture's existing weight in a country's total labour force also has a powerful influence on the rate and direction of change in the size of the farm labour force. Countries that are classified as "underdeveloped" differ markedly in the extent to which the occupational composition of their labour force has been modified. Whereas most of the less developed countries in Asia and Africa still have some 70 to 80 per cent of their labour force in agriculture, in some of the countries of Latin America this percentage has fallen to 50 per cent or less.

Projections of the growth of the total, farm, and nonfarm labour force of a country are highly sensitive to agriculture's initial share in the total labour force as well as to the rate of growth of the total labour force. The influence of these factors can be shown most concisely by the following identity :

$$P'_A \equiv \frac{P_T}{P_A} P'_T - \frac{P_N}{P_A} P'_N$$

in which P_T, P_A, and P_N stand for the total, farm, and nonfarm labour force respectively and the primed variables represent annual percentage rates of change. Given the rate of growth of the total labour force and the rate of increase in nonfarm employment, the rate of change in the farm labour force obviously depends upon the ratio of total population to the farm labour force and the ratio of nonfarm employment to the farm labour force. If we consider three hypothetical countries — Earlyphasia in which 80 per cent of its total labour force is in agriculture, Middlephasia with 50 per cent in agriculture and Latephasia with only 25 per cent of the total labour force in agriculture — the strong influence of agriculture's initial share in the rate of change in the farm labour force can be illustrated easily. The two weighting coefficients and the relationship between them is summarized in the following tabulation for each of the three hypothetical situations :

		P_T/P_A	P_N/P_A	Coefficient of P'_T divided by the coefficient of P'_N
Earlyphasia :	$P_A/P_A = .8$	$\frac{1.0}{.8} = 1.25$	$\frac{.2}{.8} = .25$	5
Middlephasia :	$P_A/P_T = .5$	$\frac{1.0}{.5} = .20$	$\frac{.5}{.5} = 1$	2
Latephasia :	$P_A/P = .25$	$\frac{1.0}{.25} = 4.0$	$\frac{.75}{.25} = 3$	1.25

Finally, if we relate these hypothetical situations to the identity that shows the dependence of the rate of change of the farm labour force on these weighting factors and on the rates of change in the total and nonfarm labour force, it is apparent that in Earlyphasia the rate of increase in nonfarm employment would have to be five times as rapid as the rate of growth of the total labour force to maintain a constant farm labour force. But in Middlephasia, if nonfarm employment increases twice as rapidly as the total labour force, the farm labour force will not increase, and for a Latephasia country, if the rate of increase in the nonfarm labour force exceeds the rate of increase in the total labour force by a mere 25 per cent the absolute size of farm labour force will be declining.

The significance of this simple exercise in the "arithmetic of structural transformation" is magnified by two highly important characteristics of the contemporary underdeveloped countries. First is the unprecedentedly rapid growth of population which, with a lag, implies similar rapid rates of increase in their total labour force. Second is the combination of circumstances that lead to a rather abundance of labour. The reasons for this are complex, but it is sufficient to note here that this is a tendency that is not easily changed, in part because for a good many industrial processes the technical superiority of the latest capital - intensive technologies, developed in the economically advanced countries, is so decisive that it more than offsets the difference in relative factor prices in an underdeveloped country.[4]

Rates of growth of total population and labour force of 2 or 3 per cent have become commonplace in the contemporary less developed countries, and it appears to be extremely difficult to achieve expansion of nonfarm employment at a substantially higher rate than the total labour force is growing. Recent experience suggests that rates of growth of nonfarm employment of 3 per cent must be regarded as rapid and 4.5 per cent appears to be something of an upper limit. If total labour force is growing at only one per cent, the rate that was typical of the contemporary industrialized countries as they experienced their "population explosion," growth of nonfarm employment at 3 per cent per annum will lead to rapid structural transformation. Even a country of the Earlyphasia variety would begin to register a decline in the absolute size of its farm labour force after only 29 years if those conditions were fulfilled. But if the total labour force is growing at 2 per cent while nonfarm employment is increasing at 3 per cent, this turning point would not be reached for approximately 125 years. If the total labour force and nonfarm employment are both increasing at 3 per cent, even the relative size of the farm labour force will not decline. And with a 3 per cent rate of growth of the total labour force the rate of structural transformation would be slow even if it were combined with extremely rapid growth of nonfarm employment ; a rate of 4.5 per cent annually would only lead to a decline from 80 to about 60 per cent in agriculture's share of the total labour force in the course of 50 years. The comparisons in the tabulation below point up the sharp contrast in the prospects for changes in the occupational composition of the labour force in countries of the Earlyphasia and Middlephasia varieties over a 50-year period for which hypothetical growth paths have been computed.[5]

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4 For an excellent discussion of these issues, see W. A. Lewis, **Development Planning**, New York, 1966.

5 For fuller detail including a series of charts showing hypothetical growth paths of total farm, and nonfarm labour force, see B.F. Johnston, **Agriculture and Economic Development: The Relevance of the Japanese Experience, Food Research Institute Studies**, Vol. VI, No. 3, 1966 pp. 267–73 and Appendix III.

	Earlyphasia		Middlephasia	
	Farm labour force as % of total at end of 50 years	Years before farm labour force begins to decline	Farm labour force as % of total at end of 50 years	Years before farm labour force begins to decline
A. If total labour force is increasing at 1% and nonfarm labour force is increasing at 3%	48	29	2 *	0
B. If total labour force is increasing at 2% and nonfarm labour force is increasing at 3%	68	50	19	32
C. If total labour force is increasing at 3% and nonfarm labour force is increasing at 4.5%	59	50	2 *	21

The combined influence of high rates of growth of population and labour force and a situation in which agriculture's initial share in the total labour force is large have a number of important implications. Perhaps the most fundamental is that positive measures to encourage family planning to bring birthrates into balance with sharply reduced death rates is crucial for the realization of a country's goals for general economic growth. There are some grounds for optimism that just as the decline in death rates for the contemporary underdeveloped countries has been unprecedentedly rapid, so also will be the decline in birthrates. The well-informed director of the Population Council's demographic division concludes, however, that the rate of population growth in developing countries is not likely to be reduced substantially in less than about two decades ; and a further 15 to 20 years will be required before a reduction in birthrates will show up as a reduced rate of growth of the labour force.[6]

Of principal concern in the present context, however, are the ways in which the prospective changes in the total and farm labour force influence the priority to be given to investment in mechanization as opposed to alternative measures for promoting expanded agricultural production. The following points appear to be particularly relevant to the choice of measures for promoting agricultural development.

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* As the nonfarm labour force becomes a large fraction of the total, it obviously becomes impossible for its rate of growth to substantially exceed the growth rate of the total labour force. The computations summarized here made the simplifying assumption of constant rates of growth of the total and nonfarm labour force. If the differential between the assumed growth rates is large and the initial conditions are those of Middlephasia, a "year of absurdity" will be reached within the 50-year period in which the nonfarm labour force exceeds the total.

6 D. Kirk and G. Jones, **World Population: Causes and Consequences of Growth Differentials**, Iowa State University, Ames, November 1966.

(1) The familiar arguments concerning the need for agricultural mechanization in order to "release" labour for nonfarm jobs have little validity under the conditions that prevail in underdeveloped countries today. The problem instead is to achieve sufficiently rapid expansion of job opportunities to absorb the new entrants to the industrial labour market. The growth of sizable "floating populations" in the environs of Buenos Aires, Dakar, Calcutta, Lagos, and other cities in developing countries is visible evidence of the magnitude of the problem.

(2) Owing to its special character as the "self-employment sector" par excellence in an underdeveloped country, agriculture must for many years continue to provide productive employment for the bulk of the labour force — and a large fraction of the annual additions to the labour force. Thus the size of the farm labour force in most of the developing countries must be regarded as a datum determined by exogenous factors. Hence, the social returns to investment in mechanization that mainly substitutes for labour are likely to be low. On the other hand, investments in inexpensive farm implements that serve to ease seasonal labour bottlenecks may yield high returns, in part because they contribute to fuller year-around utilization of the farm labour force.

(3) Policies that will lead to more rapid growth of nonfarm employment are important. There is certainly some scope for reducing the queuing up for available jobs in urban areas by narrowing the excessive wage differentials that often characterize the "modern" industrial sector and for encouraging a less capital-intensive pattern of investment in other ways as well. But for most developing countries such efforts can only lessen, not eliminate, the need for agriculture to continue to absorb a large part of the annual additions to the labour force. No other conclusion seems possible given the prospective rate of growth of population and the magnitude of the capital requirements for transportation, educational facilities, and other types of infrastrucure — as well as for agricultural and industrial development.

(4) Developing nations thus face a formidable challenge if they are simultaneously to satisfy the resource requirements for agricultural expansion and for industrial development. The fact of rapid population growth underscores the need for a substantial rate of expansion in farm output ; it also increases the capital requirements for structural transformation. But the extent to which agriculture competes with the industrial sector for the scarce resources of capital and foreign exchange will vary considerably depending upon the type of agricultural development strategy that is pursued.

(5) Agricultural research and extension programs to develop technical innovations that are suitable to the existing small-scale farm units and which substantially raise the productivity of the farm-supplied inputs of labour and land that have relatively low opportunity cost are of key importance. Historical experience in Japan, Taiwan, Mexico,[7] and other countries indicates that agricultural research

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7 Mexico's experience has differed considerably from that of Japan and Taiwan in the extent to which the increase in output has been concentrated in a relatively small number of large, capital-intensive farm units. It has been argued elsewhere that the "Japanese model" has greater relevance to contemporary underdeveloped countries than the "Mexican model" (Johnston, 1966).

and extension programs aimed at the development and widespread dissemination of technical innovations which will lead to substantial increases in crop yields can be very effective in bringing about increases in farm productivity — in output per unit of total input. Varietal improvement combined with increasingly heavy application of chemical fertilizers and use of insecticides and other means for controlling pest damage stand out as the most strategic factors for increasing agricultural production because they complement the labour and land resources already committed to agriculture. Considerable progress in varietal improvement has already been realized in spite of the limited resources that have been devoted to research relating to tropical foodcrops, and progress in plant genetics, experimental design, soil science, and other technical fields will facilitate further significant progress as research efforts are intensified. Technical progress in the manufacture of chemical fertilizers, which has already led to large reductions in their real cost, increases the likelihood that farm output expansion based heavily on increased use of fertilizers will be profitable.

(6) Failure to exploit the opportunities that exist for relatively low-cost expansion of agricultural output is to be attributed largely to inadequate research and extension programs; the associated inputs of high-yielding varieties and knowledge of fertilizer requirements under a wide variety of conditions that are essential in order to reap the potential benefits from substantially expanded use of fertilizers are lacking. Low levels of farm cash income and foreign exchange shortages also militate against expanded use of fertilizers, especially on root crops which are grown in large part to satisfy subsistence needs. To the extent that this is a limiting factor, it applies a fortiori to the requirements for purchase of farm machinery.

(7) The social as well as the private returns to investment in mechanical equipment will increase, of course, as structural transformation brings about a gradual decline in the relative and eventually the absolute size of the farm labour force. Expansion of the market for purchased agricultural products implies higher farm cash incomes and increased ability to purchase inputs; and the need to increase output per farm worker increases at an accelerating rate as the farm labour force declines from some 70 to 80 per cent of the total to the 20 per cent and less that characterizes developed economies. These changes also mean a great increase in the employment opportunities available in the nonfarm sectors. This will obviously result in a bidding up of farm wage rates, and a rise in the opportunity cost of the labour of self-employed farm workers.

These considerations help to explain why mechanized production is generally of such limited importance in the less developed countries, particularly those that resemble the Earlyphasia situation described above. Where labour is abundant and wage rates low and where capital is scarce and interest rates high; purchase of expensive items of farm equipment is likely to be unprofitable. The tendency to equate agricultural modernization with mechanization may, however, lead to government policies to encourage mechanization through subsidies, duty free imports of farm machinery and fuel, and creation of large farm units that, superficially, overcome the scale barrier to mechanization.

In addition, a limited number of farm operators may find agricultural mechanization profitable even though the social returns to such investment are much lower than from expenditures for agricultural research and extension education. This situation appears to characterize some of the Latin American countries where the agricultural sector is characterized by a "dual-size structure". Owing to the size of the farm population relative to the cultivated area, the average number of farm workers per cultivated acre is necessarily large. But a large fraction of the farm population is crowded on to extremely small holdings that produce only a very small marketable surplus and, accordingly, have little cash income for purchased inputs. At the opposite extreme in this bimodal distribution of farm land, a relatively small number of large farm operators control a major part of the agricultural land and account for the bulk of commercialized production.

Although the wages paid farm workers by these large land owners are meager, they are frequently above the marginal product of labour in the minifundia because of the tendency of farmers with extremely limited resources of land and capital to push their inputs of labour to a point where its marginal product has fallen appreciably below its average product.[8] And it is, of course the average product of members of farm households that determines the income that must be at least matched to attract hired labour. Furthermore, both the monetary and non-monetary costs of supervising a large farm labour force are likely to encourage large-scale operators to invest in labour-saving equipment in spite of the low wage rate ; wherever there is the threat of labour union action to push for higher wages, this tendency will be accentuated.

Implicit in this argument is the proposition that large landowners often have control over large holdings not because they pay a price that reflects its opportunity cost but for historical and political reasons, including the fact that land taxes have been held at low levels. Further, such landowners often have preferential access to credit at interest rates below the "true" price of capital and also have preferential access to technical knowledge because of superior education and wider contacts. Finally, in such a situation there is likely to be serious underinvestment in public education and in publicly supported programs of agricultural research and extension because landlords are not keen to tax themselves to provide such services to the mass of the rural population ; and the taxable capacity as well as the political power of the latter is limited. This type of situation is apt to result in a highly stagnant traditional subsector of the agricultural economy because its members have restricted access to technical knowledge and land as well as limited capacity to sell a marketable surplus or to buy farm inputs. And to the extent that the large-scale subsector satisfies a lion's share of the growing demand for purchased agricultural products, investment in mechanization may be highly profitable for the large, commercial operators. Nevertheless, given the underlying economic conditions, it is profitable that much higher social returns would be realized from outlays for the research, extension, and rural education required for a broad-thrust approach to agricultural development based on labour-intensive, capital-saving techniques of production.

In concluding this brief discussion of a complex set of problems, I would like to relate the analysis specifically to the question of research and development priorities for the tropical root crops.

(1) *Obstacles to mechanization of root crop production.* — The general arguments that cast doubt on the returns to investment in mechanization seem to

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8 J. W. Mellor, **The Economics of Agricultural Development**, Ithaca, New York, 1966

apply with particular force to the tropical root crops. These crops tend to be low in value and, as previously noted, they are often grown largely for subsistence consumption by farm households. Hence, the inherent limitations on use of purchased inputs apply with particular force to these crops.

(2) *Returns from varietal improvement.* — Large returns from varietal improvement are usually the result of plant breeding programs directed at the development of varieties with the capacity to respond well to high levels of soil fertility. However, there appear to be significant possibilities for raising yields of the tropical root crops by the development of varieties resistant to disease or virus damage or by simply identifying and introducing cultivars with yield characteristics superior to the local varieties. As one important example, the work carried out some years ago by the East African Agriculture and Forestry Research Organization at Anami in Tanganyika has provided the basis for very substantial increases in cassava production based on the introduction of mosaic-resistant varieties.[9] The problems to be overcome in research, in the organization of programs for multiplication of improved planting material, and in bringing about the widespread adoption of higher yielding varieties should certainly not be underestimated. The fact remains, however, that such measures are particularly well adapted to the requirements for an efficient strategy for agricultural development in the early phase of economic growth and should be assigned a high priority.

(3) *Expanded use of chemical fertilizers.* — Expansion of tropical root crop production, as agricultural production generally, will come to depend increasingly on providing and maintaining high levels of soil fertility through the use of chemical fertilizers. Larger uptake of soil nutrients as crop yields are raised will in itself increase the need for application of chemical fertilizers. Moreover, the heavy labour costs associated with frequent clearing of plots under bush fallowing can almost certainly be reduced by lengthening the period of cultivation through the application of chemical fertilizers. The gradual increase in farm cash incomes as structural transformation of these economies takes place will make it possible for root crop producers to rely increasingly on purchased inputs. Because chemical fertilizers represent a form of capital that gives a quick payoff and is highly divisible — and therefore suitable for use on small units — they are particularly well-suited to adoption by smallholders in the early phase of development. And the fact that fertilizer inputs are highly complementary to existing resources of labour and land, and also to research directed at varietal improvement, means that return to outlays for fertilizers are likely to be very high. Once again the difficulties of realizing this potential should not be underestimated. There still seems to be an acute need for better understanding of fertilizer requirements for the various root crops under different soil and climatic conditions, and the extension services and sales organizations required to promote widespread use of chemical fertilizers are lacking in most of the developing countries.

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9 B. F. Johnston, "Choice of Measures for Increasing Agricultural Productivity: A Survey of Possibilities in East Africa." **Tropical Agriculture**, April 1964.

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DISCUSSION

Chairman :

I would like to invite questions on Dr. Jones' paper.

Mr. Williams :

Mr. Chairman, most people agree that the cost of production of tropical root crops throughout the world (from figures quoted by economists) is fairly high and here in Trinidad at the Texaco Farm it was shown that the large proportion of this high cost of production was due to high labour input. The developing countries have the problem of rationalising their agriculture in the face of a lot of employment , Would you kindly explain how this adjustment to be made is made?

Dr. Jones :

In the first place I think that the evidence is pretty clear that for the tropical root crop with which I am concerned and about which I know a little bit, that the costs of production are remarkably low. And I tried to argue this without trying to bring together data from field study and farm management studies because it is terribly difficult to fit together. I tried to argue this essentially from a price standpoint. That is, if the commodity is selling at a very low cost per thousand calories, then it must be relatively inexpensive to produce and this is consistent, I think, with some of the other data I have.

Now, I think there was another part of your remark to which I would like to respond, although I think probably Bruce Johnston, or some of the others would want to say more about this this afternoon. This is a whole question of having commodities which require high labour inputs and it could be produced with much lower labour inputs if you introduce mechanisation. Certainly this is an appropriate policy in a certain stage in the development process, but that stage is only reached when the demand for labour is so strong in the non-agricultural sectors that the people who are displaced by the introduction of mechanical equipment will have little difficulty in finding employment, but for a large part of the under-developed world, this stage has not yet been reached. This causes me and Dr. Johnston and others to be extremely cautious in our recommendation of labour displacing interventions even though it may reduce the cost in terms of man hours, because what we are concerned about is cost in terms of economic units. It doesn't do any good to reduce your man hour cost if you throw a thousand people out of work and they have to go on welfare. As far as the States is concerned the cost is still being met. Does that explain your question?

Dr. Rogers :

Dr. Jones, in your paper you say "at least the large amount of agronomic research in manioc culture seems not to have resulted in economically important advances". First, I would like to ask where this large amount of agronomic research has been done and how you got the idea that it is not justified.

Dr. Jones :

Well, maybe I should not have said that. Actually there has been quite a lot of agronomic research on manioc done in Indonesia, Brazil and in various parts of Africa. What I was trying to embrace under agronomic research was a lot of work about the length of the cutting and whether to hill or not to hill, and whether the plant is at a 45° angle or 60° angle, and others of this sort, and there has been a lot of it and as far as I have seen it's unproductive. But I will correct that in the text so that it would not be quite so offensive.

Dr. Johnson :

I would like to ask Dr. Jones a question on the first part of that same sentence. "It is not clear that changes in farm practices can significantly alter a ton per acre per man day." Now, I am not quite sure, I think as an aside he did say that he was less certain at that stage than he was before. Now I think it is known that many of the practices in the production of food crops are so behind and are not existent at all, that even by adopting these practices we can get significant changes in returns per acre and per man on the farm — at least that is from our experience. So I would like to hear Dr. Jones comment further on this point.

Dr. Jones :

Well, again I am not a qualified expert here, and again I'm reasoning from knowledge about manioc. I have not seen evidence that changes in farm management produce enough increase in manioc production to justify the change. The reason I qualified the remark when I was reading in the paper was because I had not realised until a couple of days ago 'that it might not be economic to stake yams. I' always assumed that you had to stake yams to get a decent yield.

Mr. James :

I am rather interested in Dr. Jones' statement where he singles out the physical effort of clearing land for agriculture as the major cost of food production in agriculture. This interests me because I am engaged now in the development of small farm units in a particular area in Trinidad, where when before we started my great fear was that this same problem of clearing the land would have been the major obstacle to development. As it emerged this is not at all the limiting factor. In fact nobody has shown very much interest in mechanical clearing of land, whereas almost immediately as herbicides were introduced it was accepted. So that it seems to me at this point that after cultivation practices, there seems to be a much more limiting factor in terms of labour input and therefore a cost item in production of food crops and root crops than the physical effort in clearing land — and this is land from virgin forest.

Dr. Jones :

I am very handicapped on these questions. What I guess I meant there, was that land costs in many part of Africa is still essentially zero. The cost of land is the cost of clearing. This is rapidly becoming not true, but it is still true in large areas. The other question about the potential possibility of substituting mechanical processed for clearing the land as against the mechanical process for field operations. I just have a hunch that you find mechanisation is more efficient in field operations than it is in clearing on the cost basis. The cost advantages is clearer in field operations than it is in clearing. I do not know your situation here, but certainly the kind of clearing costs that we run up in certain parts of the tropics, Africa, especially the forested areas and the bush area in Tanzania, were fantastically high, much higher run in labour costs I think than the mechanised field operations.

Mr. Sandys :

I would like to refer to the question of the cost of clearing land. I was in the country now called Malawi for quite a few years and we had experience there clearing bush (from light to heavy bush) and we tried just about every method, from people chopping away with axes to blasting with gun powedr, and big D-8's heaving behind them. And we found that unless you were in a particular hurry to clear an acreage of land, the cheapest way was to put out the clearing to contract. Usually you would find some locals who would get together a gang of people and between them they would clear at a contract price per acre, and this proved to be the most economical way of doing it.

Mr. Pilgrim :

Just a general comment on the paper in general. These papers naturally tend to make statements of what is at the present moment comparing root crops with cereals, giving trends that have occurred in the movement from root crops to cereals, etc. in other countries. This worries me to some extent because I somehow feel that it gives us an unnecessarily gloomy picture of the future for root crops. Is it not true that cereal crops have received over the past years, very very much more input in research work than the root crops? Is it not true, particularly in the

West Indies, that the system has been built up in which a lot of capital has been put into processing, marketing of crops produced elsewhere, cereal crops from temperate areas for introduction into the West Indies in direct competition with our local food crops? Is it not true that the money put into the advertising of cornflakes is far way above anything that is put into the advertising of banana chips, or in producing cornflakes versus banana chips? On this statement in Mr. Rees' paper that "findings indicate that greater scope exists for mechanising the production of cereals and starchy roots". Is it not true that the machines being used have been developed for cereal production in temperate countries and that no serious and sustained effort has been made to produce machines for the cultivating and harvesting of root crops? Isn't it true that our very International Symposium on Tropical Root Crops is the first? Think of the number of symposia that have been held on other types of crops. So taking all these things into consideration, isn't there a case for very much more work to be done on tropical root crops and might it not be that if this work were pursued, the situation of tropical root crops versus cereal crops would be greatly altered. I am just wondering on these matters, because there seems to be undue pessimism over the future of root crops.

I am just trying to get this thing in the correct perspective. Is it not true that the main issue is that we really have not put into our root crops any of these inputs in brains, time and money which have been put into these other crops? And should we not set about finding ways and means of doing this?

Dr. Steppler :

I would just like to make a comment, Mr. Chairman, on this question of mechanisation, particularly in answer to what Mr. Pilgrim has said and the suggestions that there has been a lot of brains, money, etc. that has gone into mechanisation of temperate crops. I hope that the same kind of development that took place in mechanisation in many temperate crops is not the pattern that is followed here, because in many instances these machines were forced upon the farmer — I say forced upon the farmer in the sense that they were not developed in full co-operation with the other segments of agricultural research. The harvesting machines for grain, for example, were largely developed independent of the agronomist dealing with gain production. I think that the situation that faces the tropics in root crops and in many other crops is very exciting, because I believe that they have an opportunity to have an agricultural engineer, an agronomist and a plant breeder sit down together (and I might even put the economist with them to sit down together) and develop ways and means which maximise the production, the efficiency of the man, the efficiency of the use of land, of the machines and the capital input. I think we have a very exciting potential here. There have been just suggestions of these in the work that has been done in the United States. I thing particularly with tomato harvesting, where an agricultural engineer and a plant breeder sat down together and between the two of them they designed a plant and they designed a machine. I think this is the future that we have here.

Mr. Ball :

I would like to takeup the point mentioned about the designing of machines for root crops. While it is true that much of the equipment on the market has been designed for climates possibly not typical of areas where tropical root crops are grown, it should be said that any failure to apply these machines in areas where tropical root crops are grown is probably due to a failure to appreciate that a system of production is required than to a failure in the designing of machines. This may be a sweeping statement to make, but it is our experience that if it is understood that the application of machines requires a logical system of preparation of land right through to harvest that the machines can be very, very much more successful. This has been amply demonstrated in the case of sugar cane, but in root crops we are finding this in the case of sweet potatoes, and I am sure that if you examine the question the logic of it will be apparent. Just a final comment. The equipment that has been designed in the United States and Europe, owes much of its success to the fact that the people who use it appreciate what it is designed to do and are prepared to make allowances in their production systems to suit the equipment. From our experience of root crops and other tropical crops this is not the case. People expect the machines to do very much more in the actual system they are using than the machines can. Indeed, there is the need of changing the system to suit the machines, as well as designing machines to suit the system ourselves.

Dr. Jones :

I should like to reply to this. I do not want what I said before to be misunderstood. I think that we can quite likely develop mechanical harvesting later on for most of the tropical roots just as we harvest the temperate zone roots. We harvest sugar beet mechanically now. It looks as a difficult problem but we changed the system, we changed our product. But I argued in my remarks that the real need for mechanised production of tropical roots is probably some place in the distant future, but they have already arrived in a wealthy country like this one, but in the poorer countries where the tropical root crops constitute a very large part of the diet, the advantages to be got in this type of labour saving activity are apt to be negative. So that, of course the research has not gone into the tropical roots that has gone into cereals and I think that we are all agreed that it 's highly desirable that a great deal more research be done on these crops, just as we are now getting from cereals, like sorghum. This should be done.

On the final remark, I do not think that I could agree with you. I think that the reason that the pôor people eat what they do is because it is cheap. And the reason why I am interested in the tropical roots is that they are already cheap, and they show great potential for continuing to be among the very lowest cost providers of food energy, and this is what is important and this is what needs to be in front of everybody when talking about tropical roots.

Dr. Edwards :

I wonder if I might comment very briefly that the West Indies is in some way a peculiar part of the tropics and I think this may be one example.

Mr. Cacho :

I would like to offer a comment on what Mr. Pilgrim has said. Seeing that he is an agronomist, he has dealt with the production side of it, and I think that the point he is making is that if more research is poured into the production of root crops, productivity will go up, price will go down, and therefore the demand is likely to increase. This all sounds very good. But I think that he has been dealing with the supply. On the demand side, this is where our problem really lies, particularly when we look at the demand curve forward as Dr. Alexander and other people have been trying to do. I think that it is reasonably clear, although there is still a certain amount of conflict on this, that the income elasticity of demand for these root crops is low. As people's incomes go up (I'm talking about the Caribbean), they tend to go away from the starchy roots on to Irish potatoes and rice. We also know that the class elasticity of demand is low as you move up from one income bracket to another. Therefore, as people move up they tend to move away from these.

Then there is the peculiarity of which Dr. Edwards spoke. You know, this sort of outward look rather than inward look, particularly in the urban areas. And when you move from the rural to the urban areas, in Jamaica for example, you are going to have people changing their pattern of consumption, which is again a move away from the roots. I think that this needs to be emphasised, particularly when we have a number of agronomists here, because here we are, talking in terms of supply and demand, and what we do not want to happen is for a research to be made. We produce more efficiently and we flood the market, and as we get more and more of this stuff on, less and less of it is perhaps bought.

I think that we are also pretty clear that the demand curve for these starchy crops is a backward sloping one. So that if you can produce more, and reduce the price it means that perhaps the producers will suffer. Now, I agree with Mr. Pilgrim that perhaps much can be done to stimulate demand and therefore I am looking at the situation as it exists at the present time. I agree that on the supply side we want to reduce price so that there is a little more competition, but on the demand side we want to take steps which will change these social, cultural or other factors, which are responsible for the income elasticity of demand, the class elasticity of demand and the classification of these things as inferior goods. These are the things we want to work on.

Mrs. Rawlins :

Mr. Chairman, first I should like to thank Dr. Jones for his very clear exposition of the secular and economic trend that might be expected in root crop production. But I would rather more to turn my comments to Dr. Alexander's paper because this comes down to 'brass tacks' about a situation with which I, too, am familiar. Dr. Alexander's description of the pattern of supplying demand in Trinidad, I think, is very clear and very true. However, perhaps it has two limitations. One is that his consumer survey, I rather feel may be limited to a study of the purchasing patterns amongst the urban middle class groups, the rural groups. It is probably true that these latter still follow the trend of consuming root crops that they have produced themselves rather than going to the supermarket to buy rice and Irish potatoes. That is one limitation. The other is that the pessimistic description of a decline in demand for root crops to which Mr. Pilgrim referred does not seem to me to take account of population growth. At least for some time to come, it seems to me that there would be room for increasing demand, at the national level, for root crops due simply to the increase in population; increasing particularly at that low level of income where the consumption would continue to be directed towards these low value root crops and not to the specialised supermarket products. So that, these two limitations, I hope, will balance off the otherwise very vivid description of the situation in Trinidad.

Mr. Francis :

I want to follow up this question of demand for starchy food crops a bit. I think it is important to note that the price of starchy root crops particularly in Trinidad and Tobago is an important limiting factor in the amount that is being sold or disposed of. From my own experience, I know that I would consume quite a lot more sweet potato, tannias, etc. if the prices were not in the region of 20c. per pound, as it so often is.

I see Dr. Alexander's Table 3 indicates that sweet potatoes (and I think that he has a downward bias in a number of his prices because I pay the prices and I know that they are above what he has here) are more expensive than Irish potatoes. And if Irish potatoes are brought from abroad and landed here and sold at a profit at 12c., I keep wondering whether or not, if we are to compete fairly with Irish potatoes, we shouldn't sell our sweet potatoes at less than 12c. But if we cannot produce it efficiently, certainly we will not be able to sell it at a more competitive price. So I think that price is an important factor in the amount that we are able to sell regardless of whether or not there is a backward bend in demand curve.

I want to follow up a point made by Dr. Jones which I think he emphasised by repeating. He pointed out that if we mechanised the root crop farming then we are likely to make labour redunant in a number of tropical areas. If, as appears to be the case in Trinidad and Tobago, root crops are produced mostly by peasant farmers who depend to a large extent on the supply of labour of their own families, and who do not in fact hire labour, then apparently what we are aiming at doing is increasing efficiency and the total volume of production, and perhaps improving their own economic status rather than in any way, make labour redundant by so doing. Apparently the only way we can make labour redundant is, if by improving efficiency and total production we satisfy the demand with fewer peasants being involved in agriculture, and therefore we drive some people out of agriculture. Again, if we reduce the price, and demand actually increases, then certainly we might be able to sustain more peasant farmers by perhaps a more efficient method of production.

Mr. Ferrer :

I think a good bit of the answer to this Irish potato business could be obtained if we multiply what Dr. Alexander said about the availability of Irish potatoes throughout the year, by what Mr. Francis had to say about the price. The point is, that Irish potatoes are available throughout the year. At some time of the year you get some from Canada, and when they are out of season we switch to Holland, Madeira and the Canary Islands. So from January to December you can go to any supermarket and you will get Irish potatoes.

It is not the same situation with these other root crops. As we know, they are all seasonable. Right at this moment you can probably get all the root crops that we want in the market, but in July, August, September and October, in the wet season, these things become very scarce and the price, of course, rises tremendously. And it is unfortunate that there is so little difference between the climatic factors in the Caribbean territories, that it is impossible to get, for instance, eddoes and tannia at periods other than the seasons when it is also plentiful in Trinidad. If that were possible, I have no doubt that the consumption of these root crops would probably show a better picture than it does show from those tables that we have here.

But I think that the great point is that these Irish potatoes are available throughout the year. So that, obviously, a housewife who goes to the market in August or September will hardly pay the price of sweet potatoes, which are out of season at the time when she can get Irish potatoes at a very cheap price. And she can do it all the year round. And that is a very important reason why the consumption of Irish potatoes is at that level.

I may mention that the Trinidad Government is looking at this problem, and for the last two years we have been regulating the import of Irish potatoes into the country so as to give these other crops a little room to manoeuvre, and we hope that people will be stimulated to try to produce these crops a little out of season. If they find the methods of bringing yams and sweet potatoes in July - August - September you may possibly find that the consumption of these items will increase.

Dr. Royes :

I am speaking specifically on a point that Mr. Ferrer made. I am more or less involved in turning up what these gentlemen want — out of season production and various and sundry things. There is little doubt in my mind that if you want yams or tannias all year round you can get them. We just have to find out how to break dormancy and induce dormancy. This is not impossible but it will take some time. This is the turning, as you say of brains, money and resources on to root crops to make them what you want.

Dr. Johnston :

I want, first of all, to express my appreciation to Dr. Alexander for the extremely interesting and original research that he reported in his paper. I have one or two minor points to raise on that, and that is with regard to this difficult but very important question of trying to obtain understanding of consumer preferences for crops. It is difficult to get an indication of preference that is uninfluenced by difference in relative price. I have a hunch, e.g. that the very low position of tannia compared with dasheen may reflect the fact that consumers have in mind that tannia was half as expensive as dasheen, whereas in terms of preference what we are really interested in is relative strength of demand and equal prices.

Also, comparisons of Tables 1 and 2 and some of the discussions which we had this morning point to the great importance of seasonal variations in root crops. And in this regard I was very much concerned with the remarks which Dr. Royes just made about doing no work on cassava, because, at least in West Africa, one of the great advantages of cassava is not only that it is available in the processed form but even the fresh roots are available in relatively uniform quantities throughout the year, because possibilities of spreading out both the planting and harvesting periods. I am very interested to know whether this is not the case in Trinidad or the West Indies.

And finally, I just want to comment on the extremely interesting contrast which is pointed out by Dr. Alexander's work in the pattern of staple food prices here in the West Indies as compared to tropical Africa, where e.g. as Dr. Jones emphasised root crops, particularly cassava, are so much less expensive than rice and some of the other commodities that appear to be either on a calorie basis as well. And when I say that they are much less expensive than rice, I am speaking in terms of equal quantities of calories, price per thousand calories, whereas Dr. Jones mentioned they seemed to be very much more expensive than rice, or even white potatoes here. We have extremely interesting questions to enquire into the reasons for this. My guess would be that part of it is, as has been suggested, in urban areas the starchy roots have essentially become a vegetable and not a staple root.

Another factor that might be relevant, but I do not know the facts, is simply that yields, particularly in the case of cassava, may be lower than the average yields in West Africa. And finally, it may reflect in part a difference in the purchasing power of current seasons in this area. And certainly the values of the export earnings for the islands of the West Indies relative to the population is very much larger than the economies of West Africa. This factor of the purchasing power of other currency probably influences the fact that the local price of the imported produce compares very much more favourably with the locally produced product.

Mr. Gooding :

I have a general comment to make on Dr. Alexander's paper and a short question. The general comment concerns the effects of research on root crops production and there were some doubts as to just how research might affect the situation of root crops in the general economy. Well, in certain areas we have limited land as in Barbados. The way I visualise it, is the increased production of root crops is not going to increase consumption, but it is going to free land which is now in production of these root crops for growing other crops. One I can think of is Irish potatoes, which is increasing in demand and I can honestly say we have reached a situation in Barbados, where if the knowledge we now have were applied tomorrow, we could reduce our acreage under tropical root crops by probably 1000 to 1500, that would more than supply our potato need assuming that we could grow them on that land that freed Irish potatoes.

Secondly, I really wonder whether Dr. Alexander was referring to the marketing situation in Barbados and Trinidad when he wrote his paper because he described almost exactly the same situation that existed in Barbados and it is just as bad in Trinidad as it is in Barbados. In respect of the home produced tropical root crops, you have the same absurdity but the root crops are harvested miles away from the town, taken into the town and then if they are not sold in the town they may be redistributed from the town to the country. The situation in Barbados is that you can very seldom buy local root crops in the country but you can go into any village shop and buy imported canned foods and if you can see anything more absurd than that, I don't know what it is.

And just one short question please. The prices of yams and sweet potatoes which you quote as 12c. and 14c. respectively, I presume that these are retail prices. What are the field prices the farmer receives for these commodities?

Dr. Alexander :

These prices were average prices obtained, that were used in the national accounts. The margin between the retail price and the farm price for yam is, I think, about 4c. per pound. Mr. Ferrer can bear me out on that. And the sweet potatoes — I cannot say offhand — Mr. Ferrer is the man who has worked on margins.

Mr. Ferrer :

There is a guaranteed minimum price on yam offered by the Government. For yams it is 9c. per pound ex-farm and for sweet potatoes it is 5c. per pound ex-farm. There are, in addition to government agents who go around and collect, depots in different parts of the country where the farmer can take his produce and get a guaranteed price.

Dr. Alexander :

I might add the farm price depends to a great degree on the farmer's ability to market his merchandise in many areas, even though we have guaranteed prices of 5½ for sweet potatoes and 9 for yams and the farm price in many instances today may be substantially higher.

Mr. John :

I would just like to call attention to the last paragraph of Dr. Alexander's excellent paper in which he mentions the necessity for increasing the variety of uses for starchy roots. He makes mention of the inclusion of these roots in preparing snacks, of course, and he talks about the potential for their use in livestock feed formulations. He, however, does not mention the wonderful potential for these starchy roots in the housewife's kitchen. I believe if you look on page 5 you will see that dasheen, yams and sweet potatoes win hands down in taste, whereas Irish potatoes win in the varieties of ways in which it can be prepared, and I would like to point out that if we could greatly increase the ways in whicn these starchy roots can be prepared and presented in the lunch table, this would be one of the factors which could increase their demand.

Dr. Alexander :

I do not disagree with that statement and I think a lot of these territories have been thinking along those lines and talking about food technology laboratories. So far the situation is all talk. My view is that if we were to present yams in particular, in modified forms (say in french fried form the consumer could pick up the supermarket, or in flakes or instant form), I think we will see consumption in demand of these, but the other shortcomings of the products mitigate against their use.

THE DEVELOPMENT OF THE IRISH POTATO INDUSTRY IN JAMAICA

— by —

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The production of Irish potatoes in Jamaica dates back to 1897. In that year two varieties of "seeds' were imported from the United Kingdom and 'tried out' at elevations of about 3,000 ft. The results were encouraging; and in 1900 the Jamaica Agricultural Society imported other varieties for further trials. At the same time efforts were made by the Society and the early pioneer farmers to popularise the production and consumption of the crop. Soon local demand began to respond favourably, and as a result, production was progressively extended into new areas.

But the expansion of the crop was to receive an early set-back. Local production depended (and still depends) on imports of seeds and thus it was that the lack of shipping space during World War I caused a reduction in the supply of seeds. Supply of 'seeds' was inadequate to meet demand and prices rose from 14/- per barrel (of 150 lb.) in 1913 to 42/- in 1917.

High prices for seed potatoes threatened the survival of the industry. In response, farmers requested government to provide credit assistance to enable them to continue production. In addition, they initiated discussions on regulating the market for Irish potatoes. At the same time, the Department of Agriculture conducted a series of experiments in an effort to establish the crop on a more viable basis. (A summary of the more important experiments is given in the Appendix.)

The later development of the Irish potato industry may conveniently be divided into three periods, namely :— an exploratory period, a period of expansion, and the attainment of self-sufficiency. The exploratory and expansion periods overlap to a certain extent as some exploratory work continued through the expansion period and in fact, is still continuing.

THE EXPLORATORY PERIOD

The main exploratory activities of the industry may be regarded as having taken place during the period prior to 1950 and particularly during the 1940's with which period was associated most of the field experimentation. However, it was during the period *1950 – 1954* that there was a greater drive towards commercial field operations. During this period there were noticeable increases in the demand for Irish potatoes. Due to the fact that import data over that period did not differentiate precisely between 'seed' and 'table' potatoes, and the fact that nearly all the seed potatoes are imported, it is difficult to give as accurate an estimate of the local production of table potatoes as otherwise would have been the case. However the total value of imported Irish potatoes (see Table 1) increased from *£9,832* in 1950 to *£52,794* in 1954.

Table 1. Quantity and Value of Irish Potato Imported, Jamaica, 1950 – 1954

Year	Imports ('000 lb.)	Value (£)
1950	965.3	9,832
1951	3,067.0	37,790
1952	2,445.9	33,688
1953	2,805.8	30,688
1954	5,627.7	52,794

Source : *External Trade Statistics,* Department of Statistics, Jamaica.

In 1942 a subsidy scheme was introduced by Government. During that year seeds were sold at 40/- per barrel of 150 lb., but this price was subsidized to growers to the extent of 17/- per barrel. In order to facilitate growers, control depots were established at convenient points throughout the potato growing area. Each farmer had to take delivery of seeds from the nearest depot, and he could only obtain seeds on the presentation of a *Certificate of Recommendation* signed by the Agricultural Instructor for his area. This, it was hoped, would prevent resale of seed potatoes at "black market" prices.

During the period 1947 to 1949 the rate of direct subsidy paid by Government was of the order of 10/- per barrel. Indirect Government assistance was also provided to encourage local production. In this respect seed potatoes were exempted from the *1d per lb.* import duty payable on table potatoes. There had also been in existence a Government Guaranteed Purchase Scheme for potatoes. The guaranteed prices for potatoes delivered in Kingston to the Department of Commerce and Industries (succeeded by the Marketing Department and finally by the Agricultural Marketing Department) for the period 1947 to 1949 were :

Year	*Price (per 100 lb.)*
1947	13/2 – 15/–
1948	16/6 – 18/–
1949	20/–

However, only a small fraction of the crop was sold to the Government since prices obtainable elsewhere were higher than the guaranteed price. Protection was offered to the grower to enable him to dispose of his crop readily. Importations of table potatoes could only be made on special permits and from specified countries only, importations being severely curtailed during months when the locally produced crop is on the market.

The subsidy continued uninterrupted until it was terminated during the 1961/62 crop year. Accurately recorded subsidy figures are not available for the period before 1950. The largest rate of subsidy as can be seen from Table 2, was paid by Government to growers in 1952 and this was due primarily to the disastrous effects of the 1951 hurricane.

Table 2. Subsidy on Irish Potatoes, Jamaica, 1950 – 1961

Year	No. of Crates of 100 lb.	Amount of Subsidy			Av. Subsidy Per Crate		
		£.	s.	d.	£.	s.	d.
1950	16,004	6,433	13	4		8	1
1951	16,251	2,830	9	10		3	6
1952	15,000	17,357	6	8	1	3	2
1953	15,700	7,336	8	4		9	4
1954	10,628	2,760	0	0		5	2
1955	11,691	6,300	0	0		10	9
1956	15,000	4,500	0	0		6	0
1957	16,100	7,884	0	0		9	9
1958	16,100	6,911	0	0		8	7
1959	18,500	19,348	0	0	1	0	11
1960	25,000	4,000	0	0		3	2
1961	20,535	2,000	0	0		2	0

As the production of Irish potatoes expanded, problems arose with pests and diseases. In 1950 the Department of Agriculture carried out investigations into the losses due to infestation with eel-worms. Heavy losses were sustained in that year due to a serious infestation by the root knot nematode, *Heterodera marioni*. An investigation-cum-demonstration project was laid down in relation to :

(i) inconsiderate agricultural practices ;

(ii) field sanitation ;

(iii) judicious crop rotation ; and

(iv) application of nematocides, and the practice of bare fallowing.[1]

During the period 1950-1954 there were clear indications that there was scope for increasing local production advantageously, but that there was the necessity to stabilize farmers' position. This led to the paying of more earnest attention to planning, organization, crop rotation and efficient practices. These activities developed largely within the frame-work of the Irish Potato Growers' Association which was formed for the purpose of rationalizing and expanding the industry. As production increased, problems associated with storage developed, and the Department of Agriculture carried out investigations into storage losses due to shrinkage, rotting and excessive sprouting.

THE PERIOD OF EXPANSION

The period 1955-65 may be regarded as one of expansion. Interested farmers in their endeavour to make potato growing a business continued in their quest for better techniques and cultural practices. Indeed, so great was the development in the industry that Government discontinued the payment of a subsidy for seeds in 1962. It was during this period that an Irish potato Advisory Committee

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1 **Investigations 1949-1950, Bulletin 47,** Department of Agriculture, Jamaica.

was set up within the Ministry of Agriculture and Lands. More precise and up-to-date information relating to all aspects of the industry was made available. This included information on the quantity of seeds planted, and the break-down of import data into table and seed potatoes. This latter in particular made it possible to obtain more reliable estimates of production.

The fact that Jamaica does not produce certified seeds indicated clearly that increased quantities of seed would have to be imported for the expansion of local production. Thus except for 1961 the quantity of seed potato imported increased every year since 1955. Indeed, the quantity of seeds imported more than trebled during the period 1955-66. The most marked increases in the importation of seeds were made during the period 1964-66.

Increased planting resulted in increased production and progressively reduced the need for substantial imports of table potatoes. The data presented in Table 3 indicate a somewhat erratic pattern in the quantity of table potatoes imported up to 1962, followed by a continuous decrease and finally by a cessation of imports in 1966.

Table 3. Quantity and Value of Irish Potato (Seed & Table) Imported, Jamaica, 1955 – 1966

Year	Table Potatoes	Seed Potatoes	Total Imports	
	(m. lb.)	(m. lb.)	(m. lb.)	(£'000)
1955	4.8	1.5	6.3	74.6
1956	5.2	1.6	6.8	83.2
1957	5.3	1.6	6.9	95.6
1958	10.9	1.8	12.7	164.4
1959	10.7	2.2	12.9	156.9
1960	5.4	2.5	7.9	115.3
1961	9.2	2.1	11.3	141.1
1962	11.9	2.6	14.5	132.6
1963	8.0	2.8	10.8	128.7
1964	3.5	3.5	7.0	88.2
1965	1.9	4.7	6.6	51.3
1966	0.6	5.7	6.3	n.a.

But these were not the only important developments of the period. In March 1959 the Christiana Potato Growers' Association was registered as a Co-operative Society under the Co-operative Societies Law. The Society's main aim was to improve the economic welfare of its members and pledged itself to :

(i) initiate, develop and encourage more economic and better methods of production and marketing ;

(ii) make arrangements for the pooling, curing, grading and transporting of Irish potatoes for its members ;

(iii) make arrangements for the most profitable disposal of potatoes for its members ;

(iv) act as agent for its members in procuring seed, implements, fertilizer and other necessary supplies ; and

(v) raise funds on loan to meet other objectives of the Society and for making credit advances to members.

This was a great step forward by which farmers gained new confidence in the industry. They were now able to bargain as a group to the advantage of members of the Association.

ATTAINMENT OF SELF SUFFICIENCY

The annual local production of Irish potatoes nearly trebled between 1955 and 1966 (see Table 4).

Table 4. Quantities of Irish Potatoes available for Consumption, Jamaica, 1955 – 1966

Year	Import	Local Production	Total Available	Local Production as % of Total
	(m. lb.)	(m. lb.)	(m. lb.)	(%)
1955	4.8	11.6	16.4	71
1956	5.1	8.9	14.0	64
1957	5.3	9.3	14.6	64
1958	10.9	11.1	22.0	50
1959	10.7	15.4	26.1	59
1960	5.4	15.0	20.4	74
1961	9.3	15.6	24.9	63
1962	11.9	14.1	26.0	54
1963	8.0	18.8	26.8	70
1964	3.5	21.5	25.0	86
1965	1.9	26.1	28.0	93
1966	0.6	32.9	33.5	95

Source: *External Trade Statistics,* Dept. of Statistics; Estimates by Dept. of Agriculture and Ministry of Agriculture and Lands.

In that period, not only did Jamaica become self-sufficient in Irish potatoes for table consumption but in 1966 had problems mainly in relation to storage of surpluses above the immediate demand. As a consequence attempts were made to find export markets. The achievement of self-sufficiency depended particularly on the extension of the planting seasons. Table 5 indicates the quantity of seed planted in each of the three seasons during the period 1960-1966.

Table 5. Yearly Seasonal Planting of Irish Potato, Jamaica, 1960-1966

Year	Total Planted (100 lb. bags)	Spring Planting (Quantity) (100 lb. bags)	Spring Planting (% of total)	Summer Planting (Quantity) (100 lb. bags)	Summer Planting (% of total)	Fall Planting (Quantity) (100 lb. bags)	Fall Planting (% of total)
1960	25,000	17,376	69.5			7,624	30.5
1961	20,535	17,172	84.6			3,363	15.4
1962	26,000	17,171	66.0			8,229	34.0
1963	27,785	20,943	75.4	2,162	7.7	4,680	16.9
1964	35,180	23,705	67.3	5,200	14.8	6,275	17.9
1965	47,388	35,125	74.1	2,600	5.5	9,663	20.4
1966	56,890	44,140	77.6	1,580	2.8	11,170	19.6

ECONOMICS OF PRODUCTION AND DISPOSAL OF IRISH POTATOES

The story of Irish potato production in Jamaica must be regarded as a success story in terms of the achievement of self-sufficiency. A programme of selection of varieties, fertilizer experiments, storage trials, *inter alia,* has led to the achievement of one of the desired end results, namely that of almost replacing imports of table potatoes. Other results which are desirable relate to satisfactory returns both to the growers and to those responsible for marketing potatoes.

(i) Enrivonmental Conditions of Production

(a) *Climate.* Irish potatoes thrive best under relatively cool conditions and in Jamaica production is therefore concentrated in areas where the elevation is over 1,000 ft. A rainfall of about 10 inches, well distributed during the growing season is normally required for the production of good yields. On heavier soil the rainfall need not be as high.

(b) *Soils.* Usually, Irish potatoes grow best on deep well drained soils, but in Jamaica heavier soils are sometimes used. Soils used for growing potatoes in the main potato producing areas include the free draining *terra rossa* soils, clay loams, and even some of the heavier clay soils.

(c) *Growing Seasons.* The production of Irish potatoes is seasonal, there being *two* well defined seasons in Jamaica. The main crop is planted during February-April and is reaped during the period June-August. The other crop is planted during the period November-January and is reaped during the period February to April. In the past, locally grown potatoes were available for the period February through August, the period September to January being that for which imports were allowed by Government. This led to steps being taken to find areas in which Irish potatoes could be grown to bridge this gap in the local production. Since 1963 a small crop has been planted during the Summer (June to August) for reaping during the period October to December. Exploration for new areas for growing this summer-planted crop is continuing.

The main areas of production and the growing seasons are listed below.

Area	*Time of Planting*	*Time of Reaping*
Devon Chudleigh Christiana	February to April	June to August
Darliston Guy's Hill Lucky Hill	November to January	February to April
South Manchester North Eastern St. Andrew	June to August	October to December

Varieties. Many varieties of Irish potatoes have been tried in Jamaica. They vary greatly in appearance, yield, time of maturing, resistance to diseases and pests, and eating quality. Some of the varieties tried in Jamaica and their origins are set out below.

Canada:	*Ireland:*	*Scotland:*
Up-to-date	Up-to-date	Arran Victory
Burbank	Craig's Snowwhite	Arran Consul
Sebago	Arran Banner	Kerr's Pink
Cobbler		
Green Mountain		
Kathadin		
Kennebec		
Red Pontiac		

The most important of those which are now grown commercially are: Arran Consul, Sebago, Kennebec and Red Pontiac.

In the past, there has been a tendency for growers in different areas to favour particular varieties. Today, farmers while selecting varieties which are suitable for their areas also look for heavy bearing varieties and for seeds which are not too costly. It sometimes happens, however, that the high cost of seed is related to the demand and supply situation at the source of the purchase. In this respect the cost of Sebago, a popular variety which was reported at 65/- per 100 lb. as compared with 42/- to 47/- per 100 lb. previously, has largely resulted in this variety not being used in 1967. In this respect it should be pointed out that due to the necessity for us to import seed we are at some disadvantage particularly in relation to our ability to obtain the particular varieties required. The average yields for current varieties being used in different areas are as shown in Table 6.

Table 6. Origin, Varieties of Potatoes grown, Areas of Production and Ratios of Yields to Quantities of seed planted, Jamaica

Origin of Seeds	Varieties of Potatoes	Areas of domestic production	Yield Ratios
U.K.	Arran Consul	(N. Manchester	10 : 1
		(S. Manchester	11 : 1
Canada	Kennebec	(N. Manchester	9 : 1
		(S. Manchester	9 : 1
		(Darliston	6 : 1
		(Guy's Hill	7 : 1
		(N.E. St. Andrew	8 : 1
Canada	Sebago	(N. Manchester	7 : 1
		(S. Manchester	7 : 1
		(Darliston	5 : 1
		(Guy's Hill	6 : 1
		(Portland (Sherwood Forest)	6 : 1
		(N.E. St. Andrew	6 : 1
Canada	Red Pontiac	(S. Manchester	8 : 1
		(Darliston	6 : 1
		(Guy's Hill	7 : 1
		(Portland (Sherwood Forest)	7 : 1

(ii) Cost of Production

Irish potatoes are grown on farms of varying sizes, ranging between 0.10 acre and 70 acres. The distribution of acreage by size group of farms is not available but on the basis of the quantity of seed planted the estimated area under production increased from about 2,300 acres in 1963 to 4,650 acres in 1966. In the major producing area mechanical tillage is possible in some instances. For most of the land in other producing areas manual tillage must be used and this automatically increases the cost of production. Growing conditions vary as to areas of production, soils and seasons. In addition, there is the question of the particular varieties which are suited to these varying conditions. There are also variations in terms of the cultural practices employed, and there are important aspects related to management. As a consequence of all these factors costs of production have varied widely. For the purpose of this paper costs of production data will be presented for each of the three main Irish potato growing areas.

The cost of production study carried out by the Division of Economics and Statistics of MAL in 1957 (details are shown in Appendix II) indicates very little percentage variation between the broad items of cost as the levels of yield increased.

Table 7. Percentage Distribution of Cost of Production of Irish Potatoes at Four Levels of Yield, Jamaica, 1957

Cost Items	7,000 lb. Yield (%)	10,000 lb. Yield (%)	12,000 lb. Yield (%)	14,000 lb. Yield (%)
Labour Operations	40.8	41.6	42.0	42.4
Planting Materials	25.4	25.0	24.8	24.5
Other Materials	24.0	23.5	23.3	23.1
Miscellaneous	9.8	9.9	9.9	10.0
Total	100.0	100.0	100.0	100.0

Margins based on the 1957 costs of production varied from one of –£3.14.0 per acre for a 7,000 lb. yield (the ratio of yield to quantity of seed planted being 5 : 1), to £96. 1. 3 where the ratio of yield to seeds planted was 10 : 1. The significant feature of these costs was that sizeable increases in yields are obtainable with relatively small increases in costs of production. Another important feature associated with the returns per acre is the fact that only 85% of the potatoes produced were of top market quality, 10% of lower quality and 5% had no market value. Thus on the basis of the cost/returns data there are three main areas in which returns could be increased, namely :

(i) use of improved cultural practices;

(ii) more efficient production; and

(iii) reduction of the percentage low quality tubers.

Cultural practices have changed since 1957 and are continuing to change. More farmers are adopting improved practices. On the expenditure side these changes have affected not only the total costs of production but also the percentage distribution of these costs among the major items of cost. The main increases are related to increased labour rates and to heavier applications of fertilizer, the unit costs of which have been increasing over the years. These increased costs have to some extent been held in check by a change from manual to mechanical tillage in some areas of production. In some instances high seed cost is a factor which increases production costs but the resultant higher yields per acre sometimes offset these higher costs. It should be pointed out that the seed rate per acre varies considerably, the range being between 10 and 23 bags per acre.

On the revenue side increases in yields per acre as well as increased prices to the farmer have led to significant increases in the margins per acre. There are now three recognized planting periods namely Spring, Summer and Fall. Table 5 shows the distribution of the quantity of seeds planted according to seasons. In view of the fact that Christiana is the main Irish potato (Spring planted) growing area, detailed costs of production in this area for the period between 1957 and 1966 are shown in Appendix Table II to this report. Relevant details from this Table are shown in Table 8.

Table 8. Changes in Cost of Production and Returns from Irish Potato in the Christiana Area, 1957, 1962 and 1964-1966

Items	1957 (£)	1962 (£)	1964 (£)	1965 (£)	1966 (£)
Labour Charges	43. 7.0	41.16.0	49.10.0	68. 2.0	49. 3.0
Materials	53. 1.0	71.16.0	63. 8.0	58.10.0	65.16.0
Other Charges	8.16.0	6.10.0	9. 3.0	11.11.0	10. 0.0
Interest	4. 4.0	4.16.0	4.18.0	5.10.0	5. 0.0
Total Cost of Production	109. 8.6	124.18.0	126.19.0	143.13.0	129.19.0
Value of Yield	148.11.0	178. 0.0	178. 0.0	192.10.0	210. 0.0
Margin	39. 2.6	53. 2.0	51. 1.0	48.17.0	80. 1.0
Estimated Yield (lb).	10,000	10,000	10,000	9,800	11,200
Ratio of Yield to Seed	7 : 1	7 : 1	7 : 1	7 : 1	8 : 1
Cost of Production per lb.	2.6d	3.0d	3.0d	3.0d	2.8d

Over the period 1957 to 1966 the significant features were :

(i) increasing yields per acre ;

(ii) increasing costs of production in absolute terms ;

(iii) maintenance of, and in some cases a reduction in, the cost of production per lb ;

(iv) increasing margins per acre; and

(v) absolute increase in price to farmer.

Table 9. Comparative Costs of Production of Irish Potatoes in Four Areas, Jamaica, 1966

Items	(........Christiana........)			S. Manchester	Darliston	Guy's Hill
	(Large farm)	(Medium farm)	(Small) farm)			
	(£)	(£)	(£)	(£)	(£)	(£)
Labour Operations	84.12.0	49. 3.0	52. 8.0	27.16.0	77.13.0	60. 2.5
Materials	96. 6.0	65.16.0	47.10.0	88.19.6	81.10.0	65. 0.6
Other Charges	16.15.0	10. 0.0	7.10.0	11.10.0	24. 9.0	10.10.0
Interest	8. 0.0	5. 0.0	4. 6.0	6. 0.0	5. 0.0	5.17.6
Total Cost of Production	205.13.0	129.19.0	111.14.0	134. 5.6	188.12.0	141.10.5
Value of Yield	300. 0.0	210. 0.0	150. 0.0	302. 1.0	179.11.0	183.15.0
Margin	94. 7.0	80. 1.0	38. 6.0	168. 9.0	–9. 1.0	42. 4.7
Estimated Yield (lb.)	16,000	11,200	8,000	16,150	9,000	8,400
Ratio of Yield to seed	8 : 1	8 : 1	8 : 1	9.5 : 1	6 : 1	7 : 1
Cost of Production per lb.	3.1d	2.8d	3.4d	2d	5d	4d

Summer planting has been undertaken only within recent years, but Fall planting has had a longer history. Appendix Table IV shows the relative detailed costs of production for selected farming situations in each of the three growing areas. Relevant summarized data are presented in Table 9. On the basis of these data it is clear that the costs of production per lb. for Fall planted potatoes in both Guy's Hill and Darliston are higher than for Spring planted and Summer planted potatoes. These higher costs of production are associated mainly with the terrain of the area. However, uncertainty of the rainfall tends to limit production from the Summer planted crop.

(iii) Disposal of Irish Potatoes

In two of the recognized Irish potato growing areas there are co-operative organizations serving farmers' interests. These are:—

(i) The Christiana Potato Growers' Co-operative ; and

(ii) The Darliston Potato Growers' Co-operative.

The Christiana Potato Growers' Co-operative Association (CPGCA) is a co-operative society, *sensu stricto,* while the Darliston Co-operative operates on a limited co-operative basis only, as it merely purchases seeds in bulk for its members. The CPGCA has a close working relationship with the Agricultural Marketing Corporation (AMC) which is the main purchaser of potatoes. In 1966 the AMC handled 9,500 short tons, equivalent to 57.6% of the total production for 1966, and it is of more than academic interest to examine the related transactions in the purchasing, storing and marketing of these potatoes.

The AMC purchases potatoes both from the CPGCA and from other farmers in the Christiana producing area. It also buys directly from farmers in the other producing areas. It keeps most of these potatoes in storage at its Coleyville Storage Plant (within the Christiana area), Zero Processing and Storage Ltd. in Kingston, Lydford in St. Ann, the AMC Headquarters in Kingston and the AMC's Branch Office in Christiana. In 1966 members of the CPGCA received 40/- per 100 lb. for potatoes delivered at the Coleyville Storage plant (capacity 3,500-4,000 short tons). A cess of 6d per 100 lb. is retained by the CPGCA to assist in meeting its operating costs. The CPGCA is advanced money by the AMC to purchase potatoes from farmers. The storage plant is owned by the AMC but operated by the CPGCA under conditions agreed on between the AMC and the CPGCA. The main services performed by the Association are :

(i) selecting and purchasing potatoes from growers ; and

(ii) storing and/or bagging potatoes for transfer to designated points as is necessary.

Once purchased by the CPGCA, potatoes become the property of the AMC. The AMC pays the CPGCA a fee of 3/9d per 100 lb. purchased, to cover charges for the various services rendered. The AMC supplies bags and twine, and is also responsible for providing and maintaining the cold storage facilities.

On the above basis the AMC's trading transactions on the Spring planted crop may be summarized thus :

AMC pays 40/- per 100 lb. for Spring planted potatoes
3/9d per 100 lb. to the CPGCA for services
1/6d per 100 lb. for transportation cost from Coleyville to Kingston
Total 45/3d per 100 lb.

In addition, the AMC meets the costs for the following :

(i) servicing and maintaining cold storage facilities ;
(ii) handling and sorting of potatoes leaving the storage plant ;
(iii) covering losses due to spoilage, shrinkage, excessive sprouting etc. estimated at 15% of the quantity placed in storage ; and
(iv) packaging and transportation to supermarkets.

These additional costs are estimated to total 10/9d per 100 lb., and when added to the 45/3d direct payment, give a cost of 56/- per 100 lb. for trading in Irish potatoes. When weighed against a sale price of 50/- per 100 lb., it would appear that the AMC is losing a minimum of about 6/- per 100 lb. on trading transactions for Spring planted Irish potatoes.

The Fall planted crop although producing only slightly above one-fifth the volume of the main crop (Spring planted) is adequate for about 3 months' supply and requires storage. As already indicated the AMC has to provide the storage facilities and this results in new potatoes and old potatoes being in storage at the same time. The AMC therefore has a problem in terms of disposing of the older potatoes. Because of the very nature of the crop and particularly because all the potatoes planted during any one season are reaped over a relatively short period (say 4 weeks), the volume of potatoes handled is always greater than immediate consumption. However, when production from Spring planted potatoes is as high as it was in 1966, production falls more out of step with consumption than ordinarily would have been the case. The longer period required for storage means that the AMC ends up bearing a heavier loss for storing potatoes.

Although the retail prices which are fixed by the Ministry of Trade have been relatively static over a period of years actual prices paid by consumers have varied, sometimes considerably from those fixed prices especially in the parochial markets. One reason for this is the fact that new potatoes often fetch a higher price than old potatoes. Table 10 shows recent farm gate, wholesale and retail prices for Irish potatoes.

Table 10. Farm Gate, Wholesale and Retail Prices for Spring Planted Irish Potatoes, Jamaica, 1963-1967

Year	Farm Gate Price[1] (per 100 lb.)	Wholesale Price[2] (per 100 lb.)	Retail Price[2] (Per lb.)
1963	32/- & 33/-	40/-	6d
1964	35/-	40/-	6d
1965	40/-	46/-	6d & 7d from 13/2/65
1966	40/-	50/-	7d; 7½d from 3/3/66 7d from 18/5/66
1967	40/-	50/-	7d

1 Prices fixed by the Ministry of Trade and Industry.
2 Prices ex-Marketing Department, new AMC.

In 1947-48, it was recorded[2] that due to high production costs and poor yield, farmers received prices of 50/- to 60/- per 100 lb., while retail prices at Christmas were as high as 1/2d per lb. Currently the supermarkets in the Corporate Area retail Irish potatoes at 7d per pound after purchasing at 6d per pound – these are prices fixed by Government. Retail prices in parochial markets reach 10d per pound. Supermarkets regard the margin of 1d per lb. as being too small. At the same time, the margin between farmers' prices for the Spring planted crop and the wholesale selling price is not high enough to cover all the marketing and storage costs of the AMC which is the major handler of Irish potatoes.

On the basis of a yield of 11,200 lb. per acre (for 1,400 lb. seed planted) and at a farm gate price of 40/- per 100 lb. for the Spring-planted crop, farmers who are reasonably efficient can obtain a margin of £80 per acre for a 3-4 month crop. By comparison the returns from the Fall-planted crop are on the over-all not as remunerative due to higher costs of production and lower yields per acre. The main features of the Spring-planted crop are :

(i) production is much in excess of that needed to satisfy current annual consumption;

(ii) the quantity of seeds planted in Spring exceeds that needed to obtain the production which would satisfy the annual requirements for table potatoes ;

(iii) the heavy production which ensues requires storage over long periods and this in turn leads to (a) heavy financial loss to the AMC; and (b) consumer resistance to potatoes stored for a long period, which leads to longer storage and therefore further losses to the AMC;

(iv) stored Spring-planted potatoes overlap production from Fall-planted potatoes.

The main steps to be taken in rationalizing the Irish potato industry would seem, therefore, to be related to the phasing of production so as to reduce the heavy losses suffered by the AMC in handling the main crop and at the same time to improve storage and distribution. The heavy production is largely due to the quantity of seed planted during the Spring, and to the attractive prices paid for Spring planted potatoes.

Unless local consumption rates increase and suitable export markets can be found then there is little merit in continuing to increase the quantity of seeds planted during the Spring. There is clear evidence that the quantity of seeds planted should be reduced on a basis which also takes into consideration the increased yields per acre which are being produced as a result of the adoption of improved cultural practices and the exercise of improved levels of management. Since rationalization will also involve consideration of efficient production, questions will arise in relation to farmers who would be displaced as well as those who would have to face up to a reduced quantity of seeds. Finally, the degree of variability in conditions affecting production leads to annual variations in yields per acre and ultimately to variations in production. Thus it is important that this factor be borne in mind when attempting to rationalize production.

2 T. O. Ellis, **Bulletin No. 40**, Dept. of Agriculture, 1947-48.

The price mechanism could be used as an additional deterrent to overproduction in the industry once questions relating to the quantity of seeds to be planted, a fair price to producers, and improved storage and distribution of table potatoes have been settled. By the same token the price mechanism could be used to stimulate production from Summer and Fall plantings.

In taking steps to rationalize the industry it would be necessary to look more closely into the efficiency, cost and actual volumes of production in existing producing areas. While there is economic justification for out-of-season crops being higher priced, it would be necessary, for example, to examine the justification or otherwise for fostering production in the Darliston area in which very high costs of production as well as low yields per acre obtain.

Looking at the hard core of the economic implications of present performance in the Irish Potato industry, the following are the more striking factors :—

(i) the high costs incurred

(ii) the comparative prices of locally produced and of imported potatoes;

(iii) increasing costs of seeds and fertilizer; and

(iv) price incentives, if any, which would be necessary to stimulate expansion of production from Summer and Fall plantings.

This paper on Irish Potatoes would be incomplete without reference to questions concerning substitution of and by other starchy foods. Although a detailed examination of this aspect is of more than academic interest, it is beyond the scope of the paper. Suffice it to say that Jamaicans obtain their starches from a varied number of products which include rice, flour, cornmeal, yams, sweet potatoes, Irish potatoes, cocoes, dasheens, cassava, breadfruit, plantains and green bananas. The per capita consumption of Irish potatoes is very low by comparison with that of rice, flour, cornmeal, breadfruit, yams, green bananas and sweet potatoes, and without going into details the retail price (actually paid by the consumer despite the existence of fixed prices) of Irish potatoes is often higher than those of the other locally produced starches.

CONCLUSIONS

An attempt has been made in this paper to trace the development of the Irish potato industry. Reference has been made to the various problems which were involved and the measures taken to overcome them.

Many experiments were conducted largely with fertilizers, storage, varietal trials, pest control measures, etc., and these are continuing.

Cultural practices have improved considerably and yields per bag of seed planted and per acre have also improved. Returns to reasonably efficient farmers producing under good soil and water conditions have increased and are very satisfactory.

The high production from the Spring-planted crop which is associated with the planting of too large a quantity of seeds as well as with the attractive prices paid to farmers has pointed up the necessity for controlling the quantity of seeds planted and for phasing production. In this respect, the search for new areas of production to assist in the rationalization of production is continuing.

Production of potatoes in excess of current demand has led to the necessity for the AMC to meet additional costs for storage and distribution. In turn, problems of distribution are partly related to the perishable nature of Irish potatoes and this ultimately leads to the unwillingness of some supermarkets and other retailers to handle large quantities of the crop.

The use of the price mechanism can play an important role in rationalizing production and also in improving the rates of distribution of table potatoes.

The history of the development of the Irish potato industry could point the way for the development of other crops, both in relation to the approach used, the successful measures applied and also to the pitfalls which should be avoided. Future work in stabilizing the industry should include :

(i) an over-all rationalization of production and marketing (including distribution);

(ii) improved storage facilities;

(iii) a continued search for high yielding varieties;

(iv) a search for new production areas;

(v) exploration of export markets; and

(vi) exploration of the possibility of producing seed locally.

APPENDIX

Investigations on Irish Potatoes

(a) *1936–39*

The sustained development of the industry resulted in greater demands being made on Government for assistance largely by way of the provision of advisory services. In order to facilitate the provision of such services Government resorted to a number of experiments. The earlier experiments carried out in 1936 were laid down (a) to compare yields of different varieties; and (b) to determine the effects, if any, of fertilizers on these yields. The varieties used were: Up-to-date, Kerr's Pink, Arran Consul, Green Mountain and Cobbler. An area of typically infertile soil in the main potato producing area was selected for the experiment. The area selected had given such poor yields of Irish potatoes in the past that it was considered advisable to apply a small dressing of pen manure over the whole area before commencing the experiment.

The results obtained were summarized as follows :

(i) Two of the six varieties of potatoes namely Up-to-date and Kerr's Pink gave yields which were 20-50% greater than those from the other varieties, while Cobbler gave yields which were significantly greater than those for the other 3 varieties.

(ii) Application of fertilizers at the selected rate of 4.5 cwt. per acre resulted in an increased yield of approximately 50 per cent for 3 of the 6 varieties while the yields of the other three varieties were not increased significantly.

(iii) Germination was not materially affected by the use of fertilizer.

(iv) The differences in yields (due to varietal factors) were apparently not dependent on the differences in varietal germination.

(b) *1940–48*

A series of eleven experiments with Cobbler and Green Mountain varieties were laid down during the period 1940-1948 on the chief potato-growing soils of Manchester, St. Ann, St. Elizabeth and St. Mary. The experiments were largely factorial ones designed to ascertain the quantitative requirements of potatoes for nitrogen, phosphorus and potassium and to compare local phosphate with 18% superphosphate.

No yield response was obtained from application of nitrogen, regardless of soil type. Since most Jamaican soils are deficient in nitrogen it appears that under local environmental and cultural conditions Irish potatoes have a low requirement for nitrogen. This low crop requirement for nitrogen appears to be more important than the ability of the soil to supply this nutrient.

In contrast to nitrogen, the response to phosphate and potassium was closely associated with soil type. Good yield responses were obtained from application of phosphorus on soils developed over tuffs and acid limestone shales (Wirefence Clay Loam and Wait-A-Bit Clay) and on the red bauxite soil, St. Ann Clay Loam. Phosphorus, however, did not increase yields on the brown bauxite soil, Chudleigh

Clay, and gave a variable response on the colluvial limestone soil, Lucky Hill Clay Loam.

Residual phosphorus increased the yields of follow-on crops of corn.

Potatoes responded well to applications of potassium on both bauxite soils, gave a variable response on the limestone colluvial soil, and did not respond at all on soils developed over tuffs and acid limestone shales. The benefit of Humber Fish manure on brown bauxite soils was shown to be due entirely to the potash it contained.

Residual potassium increased the yields of follow-on crops of corn, peanuts and red peas.

(c) *1949–55*

During the period 1949-55, eleven experiments and two series of observation trials were carried out in Manchester, St. Ann and St. Mary. The main varieties used were Cobbler and Green Mountain.

In contrast to previous trials, a response to nitrogen was obtained on Wire-fence Clay Loam and Carron Hall Clay. A variable response was obtained on Chudleigh Clay. Two series of observation trials were therefore designed to test the effect of including nitrogen in the fertilizer mixture normally recommended for potatoes. It is perhaps unfortunate that all the observation plots were situated on the brown bauxite soil, Chudleigh Clay. The first series of trials showed no significant yield increase from the inclusion of nitrogen, while combined analysis of the second series revealed a significant yield response to nitrogen.

Apparently the fertility of the main potato-growing soils had decreased sufficiently by the early 1950's for a positive response to nitrogen to be obtained fairly consistently.

During this period two series of experiments were carried out testing up to five methods of placement of fertilizer. The results from both series showed that the best yield response was obtained from placing fertilizers in a continuous line along the base of the furrow before planting. The second series also indicated that the higher yield obtained from fertilizer placement was due to higher availability of phosphorus.

(d) *1958–63*

Up to 1957, all fertilizer investigations had been confined to the central potato-growing districts of the island. The period 1958-1961 represented a shift in experimentation to the western potato soils around the Darliston Area of Westmoreland. The main varieties used in the NPK fertilizer trials laid down were Arran Consul and Sebago.

On the chief soil type in the Area, Windsor Stony Clay, excellent responses to phosphorus and potassium were obtained in two out of three trials while a moderate response was given to nitrogen in only one of the three trials.

In 1959 initial steps were taken by the then Marketing Department of the Ministry of Trade and Industry to provide storage (a) in trays and (b) by bulk-piling. The loss from shrinkage and spoilage for bulk-piled potatoes was less than 4% but when the Co-operative tried this in 1960 a 17% loss was recorded. Existing storage practices applied in 1959 and 1960 were examined by an entomologist loaned to the Jamaican Government by the United States Overseas Mission (USOM) to investigate *nematode infestation*. A recommendation was made for the reduction of temperature by ventilated storage. The Irish Potato Advisory Committee of the Ministry of Agriculture and Lands (MAL) working closely with the USOM entomologist recommended that MAL should assist the Co-operative to install a forced air ventilation system in the storage house and evaluate its efficiency. MAL requested from USOM/Jamaica the services of a potato storage specialist for a month to :

(i) observe the reaction of Jamaican grown potatoes under forced air ventilation;

(ii) consider the usefulness of the necessity for sprout inhibitors; and

(iii) set up guide lines for the future improvement of storage.

Two varieties were selected for the tests using forced air ventilation. A total quantity of 365 tons of potatoes was put into storage units (14′ x 106′). The pile was built 6′ deep. (The varieties were treated separately.) Ventilation was provided by a fan nightly during the period 9.00 p.m. to 6.00 a.m. As a result the temperature fell to 66°F with one or two nights' ventilation. The potatoes retained fairly good condition, there being little shrinkage. Loss due to rotting was relatively small and it was apparent that rotting during storage was confined to potatoes which had been infested before being placed in storage. The spread of rot from these was practically nil.

Subsequent tests carried out indicated that potatoes could be stored for periods of over 4 months. Changes have been made in the cooling facilities provided. Existing storage temperature is 45°F and on the basis of experience elsewhere consideration is being given to reducing this temperature to 38°F, in an attempt to reduce storage losses.

Apart from the experimental work carried out in the above-mentioned three time periods, other work of an investigatory nature carried out on Irish potatoes included work designed to reduce the high cost of seed potatoes all of which had to be imported. Large seeds were cut into 2 or more bits and treated with chemicals to prevent rotting. These bits were then used as seed. The labour costs involved appeared to be too high and the investigations were discontinued as it was felt that the use of small whole seeds was more economical.

Concluding Observations

As a result of a large number of experiments laid down since 1940, the nitrogen, phosphorus and potassium requirements of Irish potatoes are reasonably well-known for the major potato soils in Jamaica. The standard fertilizer mixtures recommended and also the standard methods of fertilizer placement appear to be generally satisfactory. Further experimentation along these lines cannot be regarded, therefore, as urgent, although expansion of potato-growing in new areas, e.g., Yallahs Valley, might alter the present picture.

Considering the low incidence of potato scab in Jamaica, perhaps liming experiments should be considered for the very acid soils over tuffs and acid shales of the Yellow Limestone Formation.

No information is available on the use of foliar analysis in the diagnosis of the nutritional status of potatoes. In view of the increasing but variable response to nitrogen, and the low levels of this nutrient normally recommended, foliar analysis may be paricularly useful in diagnosing a deficiency early enough for a side-dressing of nitrogen to be beneficial. It has been suggested that an internal brown spot in potato tubers is due to boron deficiency or copper toxicity, and a leaf analysis survey might serve to locate possible trace element deficiencies or toxicities.

Considerable information might be obtained, therefore, from a leaf analysis survey of Irish potatoes growing on a variety of soil types. Leaf analytical data should also be obtained from any fertilizer experiments laid down in the future.

APPENDIX TABLE I

Estimated Cost of Production Per Acre of Irish Potatoes, Jamaica, 1957

Items	7,000 lb. Yield				10,000 lb. Yield				12,000 lb. Yield				14,000 lb. Yield			
Labour Operations	Man Hours	£	s	d	Man Hours	£	s	d	Man Hours	£	s	d	Man Hours	£	s	d
Land Clearing	80	4	5	0	80	4	5	0	80	4	5	0	80	4	5	0
Forking and Refining	240	12	15	0	240	12	15	0	240	12	15	0	240	12	15	0
Furrowing	64	3	8	0	64	3	8	0	64	3	8	0	64	3	8	0
Billing and Planting	40	2	2	6	40	2	2	6	40	2	2	6	40	2	2	6
Applying Fertilizer	16		17	0	16		17	0	16		17	0	16		17	0
Weeding and Moulding	120	6	7	6	120	6	7	6	120	6	7	6	120	6	7	6
Spraying	200	10	12	6	200	10	12	6	200	10	12	6	200	10	12	6
Reaping	48	2	11	0	72	3	16	6	84	4	9	3	96	5	2	0
Assorting	16		17	0	24	1	5	6	28	1	9	9	32	1	14	0
Total — labour	**824**	**43**	**15**	**6**	**856**	**45**	**9**	**6**	**872**	**46**	**6**	**6**	**888**	**47**	**3**	**6**
Planting Material (14 crates)		**27**	**6**	**0**		**27**	**6**	**0**		**27**	**6**	**0**		**27**	**6**	**0**
Other Materials																
Manure (Fly Penning)		2	0	0		2	0	0		2	0	0		2	0	0
Fertilizer (1,400 lb.)		21	5	0		21	5	0		21	5	0		21	5	0
Spraying Material (500 gal.)		2	10	0		2	10	0		2	10	0		2	10	0
Total Materials Cost		**25**	**15**	**0**		**25**	**15**	**0**		**25**	**15**	**0**		**25**	**15**	**0**
Miscellaneous																
Tools and Equipment		2	3	9		2	5	6		2	6	3		2	7	3
Overheads		4	7	6		4	11	0		4	12	6		4	14	6
Rent		4	0	0		4	0	0		4	0	0		4	0	0
Total Cost of Production		**107**	**7**	**9**		**109**	**7**	**0**		**110**	**6**	**3**		**111**	**6**	**3**
Value of Production		103	13	9		148	11	0		177	15	0		207	2	6
Margins Per Acre																
Estimated Cost of Production		107	7	9		109	7	0		110	6	3		111	6	3
Estimated Value of Production		103	13	9		148	11	0		177	15	0		207	7	6
Estimated Margins + or –		**–3**	**14**	**0**		**+39**	**4**	**0**		**+67**	**8**	**9**		**+96**	**1**	**3**

APPENDIX TABLE II

Cost of Production of Irish Potatoes per acre, Christiana, Jamaica, 1957—1962

Items	1957 (£)	1962 (£)	1964 (£)	1965 (£)	1966 (£)
Labour Charges					
Land Clearing	2. 2. 6	2. 0. 0	2. 0. 0	2. 10. 0	2. 0. 0
Ploughing	12. 15. 0	5. 0. 0	10. 0. 0	10. 0. 0	12. 10. 0
Harrowing		3. 0. 0	4. 0. 0	10. 0. 0	
Furrowing	3. 8. 0	1. 10. 0	5. 0. 0	3. 12. 0	7. 10. 0
Fertilizer application	17. 0	18. 0	10. 0	1. 15. 0	18. 0
Planting	2. 2. 6	6. 0. 0	5. 0. 0	4. 5. 0	3. 5. 0
Moulding	6. 7. 6	10. 10. 0	8. 0. 0	10. 0. 0	5. 0. 0
Spraying	10. 12. 6	7. 10. 0	6. 0. 0	12. 0. 0	5. 10. 0
Reaping	5. 2. 0	5. 8. 0	9. 0. 0	14. 0. 0	6. 10. 0
Transportation	—	—	—	—	6. 0. 0
Total Labour Costs	**43. 7. 0**	**41. 16. 0**	**49. 10. 0**	**68. 2. 0**	**49. 3 0**
Materials					
Seeds	27. 6. 0	40. 16. 0	29. 12. 0	28. 14. 0	31. 10. 0
Fertilizer	23. 5. 0	23. 0. 0	23. 0. 0	22. 8. 0	23. 16. 0
Fungicide and Insecticide	2. 10. 0	8. 0. 0	10. 16. 0	7. 8. 0	10. 10. 0
Total Material Cost	**53. 1. 0**	**71. 16. 0**	**63. 8. 0**	**58. 10. 0**	**65 16. 0**
Other Charges					
Overheads	4. 11. 0	3. 0. 0	5. 3. 0	7. 1. 0	5. 0. 0
Depreciation	2. 5. 6	1. 10. 0	1. 10. 0	2. 0. 0	2. 10. 0
Land Charges (Rental 6 mth.)	2. 0. 0	2. 0. 0	2. 10. 0	2. 10. 0	2. 10. 0
Total other charges	**8. 16. 0**	**6. 10 0**	**9. 3. 0**	**11. 11. 0**	**10. 0. 0**
Interest @ 8%	4. 4. 0	4. 16. 0	4. 18. 0	5. 10. 0	5. 0. 0
Total Costs	*109. 8.6*	*124. 18. 0*	*126. 19. 0*	*143. 13. 0*	*129. 19. 0*
Estimated Yield	10,000 lb.	10,000 lb.	10,000 lb.	11,200 lb.	11,200 lb.
Value of Yield	£148. 11. 0	£178. 0. 0	£178. 0. 0	£210. 0. 0	£210. 0. 0
Gross Margin	£ 39. 2. 6	£51. 1. 0	£53. 2. 0	£66. 7. 0	£80. 1. 0
Cost per lb.	3d	3d	3d	3d	3d

APPENDIX TABLE III

Cost of Production of Irish Potatoes per acre on Large, Medium and Small Farms, Christiana, Jamaica, 1966

Items	Large	Medium	Small
	(£)	(£)	(£)
Labour Charges			
Land Clearing	1. 0. 0	2. 0. 0	2. 0. 0
Ploughing	14. 0. 0	12. 10. 0	11. 5. 0
Harrowing	10. 0. 0	–	–
Furrowing	7. 0. 0	7. 10. 0	8. 10. 0
Fertilizer application	12. 0	18. 0	1. 14. 0
Planting	1. 16. 0	3. 5. 0	3. 0. 0
Re-forking	7. 4. 0	–	–
Moulding	3. 0. 0	5. 0. 0	7. 0. 0
Spraying	20. 0. 0	5. 10. 0	6. 0. 0
Reaping	6. 0. 0	6. 10. 0	8. 0. 0
Transportation	14. 0. 0	6. 0. 0	4. 19. 0
Total Material Costs	**84. 12. 0**	**49. 3. 0**	**52. 8. 0**
Materials	(20 bags)	(14 bags)	(10 bags)
Seeds	47. 0. 0	31. 10. 0	23. 10. 0
Fertilizer	34. 0. 0	23. 16. 0	17. 0. 0
Fungicides and Insecticides	15. 6. 0	10. 10. 0	7. 0. 0
Total Material Costs	**96. 6. 0**	**65. 16. 0**	**47. 10. 0**
Other Charges			
Overheads	8. 5. 0	5. 0. 0	5. 5. 0
Depreciation	6. 0. 0	2. 10. 0	5. 0
Land Charges (Rental 6 mth.)	2. 10. 0	2. 10. 0	2. 0. 0
Total Other Charges	**16. 15. 0**	**10. 0. 0**	**7. 10. 0**
Interest @ 8%	8. 0. 0	5. 0. 0	4. 6. 0
Total Costs	*205. 13. 0*	*129. 19. 0*	*111. 14. 0*
Estimated Yield	16,000 lb.	11,200 lb.	8,000 lb.
Value of Yield	£300. 0. 0	£210. 0. 0	£150. 0. 0
Gross Margin	£94. 7. 0	£77. 2. 0	£ 42. 12. 0
Cost of Production per lb.	3d	3d	3d

APPENDIX TABLE IV

Comparative Cost of Production of Irish Potatoes in Southern Manchester, Darliston, and Guy's Hill

Items	Southern Manchester (£)	Darliston (£)	Guy's Hill (£)
Labour Operations			
Land Clearing	2. 10. 0	1. 0. 0	4. 0. 0
Ploughing	5. 0. 0		
Forking		17. 10. 0	21. 17. 6
Refining		12. 10. 0	
Harrowing	2. 10. 0		
Furrowing	2. 10. 0		7. 13. 0
Drains			3. 16. 8
Fertilizing			5. 6
Planting	4. 0. 0		4. 2. 0
Moulding & Weeding	4. 0. 0	(26. 13. 0)	9. 13. 0
Spraying	2. 10. 0	(20. 0. 0)	1. 3. 9
Reaping	4. 16. 0		4. 8. 0
Transportation			3. 3. 0
Total Labour Costs	**27. 16. 0**	**77. 13. 0**	**60. 2. 5**
Materials			
Seeds	36. 19. 6	35. 5. 0	32. 18. 0
Fertilizer	34. 0. 0	34. 10. 0	24. 6. 6
Poultry Manure	7. 10. 0		
Dithane	10. 10. 0	8. 9. 0	
Dieldrin		2. 11. 0	
Spray Material			6. 15. 0
Gas Pump		15. 0	
Transportation of seeds & fertilizer			1. 1. 0
Total Materials Costs	**88. 19. 6**	**81. 10. 0**	**65. 0. 6**
Other Charges			
Overheads	3. 0. 0	7. 15. 0	6. 0. 0
Pump	6. 0. 0	11. 14. 0	2. 0. 0
Land Charges	2. 10. 0	5. 0. 0	2. 10. 0
Total Other Charges	**11. 10. 0**	**24. 9. 0**	**10. 10. 0**
Interest @ 8%	6. 0. 0	5. 0. 0	5. 17. 6
Total Costs	*134. 5. 6*	*188. 12. 0*	*141. 10. 5*
Estimated Yield	.9:5:1-6,150 lb. -	.6:1 - 9,000 lb.	7:1 - 9,800 lb.
Total Value of Yield	£302. 14. 0	£179. 11. 0	£183. 15. 0
Margin	168. 9. 6	–£ 9. 1. 0	£ 42. 4. 7
Cost of Production per lb.	5d	5d	4d

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ROOT CROPS IN THE BARBADIAN ECONOMY

— *by* —

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It may be difficult to assess the precise importance of locally grown root crops in the Barbados economy, but there can be no doubt that their contribution to the local diet is considerable. Their value in terms of calories is approximately 323 per head per day or about one-fifth of the calories obtained by the local population from all carbohydrate foods consumed, other than from sugar.[1]

The gross value of the crop is over 2¼ million dollars. Official statistics for 1965-66 show that on plantations of 10 acres and over, some 6,000 acres of root crops were planted and these were expected to yield over 24,000 tons. When however, peasant holdings are included, the total cultivated area rises to some 7,000 acres and the total expected yield to 27,000 tons.[2]

II

The root crops provide cheap food in Barbados. They are sold ex-field at 3 to 4 cents per pound. This low cost is the direct result of the system under which they are grown, a system that is unusual and of more than passing interest, and which is related to the system of cultivation of sugar cane that has developed over the centuries in Barbados.

Barbados is a classic example of a one-crop economy. Virtually all the cultivable land is devoted to sugar cane. The crop is normally planted in late October to November, at the end of the rainy season, and is not harvested until about 15 months later in February or March. The rootstocks of the cut cane are allowed to shoot again and produce a second crop, the so-called first ratoons, harvested twelve months later. This cycle may be repeated three or four times, so that one planting of cane may give several crops, usually four or five. The number of ratoons for each field is determined by the yield of the last crop. When the yield has declined beyond a certain level the field is prepared for replanting. This land preparation has to be completed in the dry season, normally by the end of May, as otherwise the ground may be too wet for machine operations. So we now have a tilled, prepared field, awaiting the planting of a new crop of cane in November, six or seven months later.

Before the Second World War ratooning was usually not carried very far ; sometimes there may not even have been any ratooning, and one half of a sugar plantation may have been in preparation for the next crop of cane. Traditionally, and dating back to the necessity of growing food to feed the labour force living on the plantation, some form of catch crop was planted on at least some of this land :

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1 See Appendix Table I

2 See Appendix Table II

it had to be a crop of relatively short duration to fit in the period between harvesting and replanting, and it had to require no special cultivation, as the land was already cultivated for cane and it was unlikely that re-tilling could be undertaken later in the year owing to the wet condition of the ground at the end of the rainy season.

Many food crops were cultivated in this way : the soil preparation and spacing (rows 5 feet apart) imposed by the requirements of the subsequent crop of sugar cane, were probably not ideal for any one of them, but obviously to grow a crop of this kind was better than leaving the ground unused and exposed - although, it may be mentioned in passing, only a few decades ago it was supposed that there were great virtues in leaving land fallow, and there was much doubt as to the wisdom of the "catch-penny practice" of growing food crops on good cane land.

The catch-crops commonly grown included maize and various pulses, but by far the greater proportion were the root crops yams, sweet potatoes, eddoes of several kinds, and cassava.

During the Second World War came legislation requiring all estates of 10 acres and over to plant a minimum of 35% of their acreage in food crops – a grim necessity in the days of heavy U-boat activity in the Caribbean.[3] The law, "The Local Food Production (Defence) Control Order 1942", has been retained on the statute books but now requires only 12% to be planted in food crops annually, 10½% in preparation land and 1¼% in "thrown-out land" – this being land that will not be planted in cane in the year in question, but must be devoted to a specified food crop, usually sweet potatoes, late planted for harvesting in the crop season (February to May), a period when other root crops are normally not available.

The provisions of the present law are quite realistic, so far as root crops are concerned. The supply of root planted to the law's requirements just about meets the domestic demand. Some excess acreages are planted, especially of yams, but an export trade in this commodity amounting to about 1,000 – 1,500 tons per year, and bringing in over half a million dollars of foreign exchange, is now developing. In 1965 the minimum acreage compulsorily required for planting in food crops was 5,862, though in fact 6,938 acres were actually planted on those estates to which the law applied. Of this, some 5,500 acres were planted in root crops; the distribution is indicated in Appendix Table II.

It may be noted in passing that the increased ratooning attainable with modern canes and cultivation practices has reduced the proportion of sugar land in preparation from one-third, as it was before the war, to one-fifth or less of the plantation's acreage and thus the land available for catch crops is much less than it was twenty or thirty years ago.

Let us consider now how this system of catch-cropping of foodstuffs, hallowed by law, affects the cost of the root crops grown on sugar plantations.

3 It is of interest to note that legislation on food crop production is not new. As far back as 1631, when tobacco was the main commercial crop, an Order of Council had to be passed restricting the planting of tobacco until such time as more food was produced.

Except for the late planted sweet potatoes (locally called "fall potatoes"), land preparation is done specifically for the following crop of cane. The land lying fallow, is inevitably attracting its share of plantation overheads. These costs are carried by the subsequent crop of sugar cane ; the argument is that these costs are being necessarily incurred by the cane crop. So, if a food crop is grown during what would otherwise be a fallow period it makes no difference to the costing of the cane; the only costs incurred by the food crop are those of planting, weeding, fertilising (if any), disease control and harvesting, and a rather arbitrary figure compensating for the reduction in sugar cane yield supposedly caused by the presence of the food crop in its early stages. (Canes are planted in October/ November ; most of the yams are not harvested until January.) Thus the costs attributable to the food crop are relatively low and the food crop can be sold cheaply : 3 to 4 cents per pound ex-field is the usual price to hucksters, who come with carts and lift the crops themselves. If estate-labour lifts the crop the price is usually about 1 cent higher. Typical costings for yams and sweet potatoes grown under this system are shown in Appendix Tables III and IV. (Note that in all costings the labour contains an addition of approximately 5.76% which covers 3 weeks holiday with pay, compulsory under Barbadian law.)

A rather different situation exists with "fall sweet potatoes", for in this case the land has been specifically put aside for this crop, and there can be no question as to whether preparation and over-heads should be charged to the potatoes – they *are* so charged. A typical costing sheet is shown in Appendix Table V.

III

The developing export trade in yams has already been mentioned. This is of recent origin, approximate quantities exported during the past few years being :

1963-64	2,106,445 lb.
1964-65	3,515,772 lb.
1965-66	2,949,646 lb.

Prices of five to seven cents per pound (sometimes more) are obtained by the growers for carefully selected tubers. About 70% of the crop from any one field is, under good condition, suitable for export; the remainder includes about 12% damaged during lifting and 18% small yams, which are often used as seed the following year. With good yields and prices the gross value of an acre of yams for export can exceed $1,000 which is satisfactory for a catch crop. It must be emphasised, however, that the export business is a high-risk venture. In 1965 growers received only 3 cents per pound because of the occurrence of hitherto negligible disease, which severely affected quality ; in 1966 partly as a result of this, growers reduced their plantings and exports showed a fall instead of the hoped-for increase.

Of course the value of such crops depends largely upon the yields per acre, and recent agronomic studies have shown that the average yields of 5 tons per acre for yams and 3 tons for early planted sweet potatoes can be considerably raised. For example, only recently has the practice of fertilising yams become widespread and very few plantations are willing to "waste fertiliser" on such a low value crop as sweet potatoes. However, it has now been shown that moderate fertilising will increase the yield of early planted sweet potatoes by an average of 2,000 pounds per acre, which at 4 cents per pound is worth $80.00.

Plant densities per acre are traditionally low, dating from the days of inter-planting between cane holes, and possibly also related to the shallow ploughing and inadequate land preparation of the pre-tractor age. Yams are normally planted at 5ft. x 5 ft. (1,742 plants per acre). Planting at 5 ft. x 2 ft. 6 in. has given from 50 to 90% increases in yield (details have been given in another paper already presented to this Conference) at relatively little extra cost; a typical comparison of the cost and returns is made in Appendix Table VI.

Increasing the density of sweet potatoes by planting closer on the ridges also gives increases in yield, but not nearly as great increases as increasing the density per acre by doubling the number of ridges. By reducing the spacing between ridges from 5 ft. to 2 ft. 6in., virtually twice the yields per acre can be obtained. This, however, departs from the preparation system usual for cane, though the possibility of ridging at 2ft. 6 in. and planting cane in alternate furrows is being seriously considered by some planters. Certainly such a system would enable the cash crop value of the land to be greatly enhanced, and, if it is valid not to charge the 5 ft. ridging to the sweet potatoes, it is valid to charge only the relatively slight additional cost of ridging at 2 ft. 6 in. in this case.

New problems loom in the more distant future. It is quite possible that mechanical harvesting of sugar cane may become essential if the sugar industry is to survive. If this should be so, it is quite certain that the topography of Barbados will not permit full mechanisation on all areas in which slopes are too steep for any currently known harvesting machines. In order for the acreage under cane to be maintained, the system of preparation in the early months of the year followed by late planting, may have to be abandoned. In its place would have to be substituted the "force back" system in which a field is tilled and planted within a month or so of reaping: the resulting crop is harvested within the next 10 to 12 months. The sugar yield per acre from the first crop is reduced but yields from subsequent crops are similar to those on the usual Barbadian system and there is, of course, a higher production of sugar per acre of land devoted to cane, as there is no land that is not harvested every year.

Such a system drives food crops out of the rotation with sugar cane on to land, which for some reason or other, may be unsuitable for full mechanisation — probably due to steepness. This would be, to say the least, unfortunate. Sugar cane, with its thick, fibrous root system and heavy fall of trash, with major cultivation only once every five or six years, is an exceptionally good crop for combating soil erosion. By contrast, a sequence of relatively short term food crops is asking for trouble. Further, there is doubt as to whether the profit to be made from "forced back" cane will be as great as that from the root crops that could be grown instead and this matter is the subject of a separate study now under way. However, assuming that the average tonnage of sugar produced in recent years must be maintained, we must face the implications of the new situation envisaged above.

On the agronomic side then, we have to consider rotations including the several root crops – yams, sweet potatoes, eddoes, cassava – pulses, corn, okras and other vegetables, perhaps tomatoes, string beans, cabbage, etc. We have to try to devise suitable systems of cultivation on contour banks or terraces that will minimise erosion, and we have to study the costs involved in such systems. So far we have little information and we cannot really predict what operations will be necessary, nor how well the various crops will perform under these new conditions. Field experiments have only just started; but, at any rate, a beginning has been made.

On some plantations the forcing back of the cane could leave areas of "good land" (not steeply graded land) for continuous food cropping. This will, of course, be an easier situation and one for which the operations will be more easily predictable, but the probable costings have not yet been fully worked out. However, food crops will attract all land preparation costs and a proportion of the plantation overheads. It seems doubtful whether these charges would be offset by the higher yields that may in some cases be obtained as a result of divorcing these crops from the cultivations and spacing imposed upon them by their association with sugar cane.

We may perhaps carry this a little further and attempt a hypothetical costing based on "reasonable assumptions". In the rotations envisaged, yams, for example, are in the ground from May to January. When they are lifted the land has to be re-tilled, to prepare for the following crop. As the severest part of the dry season is January to April nothing can be planted until the following May, so yams carry the full year's costs. It is just possible that a catch crop of okras might be planted in November to carry through until February or March, but this is by no means certain, nor is there likely to be a demand for all the okras that could be planted in all the yam fields. So we may attempt a costing on yams as the major crop. We can argue that subsoiling will be necessary only once in two or three years, depending upon the locality. Rome harrowing will probably not be necessary at all except when the cane land is first converted to food crop land. Disease control is more likely to be a problem when the land no longer has long periods of sugar cane in the rotation. With considerations of this kind in mind, Appendix Table VI was constructed. It can be seen by comparison between Appendix Tables VII and that part of Table VI referring to yams at 5 ft. x 2 ft. 6 in., that the cost now is $91.00 per acre higher, an increase of almost 50%. It is unlikely that in the face of such figures any commercial concern would continue to sell at the former price of 3 cents per pound. Even so, for purposes of comparison gross value and profit have been calculated on this basis; these may be compared with the figures for the present system shown in Appendix Table III. For tonnages of 3 to 4 tons per acre, a substantial profit is now turned into a loss.

So far we have considered the two major root crops that have been grown in Barbados for centuries. Sporadic attempts have been made to grow Irish potatoes but without any continued success. In recent years, however, Irish potatoes have assumed some importance in the local economy : in 1954 some 5,000 tons worth $630,000 were imported ; the figure for 1965 is estimated at about one million dollars' worth. To eat Irish potatoes in preference to sweet potatoes is becoming a status symbol. I think, therefore, it is not out of place to mention this commodity in a Conference on Tropical Root Crops.

Recent experiments in both Trinidad and Barbados have given promising results, suggesting that with irrigation and with the right cultivar, yields of about 8 tons per acre (modest by temperate climate standards, but probable economic here), may be obtained. On the basis of the limited information so far obtained in Barbados a forecast of the probably costing has been made (Appendix Table VIII). This is, of course, very preliminary. For example, planting is by dibble. Until we are quite satisfied that commercial areas can be successfully grown, we will not seriously consider mechanised planting. Similar remarks apply to mechanised harvesting. Bearing in mind the reductions in cost that would result from mechanisation we have some hope that cultivation of this crop could become an economically attractive proposition.

This paper has, of course, been limited in scope to one island, and has dealt with only three crops – the fact is that little in the way of either costings or field research has been done on eddoes and cassava under Barbadian conditions. However, I hope this discussion has put forward some points of interest, and if it has done no more I am sure it has shown you how important root crops are in our economy and why we are devoting a considerable amount of our research effort to studying these commodities.

APPENDIX TABLE I

Carbohydrates in the Barbadian Diet

Commodity	Imported or Local	Quantity[1] (tons)	Approximate calorific value[2] (per lb.)	Total calorie content per head[3] (per day)
Yams	Local	15,700	500	163
Sweet potatoes	”	7,500	570	87
Eddoes	”	1,200	570(?)	14
Cassava	”	400	570(?)	5
Irish potatoes	Imported	7,000	380	54
Breadfruit	Local	10	570(?)	0.1
Bananas	Local & Imp.	500	400	4
Maize & Maize Products	Local & Imp.	9,000	1,650	380
Rice	Imported	8,000	1,650	340
Wheat flour, etc.	Imported	14,500	1,660	620
Biscuits & other prepared cereal products	Imp. & locally made from imp. ingredients	900	1,820	42
Beans & Peas (dry basis)	Local & Imp.		1,550	16
Miscellaneous	Relatively small quantities			
Total				1,725

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1 These are estimated quantities of consumption in Barbados based on import figures, and estimates of local production based on the figures of the Government Agricultural Inspector, provision merchants and the Barbados Marketing Corporation.

2 Calorific values calculated from various published sources (mainly the Heinz Book of Nutritional Data) except for those marked (?), which are estimated.

3 Calculated from the following formula:

$$\frac{\text{No. of tons of foodstuff} \times 2240 \times \text{Calorific value}}{365 \times 240{,}000}$$

(The population of Barbados is approximately 240,000.)

The figure so obtained has then been reduced by 20% to allow for preparation losses and other forms of wastage in the case of root vegetables and fruit.

APPENDIX TABLE II

Acreage and yields of root crops on plantation of 10 acres and over in Barbados 1965 – 1966[1]

Commodity	Acreage	Expected yield per acre (tons)	Expected total yield (tons)
Yams	3,056	5.05	15,433
Sweet potatoes (early planted)	1,060	3.11	3,297
Sweet potatoes (late planted)	769	5.0	3,845
Eddoes	508	2.0	1,016
Cassava	59	5.0	295
Mixed Crops[2]	410	2.5	820
Total	5,862	—	24,706

1 Figure derived from report of Government Food Crop Inspector. These refer to plantations of 10 acres and over. No figures are available for small holdings, but it is estimated that root crops on these occupy a further 1,200 acres with a yield of about 2,400 tons, bringing the total to about 7,000 acres and 27,000 tons.

2 Frequently yams or sweet potatoes interplanted with corn or other food crops.

APPENDIX TABLE III

Cost of Production per acre of yams in Barbados

Operations	Cost ($)	Remarks
Harrowing		All essential operations for the following sugar cane crop and so not charged to the yams
Lining		
Ridging		
Digging yam holes	1.78	1,742 holes per acre @ 10c. per 100 holes
Cutting, carting, leading and dropping yam plants	11.70	
Cost of yam plants	27.00	
Filling in yam holes	3.50	
Fertilising	13.55	
Weeding	52.50	
Sub-total	110.03	This is the *actual cost* of growing an acre of yams
Estimated cane loss	39.00	See note (iii)
Overall Total	149.03	

Notes: (1) Selling price ex-field (with hucksters doing the lifting) is 3 to 4 cents per lb. The following is based on the minimum price of 3 cents per lb.

(ii)

Yield (tons)	Gross value	Profit per acre
3	$202	$53
4	270	121
5	336	187
6	403	252
7	470	321
8	537	388
9	604	455
10	672	523

(iii) It is commonly considered that the presence of a yam crop in the field among young canes during the first two months of their growth reduces the yield by about 1½ tons ; the trampling and general mishandling when the yams are harvested by hucksters reduces yield by a further 1½ tons – viz. there is an estimated less yield of 3 tons of cane at an ex-field price of $13.00 – $39.00 to be set against the yams.

(iv) If yams are harvested by estate labour and stored on the plantation, production costs are the same as above, except for the estimated cane loss, now 1½ tons at $13.00 per ton – $19.50

Total cost of production, therefore – $129.53

Harvesting, carting, cleaning, sorting, etc. – 69.28

Total cost $199.21

(v) Stored yams are normally sold at 4 to 5 cents per pound. On the basis of 4 cents per pound we have :

Yield —	3 tons;	Gross Value	$269;	Profit —	$ 70	per acre
	4 "	" "	339	" —	160	" "
	5 "	" "	449	" —	250	" "
	6 "	" "	538	" —	339	" "
	7 "	" "	627	" —	428	" "
	8 "	" "	717	" —	518	" "
	9 "	" "	807	" —	608	" "
	10 "	" "	896	" —	697	" "

(vi) Note that no land preparation costs nor estate overheads (including salaries) have been charged against the yam crop.

APPENDIX TABLE IV

Cost of production per acre of sweet potatoes in Barbados (early planted i.e. "Spring Potatoes")

Operation	Cost ($)	Remarks
Harrowing		All essential operations for the following sugar cane crop and so not charged to the sweet potatoes
Subsoiling		
Lining		
Ridging		
Digging holes for slips	5.59	5,226 holes @ 10c. per 100 holes
Cutting and planting slips	9.15	
Supplying	3.49	Especially in dry weather there may be high mortality among the slips and a considerable amount of supplying is necessary
Carting slips	1.16	
Weeding	28.26	
Pest control	5.49	One spraying of insecticide against armyworm
Clearing slips before planting canes	2.27	
Sub-total	55.41	This is the *actual cost* of growing an acre of sweet potatoes
Estimated cane loss	52.00	See note (iii)
Overall Total	107.41	

Notes : (i) Selling price ex-field (with hucksters doing the lifting) is normally 4 cents per pound.

(ii) On the basis of 4 cents per pound we have :

Yield	Gross value	Profit per acre
2 tons;	$179;	$ 72
3 "	269	162
4 "	359	254
5 "	448	341
6 "	538	431

(iii) It is commonly estimated that the 'Spring potato' crop reduces the yield of the subsequent crop of cane by 4 tons per acre, which at $13.00 per ton, ex-field, is worth $52.00. This loss may in part be due to the fact that spring sweet potatoes are often not fertilised and so the crop may reduce the nutrient status of the field quite substantially.

(iv) Note that no estate overheads have been charged.

APPENDIX TABLE V

Cost of production per acre of sweet potatoes in Barbados (late planted i.e. "fall potatoes")

Operation	Cost ($)	Remarks
Ploughing and rotovating or harrowing	60.00	Full cost now charged to the potatoes (see text)
Ridging at 5′ O″	24.00	" " "
Digging slip holes	5.89	Remarks as for Appen. Table IV
Cutting and planting slips	9.15	" " "
Supplying	3.49	" " "
Carting slips	1.16	
Weeding	52.44	
Pest control	5.49	" " "
Estate overheads	83.00	Buildings, water, roads, salaries, taxes, insurance and interest
Total	$244.32	*Actual cost* of growing the crop

Notes : (*i*) Selling price ex-field (with hucksters doing the lifting) averages 4 cents per pound.

(ii) On the basis of 4 cents per pound we have:

Yield 3 tons;	Gross value $269;	Profit – $ 25	per acre
4 "	" " 359	" – 115	" "
5 "	" " 448	" – 204	" "
6 "	" " 538	" – 194	" "
7 "	" " 628	" – 386	" "
8 "	" " 717	" – 473	" "

APPENDIX TABLE VI

Cost of production and returns of yams at different planting densities in Barbados (dollars)

Operation	Planted 5′O″ x 5′O″	Planted 5′O″ x 2′6″	Remarks
Harrowing			All essential operation for the following sugar cane crop and so not charged to the yams
Subsoiling			
Lining			
Ridging			
Digging yam holes	1.78	3.56	1,742 & 3,484 holes respectively
Cutting, carting, leading and chopping yam plants	11.70	23.40	
Cost of yam plants	27.00	54.00	
Filling in yam holes	3.50	7.00	
Fertilising	13.55	20.40	
Weeding	52.50	52.50	
Sub-total	110.03	160.86	Total cost of growing crop
Estimated cane loss	39.00	52.00	See note (iv)
Total	$149.03	$212.86	

Notes : (i) In the 1966/67 experiments (a low yielding year due to excessive rainfall) the average yields in experiments for Crop Lisbon yams were :

Planted 5' O" x 5' O" — 5.6 tons per acre
" 5' O" x 2' 6" — 7.7 " " "

(ii) On this basis, and at the minimum price of 3 cents per pound, average values and profits were :

Planted 5' O" x 5' O" Gross value $375; Profit $226 per acre
" 5' O" x 2' 6" " " $516 " $303 " "

(iii) In actual commercial practice the following results were obtained on one plantation (the only one making such a comparison):

Planting distance	Yield per acre	Gross value per acre
5' O" x 5' O"	13,600	$476.00
5' O" x 2' 6"	24,000	$720.00

(iv) An increase of 1 ton per acre in cane loss is estimated for the closer planted material.

(v) Planting at 5' O" x 2' 6" must give an increased yield of 2,124 pounds to cover the additional cost of $63.83 above that of the material planted at 5' O" x 5' O".

APPENDIX TABLE VII

Hypothetical costing for yams grown in its own right, Barbados

Operation	Cost ($)	Remarks
Light harrowing	10.00	Contract price
Subsoiling	12.00	$24.00 per operation, once every two years
Ridging 5′ O″ x 5′ O″	12.00	Contract price
Digging yam holes	3.56	Spaced at 2' 6" along ridges 3,484 holes at 10c. per 100
Cutting, carting and dropping yam plants	23.40	
Cost of yam plants	54.00	
Filling in yam holes	7.00	
Fertilising	20.40	
Weeding	52.50	
Disease control	16.00	2 applications of Cupravit, and labour
Estate overheads	83.00	
Total	$293.86	

Notes : (i) It is assumed that the crop will be lifted by hucksters.
(ii) On the basis of a selling price of 3 cents per pound we have :

Yield (tons)	Gross value ($)	Profit – loss of $ per acre
3	202	– 92
4	270	– 23
5	336	42
6	403	109
7	470	176
8	537	243
9	604	310
10	672	388

APPENDIX TABLE VIII

Probable costs per acre of Irish potatoes, Barbados

Operation	Cost ($)	Remarks
Harrowing	12.00	Rome harrow to cut up the cane stumps. ½ of contract price (4 month crop) See note (i)
Light harrowing	10.00	Contract price; See note (iv)
Ridging at 2′6″	12.00	” ” ”
Cost of seed potatoes	220.00	Based on quotations from Florida
Cutting, dipping, Carting and dropping seed potatoes	26.00	Estimated
Planting and filling holes	90.0	17,000 holes per acre by dibbling at 5 cents per 100 holes
Weeding	33.90	Estimated at $2.00 per acre per week for 16 weeks. Possibly efficient pre-emergent spraying, costing $20.00, could eliminate further hand weeding
Disease and insect control	42.00	4 sprayings with Cupravit, 1 with Sevin
Fertilising	60.50	6 cwt. 8 : 12 : 25; $57.00 approx. + $3.50 for labour
Irrigation	48.00	See note (v)
Plantation overheads	27.70	1/3 of $83.00 for a 4 month crop
Total	$582.20	*Actual cost* of producing the crop

Notes : (i) Probable selling price 7 to 8 cents per pound ex-planation (though 10 cents is commonly obtained ex-field for un-harvested potatoes with the present experimental production).

(ii) On the basis of 7 cents per pound revenue from 15,000 pounds is $950.00, giving profit per acre of $200.00 for a 4-month crop.

(iii) In experiments in 1966 yields from small experimental plots (irrigated in coastal areas in the dry season, unirrigated in the wet season on both coastal and highland areas — 1,000 ft. elevation) lay between 15,000 and 20,000 pounds per acre .

(iv) If the Irish potatoes are grown as a catch crop these costs might not apply (compare the argument for yams and sweet potatoes when grown as catch crops). It is envisaged that Irish potatoes would be grown on irrigated land primarily devoted to food crops, not as a rotation crop with sugar cane.

(v) Irrigation : Estimated capital cost for well, pump, pipes, etc. for 25 acres is $15,000. On 10 year depreciation basis this gives annual depreciation per acre of $60.00. An Irish potato crop takes less than 4 months : proportion of depreciation on irrigation equipment is thus approximately $20.00 Some 16 inches of water are required for the crop; assume half to be supplied by rainfall, then irrigation must supply 8 inches. One acre inch — 23,000 gallons, so 184,000 gallons will be required. The cost of pumping and distributing water (including labour) is approximately 15c. per thousand gallons; thus the cost would be $27.50, bringing the total cost of irrigation to $47.50.

THE ARROWROOT INDUSTRY IN ST. VINCENT: A CASE STUDY OF A UNIQUE ROOT CROP INDUSTRY

— *by* —

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The Commonwealth Caribbean has so far found it difficult if not impossible to produce agricultural commodities under competitive conditions. Indeed, the survival of particular crop industries has, for the most part, depended on one of two conditions: either the product has been accorded preferential treatment in the metropolitan countries, or the producing territory has a monopoly on the production of the particular crop. The commodities that have been accorded preferential treatment (sugar, bananas) play a much greater role in Caribbean economies than those that are produced under monopoly conditions (arrowroot, nutmeg, pimento, sea island cotton) and hence the problems associated with the former have, quite naturally, been more widely discussed than those associated with the latter group of crops.

This paper deals with a 'root' crop, arrowroot, that has been produced under monopoly condition. The theme of this case study is the limited technological progress in the Arrowroot Industry, and the absence of adequate arrangements for supply control and for marketing, which have left an important industry in a vulnerable state. A brief description of the arrowroot plant and of the history of the industry introduce the paper.

THE DEVELOPMENT OF THE INDUSTRY

Arrowroot *(Marunta arundinacea)* is a herbaceous perennial, growing usually to about 3 feet and bearing oval leaves. The root stock forms cylindrical rhizomes below the soil surface. It is these rhizomes, which are about 9 –12 inches long and 1 inch thick, that provide the starch that has made cultivation of the crop commercially feasible. The two varieties of arrowroot native to St. Vincent, the 'Banana' and the 'Creole' do not set seed, and propagation has so far been by means of rhizome bits. The plant is extremely resistant to adverse weather conditions and has hitherto been subject to only one disease, the 'arrowroot burning disease' *(Rosillinea bunodes)* and one pest, the arrowroot leaf roller *(Calpodea ethleus)*: even these have been relatively minor in their effect. Less yield uncertainty has, therefore, been associated with arrowroot production than with most other crops grown in St. Vincent. This has undoubtedly been partly responsible for the crucial role that arrowroot has played in the economy of St. Vincent for over a century.

Commercial production of the crop began about the middle of the nineteenth century, when a decline in price made sugar production unfeasible on some plantations and alternative crops had to be sought. In many respects arrowroot proved an excellent substitute.

In the first place, the plant thrives well in all the soil types of the island, though apparently, it does best in well drained sandy loams. Large quantities of clean fresh water are necessary for processing this starch and this St. Vincent has in the numerous streams originating in the island's mountainous interior.[1]

Secondly, an inspection of the data shown in Appendix Table I reveals that the labour requirements of arrowroot are very similar to those of sugar-cane. The crop is reaped every twelve months and the harvesting demands a great deal of labour so that, as in the sugar industry, there is a seasonal pattern of employment, a great deal of work being provided between November and April when the roots are being reaped, and comparatively little being available at other times of the year, except for gangs of women who are needed to weed the crop three times annually. The substitution of arrowroot for sugar, therefore, affected the agricultural labour force little except insofar as the hoe replaced the machete as the implement for reaping.

Thirdly, the capital required to convert the numerous small muscuvado factories then engaged in sugar manufacturing into arrowroot factories was relatively small. The building that housed the sugar factory and the wheels that powered it could be used in arrowroot manufacture. Changes were, however, necessary in the plant, but even these could be carried out with relatively little expense. The major items required were a saw-grater to crush the rhizomes, sieves to strain the starch and racks for drying purposes. These could be made locally.

Finally, since the main market for arrowroot starch was the United Kingdom, the same marketing arrangements that had been used to market sugar could be used in the case of arrowroot starch. Each large holder consigned his starch to a broker in London, who undertook to dispose of it and remit the proceeds less expenses.

From these rudimentary beginnings the crop increased in importance and for the first half of the twentieth century arrowroot exports accounted for about 50 per cent of the island's total gross agricultural income (see Figure 1).

In the process of evolution two adjustments had to be made; one on the production side and the other in the marketing of the commodity.

The salient feature of the pattern of land tenure in St. Vincent in the second half of the nineteenth century was the small number of large holdings and the almost complete absence of small holdings. In the first half of the twentieth century, however, there was a marked tendency towards fragmentation (see Appendix Table II), and adjustments had to be made within the structure of the arrowroot industry to accommodate the peasantry that emerged. The manner in which this was accomplished is relatively straight-forward. The peasants produced the rhizomes and the plantation owners who operated factories in the vicinity processed them for a share of the starch yield. The proportion charged tended to vary from factory to factory ranging from 20 per cent in some to 25 per cent in others. The remainder of the peasants' starch was disposed of through the factory-owner who either bought it outright or sold it through his agent in London on the peasants' behalf. Since at least a year elapsed between the planting and reaping of the crop and since, moreover, a great deal of capital was often required to finance the reap-

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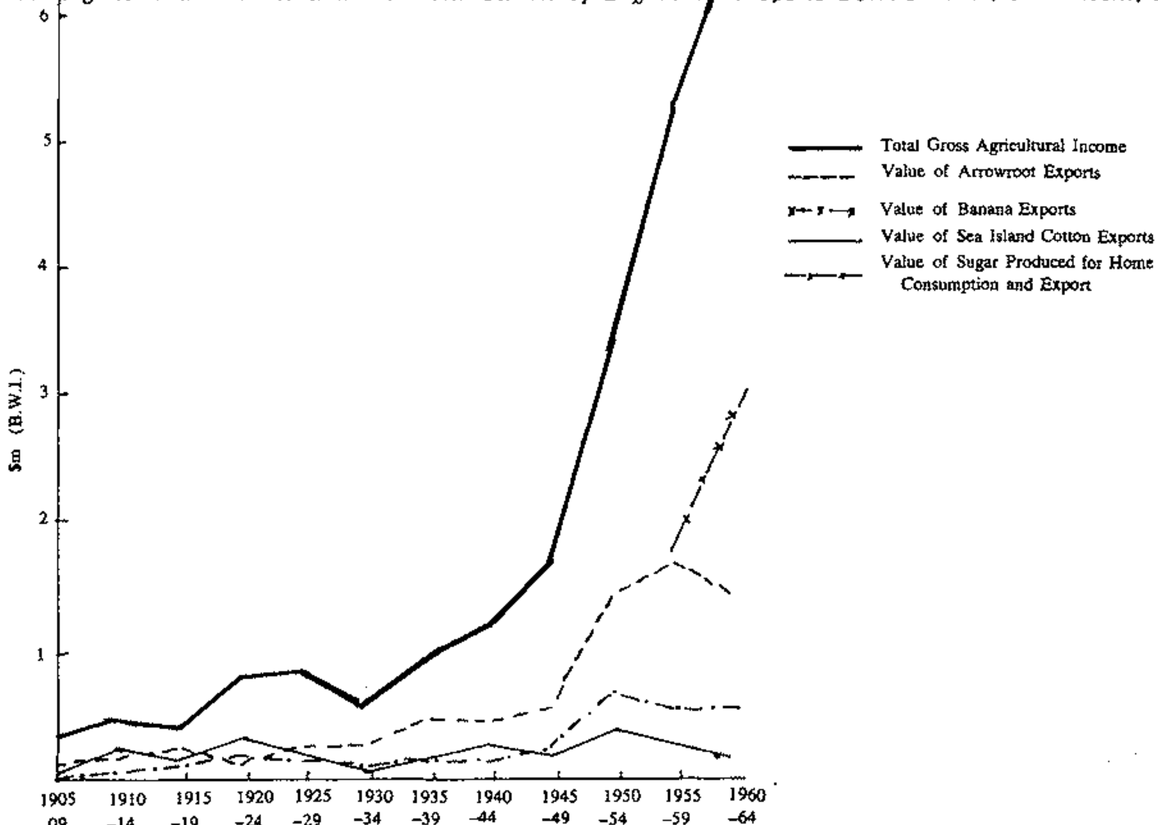
1 It is significant that in Antigua where some attempt has been made to develop the industry on a commercial scale, one of the major limiting factors has been the salinity of the water used in processing, which seriously affects the viscosity of the starch.

Figure 1

Total Gross Agricultural Income and the Contribution of Different Crops to Total Income, St. Vincent, 1905–1964



Note: Value is Based on the Annual Average for a Five-Year Peric

Sources: *Report of the Department of Agriculture*, St. Vincent, 1905 1961 and *Digest of Statistics No. 12*, St. Vincent Statistics Unit, 1965.

ing of the crop, the factory owners often made advances to peasants to finance their living expenses and the harvesting of his roots.

On the marketing side the major development that occured was the establishment of the Arrowroot Growers Co-operative Association. Under the system whereby individual large growers consigned their starch to different agents in the United Kingdom there was persistent tendency for the market to become glutted. All efforts to form a voluntary co-operative failed and in 1930 the Government was forced to set up a statutory body to market the commodity. The specific powers granted to this organisation under ordinance are :

(a) to market and control all arrowroot produced in the colony of St. Vincent and intended to be exported therefrom;

(b) to undertake and promote research in the cultivation of the plant and in production, processing and marketing of the crop;

(c) to erect and operate central factories for the processing of arrowroot.

Management of the Association is vested in a Board consisting of eleven persons; the Director of Agriculture, the Financial Secretary, and nine other persons elected by and large from among the members of the Association.

Most of the capital required by the Association to commence operations was provided by the Government ; $144,000 as an interest-free loan and $14,400 as a grant. The funds were used mainly to purchase equipment for pulverizing the starch. Since there were so many different factories involved in starch processing, the quality of the starch received by the Board tended to vary widely: some 26 different grades having been recognized. By pulverizing the starch it receives, the Board has been able to standardize the product into five grades.

Thus in the mid 1950's the industry consisted of :

(i) *Peasants and Planters* who cultivated the rhizomes. According to the agricultural survey of 1956 there were 2,675 acres planted to the crop. Of these, 930 acres were on holdings of less than 10 acres, 215 on holdings of between 10 and 100 acres, and 1,470 acres on farms of over 100 acres.

(ii) *Thirty different factories* engaged in the processing of starch, each factory employing on the average 33 persons, and producing on average 300,000 lb. of starch valued at approximately $54,000.

(iii) *The Arrowroot Board or Pool* as it is commonly called, where starch was assembled, graded and shipped abroad. During the harvesting season this body employed about 160 persons, and out of season, 80.

THE LEVELS OF TECHNOLOGY IN THE INDUSTRY

The technological changes that occured in the sugar industry in most Caribbean islands in the century 1850 – 1950 had no counterparts in the arrowroot industry in St. Vincent. There are two possible explanations for this. As will be shown later, the Arrowroot Association was placed in an unusually strong position for a marketing agency operating in an undeveloped country. It is possible that the ability of the Association to obtain annual increases in prices, blinded the members to the need for increasing the level of efficiency in the industry. There is always the tendency for this to happen in a monopolistically organised industry. The tendency will, of course, be accentuated in a small community in which there is no monopolies commission, where there is no financial journalism and where the community is trading in a commodity about which very little is published in the established trade journals.

Secondly, it is possible that the cost of innovation was so high as to be almost prohibitive. Since the industry had no counterpart elsewhere, there was little scope for imitation in technology. Changes, therefore, required basic research and this is usually expensive especially for small islands. The extent to which either factor affected the rate of change in the industry can best be brought out by examining the scope there was for increasing efficiency and the efforts that were in fact made to do so, in cultivation and in processing.

1. *In Cultivation*

In the arrowroot industry as in any other industry, the level of efficiency is determined by the ratio of input to output: changes can be brought about either (a) by reducing the amount of inputs required to produce a given output, or (b) by increasing the output from a given amount of inputs.

(a) *Reducing Inputs* — It is difficult to obtain statistical data which would indicate the level of efficiency prevailing in the industry, but insofar as the data shown in Appendix Table III can be regarded as reliable estimates then it is clear that labour which accounts for over 50 per cent of the cost of rhizome production is the singly most important input. Since the harvesting of the crop requires more labour than any other operation then naturally there have been proposals for mechanizing this operation. But as has been the case in these Caribbean islands, where sugar industry has provided a great deal of employment, there was the policy issue as to the extent to which an island with a capital-short, labour-abundant factor endowment ought to substitute capital for labour. It had to be borne in mind that primary agricultural production provides employment for 35 per cent of the labour force in St. Vincent, and even in normal times the rate of unemployment in the island runs as high as 16 per cent. Mechanization of the country's most labour-intensive industry could therefore lead to serious unemployment difficulties.

Even if the employment issue were ignored and the policy had been to use the most efficient technique available, the evidence that mechanization of harvesting would have led to significant economies is not conclusive. Harvesting machines could not be simply imported as has been the case with the sugar industry in some Caribbean islands. For arrowroot production being peculiar to St. Vincent there are no such machines in existence. Nor did it seem feasible to have machines specially designed for harvesting arrowroot. Since the market for the machine would be small, being confined to St. Vincent, the cost of producing the machines would have been high. Attempts were made to adapt available machinery to the harvesting of arrowroot. The machines tried included a single furrow reversible mould-board plough fitted with digger bodies, a mounted potato-spinner, and a mounted elevator digger. The potato spinner gave the best results but even this posed problems.

The two varieties of arrowroot grown in St. Vincent display different characteristics. The rhizomes of the 'creole' variety tend to develop in large rambling strands which penetrate the soil to great depths. The 'banana' is of a more bunched habit and rarely penetrates the soil to any great depth. Thus the 'banana' variety would have been more amenable to harvesting by the potato spinner than the 'creole'. The 'banana' variety is, however, a poor yielder of rhizomes as compared to the 'creole' and moreover, it tends to deteriorate much more rapidly after ripening than does the 'creole', hence if production were concentrated on the 'banana' variety so as to facilitate mechanization there would have been a reduction in yields.

Nor is it certain that the use of the potato-spinner would necessarily have reduced the overall cost of harvesting. In the first place, the greater portion of farm-land in St. Vincent is mountainous and arrowroot is grown both on the flat land and on the hillsides. It is likely that harvesting on the hillsides would still have to be done manually even if the operation were mechanized on the flat lands. Secondly, mechanization of harvesting would have required certain changes in cultural practices which would have increased the number of cultivation operations or increased the amount of labour required to perform certain operations. Traditionally, arrowroot has been planted by simple dibbling; mechanization would have entailed planting in ridges. Further, under the traditional system there is no need to re-plant annually; the bits that are left in the ground during reaping spring up to provide the next crop. Mechanization would have required annual replanting. Finally, there was the question of getting rid of the bush before the harvester could operate and of collecting the roots once the machine had dug them out of the ground. Both of these operations would have required a certain amount of manual labour. It is not surprising, therefore, that arrowroot harvesting operations were in fact never mechanized in St. Vincent.

(b) *Increasing Output*— Yields per acre could have been increased by the usual methods, either by improvement in cultural practices or by the introduction of high-yielding varieties; perhaps even better by a combination of both. Fertilizer and spacing trials involving arrowroot have been carried out since the 1930's and these have had some impact. For whereas in 1948 yields of 8000 lb. of rhizomes per acre were regarded as good, the corresponding figure in the 1960's was between 10,000 lb. and 12,000 lb. and in some rare cases 24,000 lb. have been obtained from an acre.

The introduction of high yielding varieties, however, poses a greater problem. This required basic research and the problem was of course made no easier by the fact that the two varieties of arrowroot produced in St. Vincent do not produce seeds. St. Vincent, like most of the smaller islands of the Commonwealth Caribbean, has never been able to finance basic agricultural research from local resources. Funds to do so, however, could have been obtained under the Colonial Development and Welfare Acts. But St. Vincent made no effort to do so until 1959 when a geneticist was employed to investigate the possibility of developing a high yielding variety that could be reaped mechanically. As is to be expected in a situation where a single scientist is working in isolation without the moral or technical support of his peers, progress has not been very rapid. At present the research has reached the stage where seeds have been obtained from varieties imported from other parts of the world and some work is now being done on hybridization.

2. *In Processing*

As mentioned earlier, arrowroot factories in St. Vincent have been mainly local contrivances, former muscuvado factories having been converted into arrowroot processing plants. Given the small output of each factory and variations in the quality of starch produced by the different factories, the path to modernization obviously lay in establishing large central factories, as has been the case in the sugar industry.

But here again there was no model of factory that could simply be imported into St. Vincent and put to processing arrowroot. Innovation necessarily involved a great deal of preliminary investigation, and since the private sector either individually as farmers, or collectively as the Arrowroot Association, was unwilling to undertake the responsibility to carry the research, the Government did so.

In 1955, the Government engaged a German firm to establish an experimental central factory. In setting up the factory the firm engaged sought to adapt the techniques used in processing white potatoes to the processing of arrowroot. The finished product differed in several significant respects from that of the old factories. While the old factories used mainly paddle-washers, the Central Factory used a barrel-washer. In the old factories the roots are crushed and sieved only once, in the Central Factory, they are crushed twice and sieved thrice. Whereas in the old factories the starch is separated from the 'fruit water' by means of settling tables, in the Central Factory, a centrifugal separator is used. The old factories are powered by man, water and in the odd case diesel oil; the Central Factory by electricity. Finally, while the starch is air-dried in the old factories, in the new, a mechanical steam-heated drier is used

The initial cost of the Central Factory was $335,000 (W.I.) and as can be seen from Appendix Table IV, the factory has experienced losses totalling over $200,000 in its 11 years of operation. Several factors have been responsible for this.

In the first place, before the manufacturing process begins, arrowroot rhizomes require more washing than do potatoes, hence to the barrel-washer installed by the Germans, a paddle-washer had to be added. Once the washing apparatus had been altered the centrifugal separator proved inadequate and another had to be obtained. The new washer and separator alone cost an additional $45,000. In addition, several minor adjustments had to be made such as the use of perforated copper sheets instead of bronze wire cloth to strain the starch. Consequently the rate of depreciation and the cost of maintenance of the plant and machinery, tended to be high.

Next the cost of power proved extremely high. Perhaps, in a labour-short Germany the substitution of electricity for man and water power might have led to economies, but in St. Vincent where electricity is expensive and labour abundant, the cost proved extremely high.

Finally, the factory attempted to revolutionize the relationship between the peasant and manufacturer. Individuals who operate private processing plants usually deduct a percentage of the peasant's starch as the cost of processing, but the Central Factory sought to purchase rhizomes directly from the peasants. This method represented an improvement over the traditional approach, since many factory operators had become notorious for deceiving the peasants both as regards the quantity and quality of the starch yielded by their rhizomes. However, for the new system to operate effectively, it was necessary for the management of the Central Arrowroot Factory to know :

(a) the total throughput of the factory in any given year, and
(b) the price the starch was likely to fetch.

It was difficult to predict the former since, as Appendix Table IV shows, the throughput varied from year to year. As for the latter, it was possible before 1960, given the instalment basis on which the Arrowroot Board purchased starch from producers.

The losses experienced by the Central Factory, however, are no indication that the industry has not benefited from its establishment. The manufacturing process in at least two of the older factories has been altered on the basis of the information derived from the Central Factory. While the centrifugal separator, the mechanical drier and the use of electricity have been considered too expensive to adopt, these two factories have initiated the Central Factory's technique of crushing the rhizomes twice and sieving them thrice.

Appendix Table V attempts to give some indication of the magnitude of the Central Factory's impact. Factory A is one of the factories in which the manufacturing process was altered as a result of the experiences of the Central Factory; (data on the other is not available). Factories C and D were in operation prior to the establishment of the Central Factory and were not in any way affected by its establishment.

Since the Central Factory is less labour-intensive than factories C and D, the wage cost per barrel of starch tends to be substantially higher in these factories than in the Central Factory. Factory A is still powered by man, wind and water, and not by electricity. This explains not only the difference in wage-cost per barrel of starch between Factory A and the Central Factory, but also, to a considerable extent, the difference in 'other expenses' between the Central Factory and the other factories. Of 5.18 cents shown under 'other expenses' for the Central Factory, 1.08 cents was for electricity, and 3.86 for depreciation and maintenance.

But most important of all is the much higher rate of starch extraction that obtains in the Central Factory and Factory A, as compared to the other factories, 8 per cent as compared to 14 per cent and 16 per cent. It seems then, that the Central Factory has benefited the industry insofar as its rate of extraction exceeds the factories it has superseded, and also insofar as the other factories have been modernized as a result of the lessons learnt from the Central Factory. It is likely, too, that the industry would have benefited even more, as more and more of the older factories were either superseded or modernized. Marketing difficulties, however, seemed to have forestalled this.

THE MARKETING OF ARROWROOT STARCH

The creation of the Arrowroot Board undoubtedly had a dynamic impact on the industry. As can be seen from Figure 1, the value of arrowroot exports tended to rise markedly after its establishment in 1930. There are two possible explanations. In the first place, the standardization of functions performed by the Board probably gave clients a greater guarantee of a homogenous product and so induced more orders. Perhaps, even more important has been the scale on which the Board has operated. This has enabled it to fulfil orders that individual producers could hardly have met. For instance, in its second year of operation, the Board received an order for 2.4 million pounds of starch, at the time the largest single order ever received for arrowroot starch in St. Vincent.

The very strength of the Board's position, however, tended to stifle its initiative. Since the Board was granted powers of sole exporter and up to the mid-fifties farmers preferred to concentrate on arrowroot production because the crop required little skill and involved little yield uncertainty, the Board has little difficulty in obtaining supplies. In fact, far from taking any positive steps to encourage production, the Board adopted a policy that could have had a disincentive effect. Producers were not paid cash-on-delivery but were given a first advance some eight months and a final payment after a further six months. Since the crop is annual, under this system of payment two and one half years elapsed between planting date and final payment !

On the sales side, too, it seems that the Board had little reason to take positive action. Arrowroot starch has a high maximum viscosity, yields a smooth jelly and is completely bland in taste. These qualities were sufficient to ensure that it enjoyed precedence over other starches in the manufacture of food for babies and invalids and since St. Vincent is the only country that produces the commodity in significant quantities dealers came to the Board to look for it.

No advertising nor marketing research was done. About 60 per cent of total exports were sold in the United States through a monopoly agent, 16 per cent in the United Kingdom through another monopoly agent and the remainder through sub-agents in the various islands of the Commonwealth Caribbean. Sales activities were confined to demanding increases in price on the ground that the industry was labour-intensive and the cost of labour was rising. The Board was apparently very successful in obtaining these increases for, as is shown in Figure 2, the price of arrowroot starch has tended to rise very markedly in comparison with that of the main starches produced in the United States.

The weaknesses inherent in both the sales and purchasing policies of the Board did not become fully apparent until the rise of the Banana Industry in the late 1950's when there was some competition between the banana and arrowroot industries for producers' resources.[2] Banana production has certain natural advantages over arrowroot, particularly for the small growers.

The production of bananas is non-seasonal and the labour requirements are not as great as arrowroot, so that not only are returns spread more evenly through the year but also family labour is sufficient to carry out most of the cultivated tasks. In addition, the Banana Board took certain steps to encourage farmers to plant more bananas. Not only were growers paid cash on delivery but the Association also undertook to provide fertilizer and pesticides on easy credit terms to growers. Consequently, there was a marked shift in resources from arrowroot to bananas, between 1958 and 1961, as is reflected in the decline in arrowroot production shown in Appendix Table VI.

Consumers in the United States, unable to obtain adequate supplies at this time, reacted in two ways. Kraft Industries, the major consumer, needed a sub-

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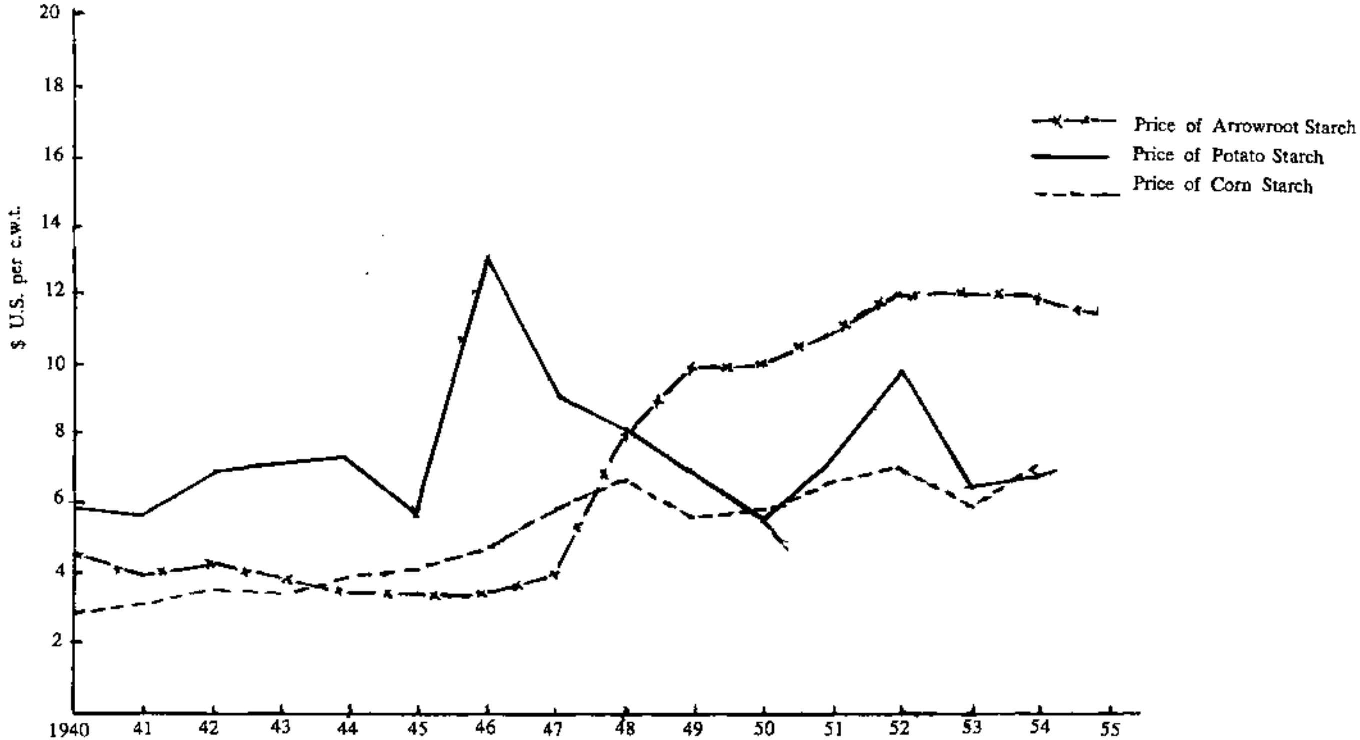
2 In the late 1950's the Banana Industry developed very rapidly in the Windward Islands (Dominica, Grenada, St. Vincent, and St. Lucia) after a British fruit firm undertook to purchase the fruits on a long term contract. In each of the Islands a Banana Board was established to assist in marketing the crop.

Figure 2 *Relationship Between the Price of Arrowroot Starch Exported from St. Vincent to U.S.A. and Prices of the Main Starches Produced in U.S.A.*



Sources: NF Starch: Raw Material Sources and Economics, *Industrial and Engineering Chemistry* Vol. XLVII No. 7 (July 1555) and *Annual Trade Report, 1963,* Kingston, St. Vincent.

stitute desperately since arrowroot starch was the chief ingredient in one of their main lines 'Miracle Whip'. They, therefore, began to research into the possibility of treating corn starch, so as to make it a reasonable substitute. Not only did corn starch prove to be good enough after some treatment, but the final product turned out to be 4 cents (U.S.) per lb. cheaper than arrowroot starch. The small consumers for their part changed their formula and used less arrowroot.

The Arrowroot Board was not aware of these developments, and decided in 1960 to imitate the Banana Board by paying growers cash-on-delivery and providing fertilizer on easy credit terms. Partly because of this change in policy and partly because of the cessation of the sugar industry in 1962,[3] lands normally devoted to sugar-cane switched to arrowroot, and the production of arrowroot in St. Vincent doubled between 1962 and 1964. But since the American consumers no longer wanted a large volume of the commodity and the other markets had been neglected, the starch could not be sold. The Association has, therefore, been forced to stockpile the commodity.

The cost of storage, of course, has not been simply confined to the cost of renting warehouses. The Board has been financing purchases by advances from the commercial banks, so there is also the question of bank charges. It has been estimated that the Association's indebtedness to the banks is in the vicinity of $2m. (W.I.).

PROSPECTS

Since most of the underdeveloped countries have their own sources of starch, the market for St. Vincent arrowroot starch will most likely be restricted to the North American continent, Western Europe and the neighbouring West Indian islands.

It has already been shown that the firms in the United States which originally purchased most of the arrowroot starch are no longer interested in the commodity. It is doubtful whether new outlets can now be found for the starch in that country. As Kennedy has pointed out, in 98 per cent of all the end uses, the prime considerations now governing the selection of any given starch are price, availability and stability of supply.[4] Starches imported into the United States on the whole compare unfavourably with domestically produced starches as regards availability and stability of supply. For in addition to the normal hazards associated with all agricultural production, supplies of imported starches can be disrupted by dock strikes, wars, and a breakdown in shipping facilities. As regards price, it has already been shown that the price of arrowroot starch now far exceeds that of the two main starches (corn and potato) produced in the United States. Moreover, given the technological gap between agriculture in the United States and agriculture in St. Vincent, it is doubtful whether St. Vincent can in the very short run reduce prices to a level that would make them competitive with the starches produced in the United States.

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3 The sugar industry in St. Vincent collapsed in 1962 after a protracted dispute between labour and management.

4 Kennedy, N. H., "Starch : Raw Material, Sources, and Economics", **Industrial and Engineering Chemistry**, Vol. xlvii, (July 1955), p. 1407.

Nor do the prospects seem very good in the United Kingdom. At best it has been estimated that the market there could have absorbed about 20,000 barrels. But it is felt that the substitute developed by Kraft Industries will make heavy inroads into the British market. On the Continent, there is likely to be similar competition from corn starch if arrowroot is at all let to enter the market there, for not only is the commodity completely unknown in European countries, but arrowroot starch is likely to be subject to heavy import duties.

Statistical data on the demand for starch in the islands of the Commonwealth Caribbean is not available but it is significant that in the early fifties, about over 6,000 barrels were being sold in the area, though this subsequently declined to 4,000 barrels. However, as a result of a recent advertisement campaign, there has been an increase in sales of about 1,000 barrels. But even if the Caribbean Market is exploited to the full, it is doubtful whether the demand will be suffiiciently great to off-set the loss of the American market. In these circumstances, the arrowroot industry will no longer be able to make as great a contribution to the economy as it did in the past. Processing of starch will have to be confined to the more efficient factories and the crop cultivated only on lands in the immediate vicinity of the factory.

APPENDIX TABLE I

Number of days employment provided by an acre of Arrowroot and an acre of Sugar cane : St. Vincent 1954

Operation	Arrowroot		Sugar cane	
	(Man days)	(Woman days)	(Man days)	(Woman days)
Preplanting	16	3	29	—
Planting	—	16	3½	3½
Weeding	—	34	—	42
Fertilizing	—	2	—	2
Reaping	36	2	16	2
All	52	57	48½	49½

Source : Labour Department, St. Vincent

APPENDIX TABLE II

Area of land in farms of different sizes : St. Vincent, 1896, 1946 and 1961

Farms in different size groups

Year	10 acres		10-100 acres		100+ acres	
	(No.)	(Acres)	(No.)	(Acres)	(No.)	(Acres)
1896	46	311	123	3,942	129	50,584
1946	n.a.	1,056	n.a.	7,578	n.a.	22,114
1961	10,828	15,954	390	7,650	32	15,871

Sources: *Report of the West India Royal Commission, 1897,* Her Majesty's Stationery Office, (p. 85)
Census of Agriculture in Barbados, the Leeward Islands, the Windward Islands and Trinidad and Tobago, West Indian Census, 1946 Jamaica, The Government Printery, (p. 28)
West Indies Census of Agriculture, 1961, St. Vincent, (Interim Report), (p. 10)

APPENDIX TABLE III

Estimated expenditure per acre of Arrowroot Rhizomes: St. Vincent, 1964

Items	Cost	Proportion of total cost
Labour	($)	(%)
Harvesting	82.24	30.0
Other operations	80.84	29.5
Sub Total	163.08	59.5
Planting Material	55.00	20.1
Fertilizer	56.00	20.4
Total	274.08	100.0

Source : Labour Department, St. Vincent

APPENDIX TABLE IV

Total Starch Output and Losses Realized by the Experimental Central Factory : St. Vincent 1956 – 1965

Year	Total Starch Output Barrels	Losses ($)
1956	5000	
1957	4000	
1958	4000	123,887
1959	3000	
1960	4000	
1961	4000	11,679
1962	6000	44,389
1963	6000	13,913
1964	6000	17,713
1965	4000	2,232

1 barrel – 200 lb.

Source : Annual Financial Statements of the Central Arrowroot Factory, 1956 – 1965.

APPENDIX TABLE V

Levels of efficiency, measured in terms of rate of extraction and cost of production in four arrowroot factories : St. Vincent, 1962

Performance and processing costs of the factories	Factories			
	(A)	(C.A.F.)	(C)	(D)
Production				
Throughput per factory in Barrels	3,976	6,195	1,771	987
Rate of Starch Extraction as % of Rhizomes processed	16%	14%	8-10%	8-10%
Cost per barrel : (cents per pound)				
Wages	1.99	1.93	4.00	2.14
Other Expenses	97	6.18	2.21	1.01
Overheads	2.07	1.79	5.25	4.42
Total Cost	5.03	9.90	11.46	7.57

Source : Financial Statements of the Respective Factories, 1962.

APPENDIX TABLE VI

Arrowroot Production : St. Vincent, 1956 – 1965

Year	Production Barrels
1956	42,000
1957	44,000
1958	38,000
1959	34,000
1960	32,000
1961	31,000
1962	37,000
1963	50,000
1964	65,000
1965	33,000

Source: *The St. Vincent Five-Year Draft Plan, 1966 – 1970*

DISCUSSION

Mr. Pilgrim :

Dr. Johnston, that section of your paper which states 'The familiar arguments concerning the need for agricultural mechanisation in order to "release" labour from nonfarm jobs have little validity under the conditions that prevail in underdeveloped countries today.' Again here somehow I detect the feeling that the use of modern agriculture in an underdeveloped country must be limited and must advance only as jobs, nonfarm jobs, are provided for the people who will be displaced. This seems to be a general theory — I may be wrong. But isn't it part of our job to force to some extent this movement by improving the efficiency, by modernising agriculture in these areas, and even, if necessary, by displacing a certain number of persons who cannot be immediately absorbed elsewhere, thus forcing the pace, forcing governments, forcing the people to find ways and means of utilising what will then become excess labour. I'm rather worried about the attitude that you must find the other job before displacing the present agricultural worker. This seems to me to indicate that it will take maybe hundreds of years before we get out of the present subsistence agriculture in many areas. Are people really going to wait this number of years for the improvement which more and more they see in other countries and don't see in their own?

D . Johnston :

It's an excellent question and I think there is certainly considerable validity in it. But I would mention as counter arguments that scarce capital funds and scarce foreign exchange that is used for investment in agricultural mechanisation is likely to reduce the availability of those exceedingly scarce resources for financing industrial development, so there is a competition that way. And secondly that there unfortunately seem to be real problems in supply creating its demand in the case of this kind of excess labour. What seems to happen too often (certainly in tropical Africa and I gather it's a very conspicuous phenomenon in some of the cities of Latin America) is that these people squeezed out of agriculture in such a way, many of them end up in shanty towns on the outskirts of the city — a sort of floating population — and even though there was a huge resevoir of labour available it does not seem to lead to an acceleration of industrial growth and employment opportunities in the industrial sector. I think this is partly a matter of faulty economic policies in some of these cases of holding wages artificially high for a privileged minority who do find jobs in the modern sector whereas a great part of the labour force finds productive employment neither in agriculture nor in modern industry.

Mr. McConnie :

Quite apart from the point that Mr. Pilgrim just brought up, there is another factor which, subject to correction, I have not seen stressed in these papers, and it is a natural tendency of the youth of today to move away from these manual jobs on the farm anyhow. Most of them want to congregate where the bright lights are and whether we want to or not, it seems to me that this tendency to mechanize and increase efficiency would have to come. It is now for the economists to find out what we are going to have to do with this displaced labour force in other sectors.

Dr. Edwards :

I think I sensed in what Mr. Pilgrim first said and the way Mr. McConnie followed it up, the frustration that many people with some responsibiity for a future in agriculture in the West Indies feel for, as they see it, having to be responsible for meeting the unemployment problem in the West Indies, and in agriculture having to be a sponge which must not be squeezed and which must, even in some way, find capacity for more water, more workers. Various problems arise. We have thousands of microscopic farms, most of which don't provide any sort of decent living for the people and which are becoming increasingly less viable. And this of course is even more difficult to change when agriculture has to provide additional jobs required. I don't know if I'm right but I'm sensing a reaction to this kind of position. The feeling that it is not fair, it isn't right, it isn't useful for agriculture continually to have to carry this burden largely alone because employment in the nonfarm sector hasn't grown very rapidly despite appreciable industrialisation programmes in the last few years. I suppose it's fair to say that in the early 1950's it was generally believed that industrialisation could solve some of the major problems of the West Indies. Now it's pretty obvious to us that it hasn't.

National income has increased substantially in some islands but employment has increased in the industrial sector hardly at all. And I think this is the reaction — people are unemployed, more have to be unemployed if agriculture is to become progressive and more modern. I suppose up to now I simply tried to summarize the problem and I haven't tried to answer it. There is, in many islands, scope in the form of unused and unutilised land. It's really quite remarkable how much land there is not being productively used in many of the densely populated islands of the West Indies. We have the labour, we have a fair amount of knowledge, why can't these be organised. But, I don't think I'll try to answer the question any more than that at this stage.

Dr. Macdonald :

I would just like to make a few comments on this question of mechanisation in peasant subsistence in agricultural areas. This is a very difficult aspect of policy and development. There is a natural assumption that if you put a tractor in you are going to displace people from the land. This, in some cases, can be correct. But if we go to America, which is the most highly mechanised agricultural country, although I believe there is one person working on the land and he can feed something like 26 people, in other words the agricultural population or agricultural labour is very low. In actual fact agriculture in America is the biggest consumer of steel and one has to remember that associated with the tractor driver is the vast industry which makes machines and tractors and also processing equipment. One of the problems in places like Uganda and East Africa is that if you do purchase a tractor, then there is a tendency to superimpose that tractor on to the peasant subsistence agriculure and of course it doesn't work. The peasant wants his sweet potatoes done in a tenth of an acre plot whereas the tractor will do it in 20 acre blocks. It is very difficult to superimpose the tractor onto this sort of system, but this doesn't mean that you cannot bring tractors into countries such as Uganda which has a fair amount of surplus land which is not being used. As an investment these tractors will go into agriculture on plantation scale and this is being done to a certain extent with sugar — I suppose competing with the West Indies.

Dr. Johnston :

Just two further points on this question of mechanisation. First of all, in so far as we are thinking of the domestic market the structure of a country in the early phase of development in itself does pose an inherent limitation on the demand for purchased food. If we have a few large mechanised farms of rapidly expanding production satisfying most of the growth of commercial demand for food this necessarily means that for the mass of the farm population that is engaged in small holder agriculture, the possibility of their expanding the cash incomes and among other things their use of purchasing goods is that much reduced and under certain circumstances the most rational strategy of agricultural development may be what is sometimes spoken of as a dual sized structure approach. A great many extremely small farms and relatively small number of large mechanised commercial farms (I have argued at some length in a paper — a paper on Agricultural and Economic Development with relevance to the Japanese Experience) that for many of the under-developed countries — the Japanese model — this process of gradually modernising, increasing the productivity of the nation's small farms, increasing your output much more by increasing the productivity of the land and labour already committed to agriculture by increasing crop yield and so forth, rather than a heavy reliance upon capital investment is likely to be the more promising strategy. But obviously there can be exceptions and one of the most important exceptions is in the case of a relatively small economy with good export potential. And then the export demand that it faces is completely elastic and there is literally within the relevant range no limit on the extent to which it can expand production and export. But of course for the under-developed countries as a group the situation isn't too promising in that respect, and if the country is a coffee producer it is likely to have a coffee quota under the International Coffee Agreement to remind itself that on the overall scale the scope for expanding export production is not unlimited.

Dr. Rogers :

Dr. Johnston, you made a recommendation for the use of fertilisers, but it seems to me before you can make a recommendation to use chemical fertilisers to improve the output of these root crops that we must have a considerable amount of education. In the development of the south-eastern part of the U.S. the farmers had the attitude that if some feriliser was good, more was beter, to the point where they burnt out all the crops, at least at first; wouldn't you have a considerable educational programme to go through to get your farmers up to the level of using this input?

Dr. Johnston :

I think you would and I think I believe I learnt from our discussion on fertiliser use on Tuesday that there are a lot of other problems that have to be resolved before it would become widely economic to use fertilisers in tropical root crops. I'm simply trying to put forward the argument and welcome challenges to it, that because of the nature of these inter-relaionships between agriculture and overall economic growth, a type of agricultural development strategy that concentrates upon reaching the point at which economic returns can be realised through varietal improvement, through greater use of fertilisers, through better insect and disease control and very probably through pre-emergent spraying to control weeds are likely to give specially high returns because of the fact that all of these are highly divisible, and can, given a reasonably competent extension programme, be applied on small farms. And, there is at least the presumption in terms of policies designed to be in the national interest that they will be more productive than investment in mechanisation which may be profitable for the individual operator particularly if he has an untypically large holding but for a country at the early stage of development it may not be in the national interest.

Mr. Francis :

With reference to Mr. Gooding's paper, Mr. Chairman, I am not quite convinced as to the reason why in arriving at his cost of production figures, in relation to both yams and sweet potatoes, in the case of sweet potatoes it's confined I think, to the spring planted crop. I am not quite convinced as to his reason for excluding the cost of harrowing, subsoiling and lining in arriving at the final figure. And I wonder whether it would not have been more realistic to have charged a proportionate part of that time which the yams occupied the land in arriving at this figure.

Mr. Gooding :

Yes, I have often wondered about this myself and in fact I have, from time to time, attempted to construct costings on that basis. There was a period when land was prepared and allowed to lie fallow. In he 1930's I remember as a boy we were always told that there was tremendous virtue in allowing the land to lie fallow — it regenerated, it recovered, it did all sorts of peculiar things and was much better — and then food crops were put on it and it was traditional not to charge any other operation other than those additional made by putting food crops on it, and I think that this has persisted. In fact, if you did of course charge for harrowing, subsoiling, lining and ridging, the amount of charge you would have to give to the food crop would depend on the number of years, the number of ratoons the cane was going to carry, probably an average about 5 and this would then be approximately a six month charge out of five. In other words, a tenth of the cost of those operations.

Mr. Paneris :

I would like to ask Dr. Johnson about one point here. In Table 5 he indicates that the full production now, compared with about ten years ago is doubled and since the population in Jamaica could not have increased that much in that time, people must now be eating Irish potatoes in place of something else. This apparently would appear to be other root crops. I also gather that the land that is used in the production of Irish potatoes is not the same land that was used for the production of other root crops. I would like to ask about the impact upon the production and the possibility of growing root crops in Jamaica.

Mr. Johnson :

I think there has been a misinterpretation in Table 5. The fact that we have produced more Irish potatoes meant that we imported less. If you look at the Table 5, column 3, you would see the total available for the consumption, that is, of which local production has been varied considerably with imports so that production went up, imports went down, so that by 1966 in point of fact, we had 33 million short tons, as against 1955 in which we had 16 million short tons. This is only of Irish potatoes and on per capita basis. In 1966 it was something less than 20 pounds per capita population wise.

Mr. Francis :

There are just two minor points I would like to address to Dr. Johnson. In 1966, it was observed that the state of self-sufficiency was achieved to the extent that they were considering the discovery of the export markets for the surplus, but at the same time I noticed that about .6 million pounds was still imported. I was wondering how that fits in with any possible consideration regarding legislation to protect the local industry. That's only on observation. And I would be glad if someone could give us some idea of the actual comparison or the ratio in prices between the locally produced and the important Irish potatoes.

Dr. Johnson :

First question. The fact that in 1966 I said that local production accounted for 95 per cent of the total quantity available, and yet I assume that that was virtual self-sufficiency. Is that the question?

The fact that we have production does not necessarily mean that all that is consumable. One could look at it that way and I think that this .6 actually came in at the very late stage when we had to look in terms of the tourist industry. That is what happened here.

Now your second question, in relation to the comparable cost of imported potatoes as against locally produced potatoes. I am sorry that I have not all the detailed figures here but in general, what happens is that we import potatoes during the latter part of the year, and at that time we are buying largely 'old' potatoes and so sometimes the price is lower than the price we could get it for in Jamaica.

Mrs. Rawlins :

I really want to make a comment on the last question, tying together the three papers. In the case of the arrowroot industry of St. Vincent, we see where they are having some difficulties, and in fact. if they continue to operate it, largely on the basis of continuing Government's support to the industry in one form or another, the Barbados situation appears to be that they manage to produce the quantity of food crops that they do because of Government regulation and even Dr. Johnson's success story of the Irish potato industry in Jamaica suggests to me that it could not have been achieved without considerable help from the Government, in one form or another, not only on the research and technological side, but also in the form of subsidy, extension work and assistance to the farmers in one form or another.

Would other people care to comment on the suggestion that most of these root crop industries could only be modernised and made successful on the basis of this Government support in various forms and apparently there is not any basis for the individual initiative of the farmers in developing these industries.

Dr. Johnson :

In the case of Irish potato I cannot say that the farmers did not take an initiative in developing this industry, they did do this. It was only when production gained in proportion that they asked for government assistance and this came largely through a subsidy. I mentioned that in 1961 the subsidy was abolished. At that time it was felt that the industry was sufficiently well on its feet for the subsidy to be withdrawn, so by and large as far as Irish potato industry is now concerned, if you have a subsidy, involved, it would largely be through marketing facilities which are provided.

CONTENTS

HEAT AND AIR-FLOW CHARACTERISTICS IN DRYING CROPS

— *by* —

B. N. Ghosh

Makerere University College, Kampala.

The importance and the need of drying a crop to a safe level of moisture content so that it can be stored on the farm for a period sometimes extending over a number of months has become accentuated by the general adoption of mechanized harvesting methods, as the crops are now removed from the field at a much higher moisture content than they were with the earlier hand harvesting methods. Various methods of drying are used on the farm, depending upon the size of the crop, initial moisture content and the drying facilities available, the general trend being towards bulk drying and storage as this method offers the maximum possibility of saving in handling and labour costs.

Published literature indicate that earlier investigations on various aspects of crop drying has tended to be concentrated on grain crops like wheat and barley, with comparatively little attention being paid to tropical or specialised crops, as exemplified by cassava (*Manihot esculenta* Crantz), sweet potato (*Ipomoea batatas*), ground nuts (*Arachis hypogea L.*) cherry coffee (*Coffea canephora*) or haricot beans (*Phaseolus vulgaris*). A programme of work has been initiated at the Faculty of Agriculture of the Makerere University College for studying the drying characteristics of a large number of tropical crops including root crops, and the results of experiments carried out to study the heat-and air-flow characteristics of the five crops mentioned above are described in the present article. Similar studies with maize, sorghum, parchment coffee and a type of pulse are being carried out at present.

Experimental results obtained with thin layer (of single grain) drying can be applied to deep bed drying on the assumption that the latter can be regarded as a series of thin beds, and that the analytical methods used to predict moisture changes in a thin bed can also be applicable to thick beds (1-2). This approach has not generally succeeded, however, as without electronic aid the number of calculations required to reach a satisfactory answer would be prohibitive of effort (3). In the present work, therefore, a bed depth of 18 in. has been used for all the investigations.

In order to facilitate experimental work during periods when naturally moist grain or crop is not easily available, investigators have to sometimes fall back upon using artificially rewetted material. Experiments carried out by Dietrich (4) with a single-layer test sample of wheat indicated that in drying from about 28 to 18% m.c. (d.b.), the average drying rate for the artificially rewetted sample was about 50% greater than for naturally moist wheat, while Bailey (5) carried out his investigations on the assumption that the drying rate is equal for both the samples. Vegetative products do not always respond to moisture in a similar manner on both absorption and desorption cycles; Ghosh (6) found that dry sisal fibre at 12% m.c. did not regain its original internal moisture level (approximately 44%) even after 24 hours of soaking in water. In the present investigation, all the five crops were in their naturally moist state at the time of drying.

DESCRIPTION OF APPARATUS

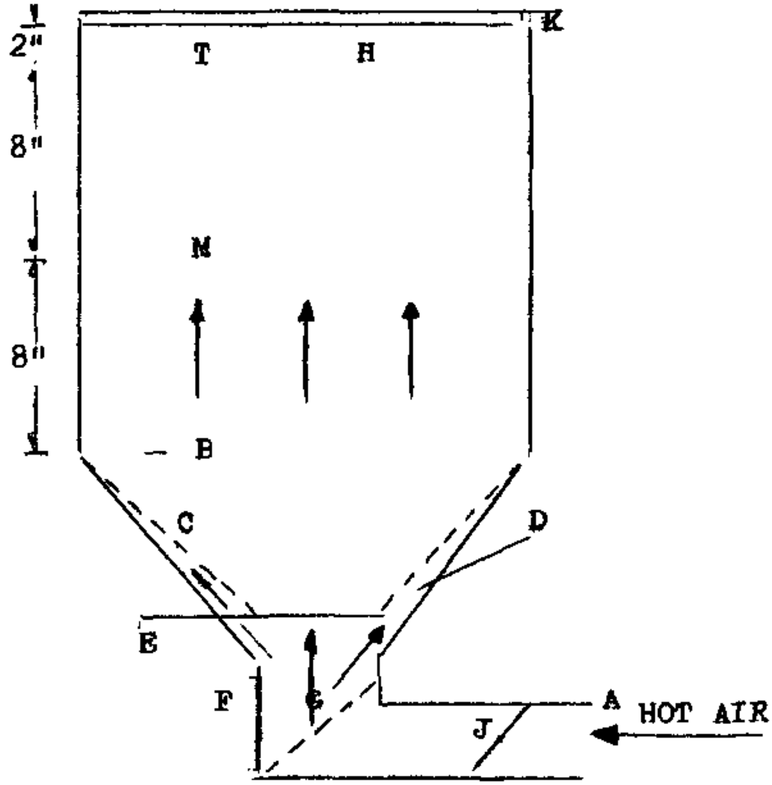
The apparatus (Fig. 1, elevation) used for the experimental work basically consist of a hopper (7) 18 in 3 with a conical bottom section for air inlet through a pipe A and a butterfly J. Inside the conical section of the hopper is located another smaller section C made of perforated metal, so that hot air can flow upwards through the mass of the material being dried. The direction of flow of air through the hopper is shown by arrows in Fig. 1. The space created by the vertical gap between the two conical sections constitute the plenum chamber, and a thermometer D inserted into the chamber gives the temperature of the inlet air at any time. A sliding gate E working on a horizontal plane is provided with a blank section for diverting the air upwards through the sides of the hopper only, a perforated section to enable the air to rise throughout the cross sectional area of the hopper and a slot for discharging the material through another sliding gate F working on a vertical plane and a removable baffle G which can be placed in position only by fully opening the gate F. A loosely fitting hard board lid H sits on the top of the material being dried and is also provided with clips K for additional support. The exhaust air escapes through the space between the lid H and the sides of the hopper. The four vertical walls of the hopper are well lagged with insulating material from outside to prevent heat losses.

A nest of 15 thermocouples, inserted through the hardboard top, in three layers of 5 each were used to measure the temperature of the drying material at intervals of 10 min without disturbing the drying process. The position of the 3 layers at the top, middle and bottom (T,M,B) of the hopper is shown in Fig. 1 (elevation) and the disposition of the 5 thermocouples in each layer in Fig. 1 (top-view) as 1, 2, 3, and 5. The sensing element of each thermocouple was enclosed in a pyrex glass tube to prevent direct contact with the drying material.

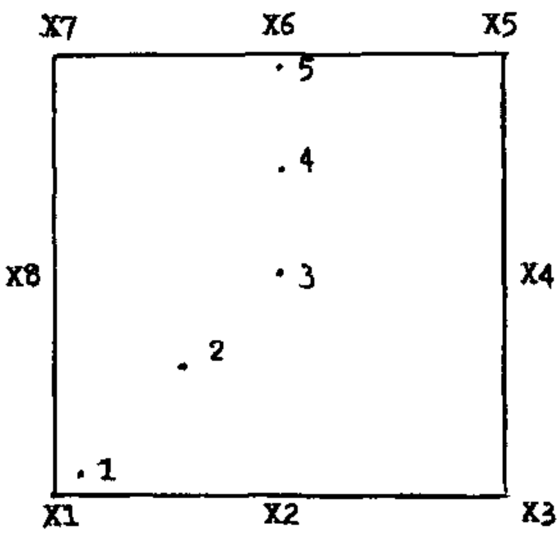
The hot air to the hopper was supplied through the inlet tube A (Fig. 1) by a thermostatically controlled laboratory drier (8) for the lower inlet air velocity used and by another electrical heater-blower unit (9) for the two higher inlet air velocities. The thermocouples were connected through contact switches to a highly sensitive spot-galvanometer calibrated to give a scale deflection of approx. 9 in for a temperature range between 0 to 100°C. The other end of sensing elements were kept immersed in ice maintained in a thermosflask. The velocity of the air entering the hopper and at exhaust (XI to X8 in Fig. 1, top-view) was measured by a velometer.

EXPERIMENTAL SCOPE

Woodforde and Lawton (10) have recently studied the temperature changes that take place during drying at the top, middle and bottom layers of a 6 in. deep bed of wheat and barley, while Boyce (3) has emphasised the importance of measuring the changes in air or grain temperature in the bed during drying. In the present experiment, cassava and sweet potatoes were each dried at three levels of moisture content using two different air velocities and nuts in shell were dried



ELEVATION



TOP VIEW showing position of thermocouples for each layer (1-5) and points of exhaust air measurement (X1-X8).

Fig. 1. Hopper

at three different air velocities each at a different level of moisture content, while cherry coffee was dried at two levels of moisture content at a constant air velocity. Haricot beans at four levels of moisture content were dried at three different air velocities. In each of the 15 experiments reported in this paper, the temperature changes were measured during drying at the top, middle and bottom layer of an 18 in. deep bed, and the airflow measured both at the inlet (bottom) and the outlet (top). All the moisture determinations were carried out by drying a sample of approximately 10 g. in an air oven for 24 h. at 103°C (Kabanyolo University Farm. Kampala), at an elevation: 3950 ft and the values have been reported on a wet basis. Although some of the material used for the experimental work could be considerea as 'dry' for safe storage before drying commenced, these were included in the test programme to study if there was any noticeable change in their heat-flow characteristics as the material dried. The maximum drying air temperature used was also kept somewhat higher (80°C) than the generally recommended values to ascertain the maximum rise in grain temperature that could be expected during deep bed drying. Even higher drying temperatures of 104°C have been recommended for drying grain to be used for feeding purposes on the farm (11), and tests carried out with wheat dried at 82°C and 104°C failed to reveal any damage (other than to germination) or discontinuity in the texture of the endosperm (10). It was beyond the scope of this experiment to study the effect of drying temperature on the subsequent germination of the grains.

PROCEDURE

The material to be tested was well mixed and a small random sample collected for initial moisture determination before filling the hopper level with the top, without making any attempt to pack the material. The hopper lid was placed in position so that the bottom of the lid rested on the material to be dried, the thermocouples were inserted in place and the electrical connections checked with the free end of the thermocouples being kept immersed in ice. The drier of the heater-blower unit was started and set to produce hot air at a predetermined temperature and velocity. The ambient air temperature along with the initial temperature of the 15 thermocouples in position were noted and the hot air conected to the air-inlet tube A of the hopper to commence drying.

Galvanometer reading were taken at 10 min intervals for all the 15 thermocouples in turn and the temperature of the inlet-air read from the thermometer D. In practice, the 16 readings took approximately 1½ to 2 min to read, and each time the same sequence of operation was followed to ensure that a set of readings for a particular thermocouple was very nearly at 10 min intervals. The velocity of the exhaust air was read during the run at the positions X1 to X8 by the velometer. Observations were continued till the temperature of the drying material through-out the dept became equal to the inlet air or for a minimum arbitrary period of 6 hrs. At the end of the run, a random sample of the dried material from the top and the bottom layers were collected for moisture determination before discharging the material from the hopper through sliding gates E and F and the baffle G.

While ground nuts in shell, cherry coffee or haricot beans could be dried in their natural state, cassava and sweet potato tubers had to be cut and reduced in size to facilitate drying. The tubers were first soaked in water for a short time to remove soil and dirt, and then shaped by hand chopping into cubes approximately ¾ in. in size.

RESULTS AND DISCUSSION

(1) *Temperature rise through material.*

With both cassava and sweet potato, the freshly cut material being at a high initial moisture (approx. 60% w.b.), the temperature rise at the top layer is very little even after 6h of drying; with the lower inlet air velocity it is confined to the bottom layers only (Figs. 2a, 3a) while for the higher velocity the middle layers are also affected (Figs. 2b, 3b). At the lower initial moisture of around 35% the temperature rises in both the material throughout the bed and the top, middle and bottom layers are well defined (Figs. 2c, 3c). The difference in temperature between the 5 thermocouple positions for each layer is also noticeable, particularly at the higher initial moisture. Woodforde and Lawton (10) measured the grain temperature during drying at 4 positions for each level, but reported only one curve for each layer. Cassava at 58.21% initial moisture was cut and left in a heap in the afternoon and drying commenced the following morning, when an increase in temperature of up to 8°C from the ambient was noticed in the material.

With groundnuts, the difference in temperature between the top and the bottom layer is approximately 18°C even after 7 h of drying at the lower inlet air velocity and the higher initial moisture (Fig. 4a), while comparison of Figs. 4b and 4c indicates that by increasing the inlet air velocity the increase in temperature throughout the bed is very rapid and it is relatively unaffected by the initial moisture content. The difference in the temperature between the 5 thermocouple positions for each layer is also noticeable, particularly for the lower inlet air velocity (Fig. 4a).

With cherry coffee at initial moistures of 39.48 and 33.96% the rise in temperature at the top layer is very little even after 7 h of drying, and there is a considerable variation between the temperatures recorded by the 5 thermocouples at either the bottom or the middle layers. Cherry coffee at 39.48% initial m.c. was loaded in the hopper at about 4.00 p.m. in the afternoon and the drying commenced at 9.00 a.m. the following morning, when an increase in temperature of up to 13°C from the ambient was noticed inside the hopper.

Two experiments with haricot beans at an initial moisture of 18.15 and 11.69% and an inlet air velocity of 2085 ft. min $^{-1}$ 1 show that the rise in temperature at the top layer is very little in both (Figs. 6a 6b) compared to the bottom layer, with a difference of approximately 34°C after a drying period of 7.5 and 6.5 h respectively. After a slight initial rise in temperature the top layer in both the cases remain more or less constant for the first 4.5 h.of drying, indicating that all the heat available for drying was being utilized at the bottom and middle layers. With higher inlet air velocities (Figs. 6c 6d) the increase in temperature throughout the bed is more rapid.

(2) *Exhaust air velocity*

The exhaust air velocities recorded for cassava, sweet potatoes, ground nuts and cherry coffee (Table 1) show that it is proportional and approximately 10% of the inlet air velocity, although there are some differences between the readings obtained from the eight positions. With haricot beans the exhaust air velocities are somewhat lower, probably due to closer packing together of the material.

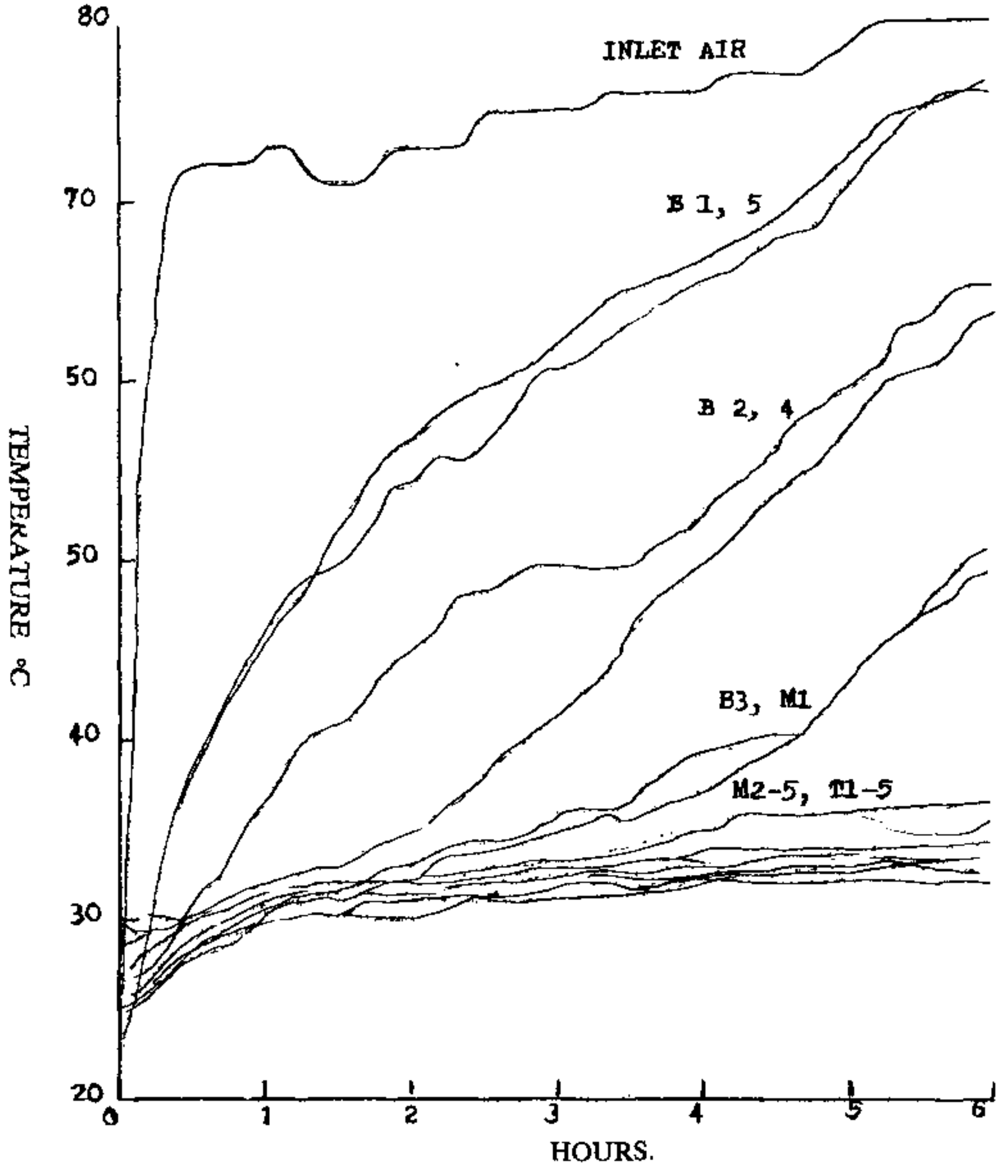


Fig. 2a. Drying time—temperature, Cassava Initial moisture 58.21%, Inlet air 3500 ft. min —1

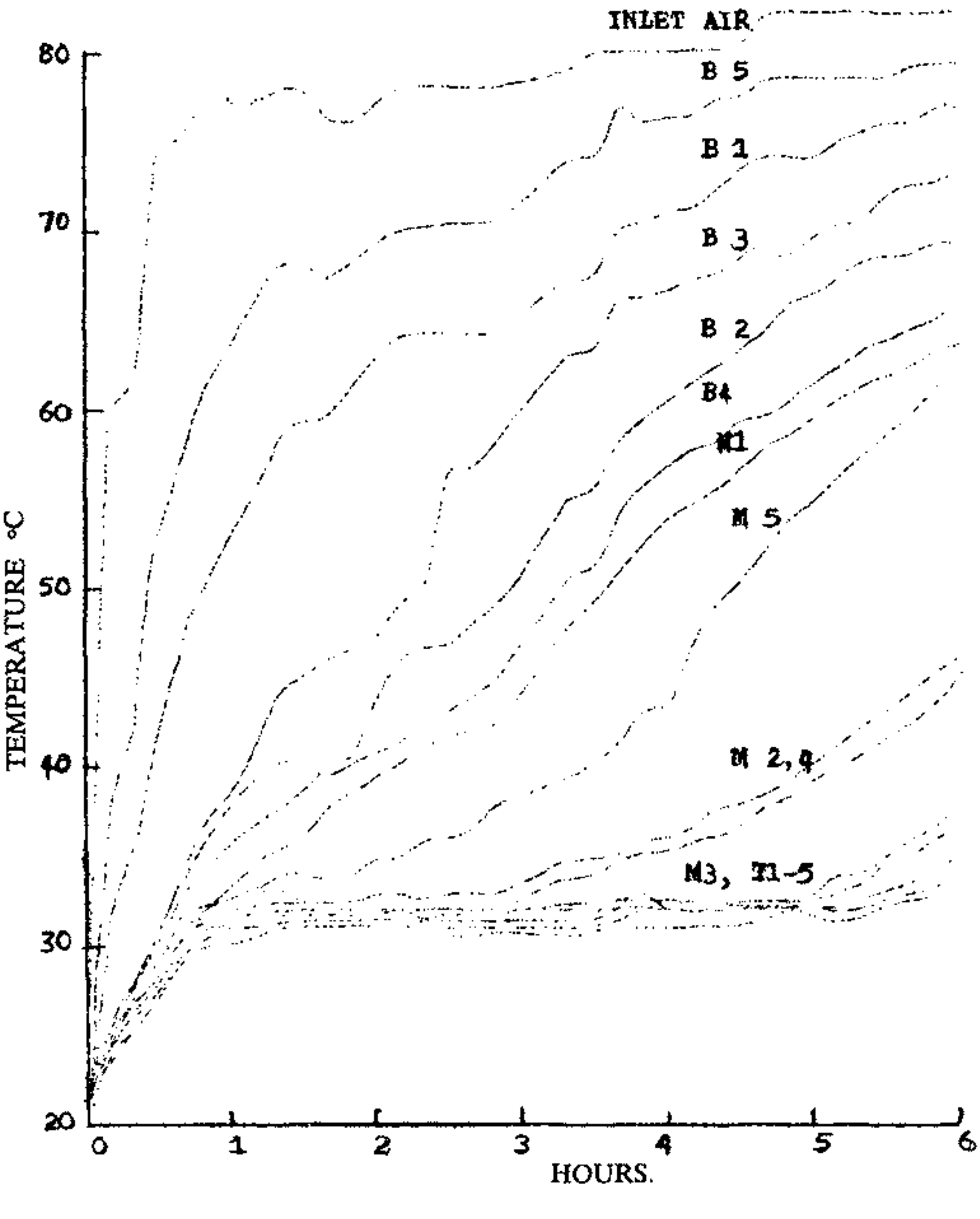


Fig. 2b. Drying time—temperature, Cassava. Initial moisture 59.98%, Inlet air 5410 ft. min $^{-1}$

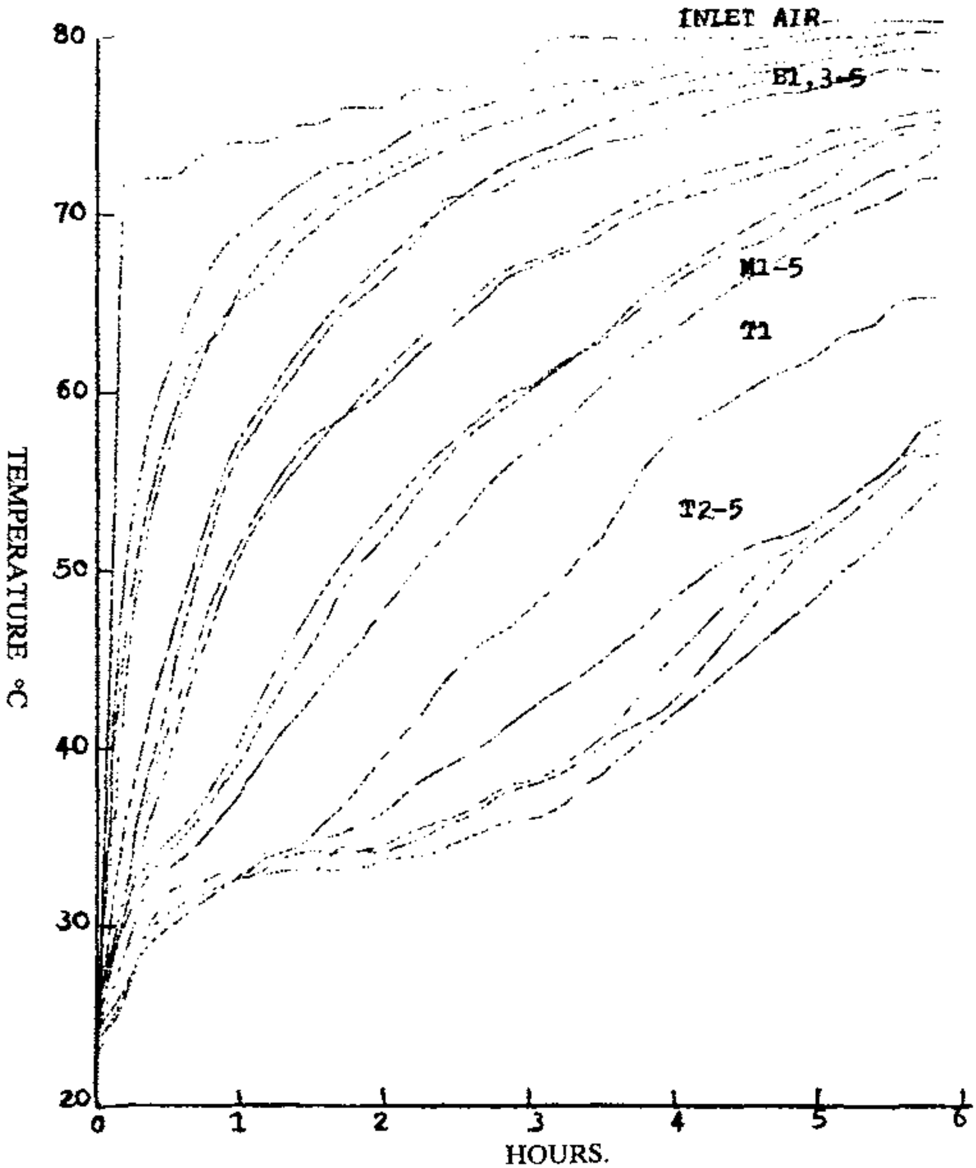


Fig. 2c. Drying time—temperature, Cassava. Initial moisture 34.22% Inlet air 5430 ft. min $^{-1}$

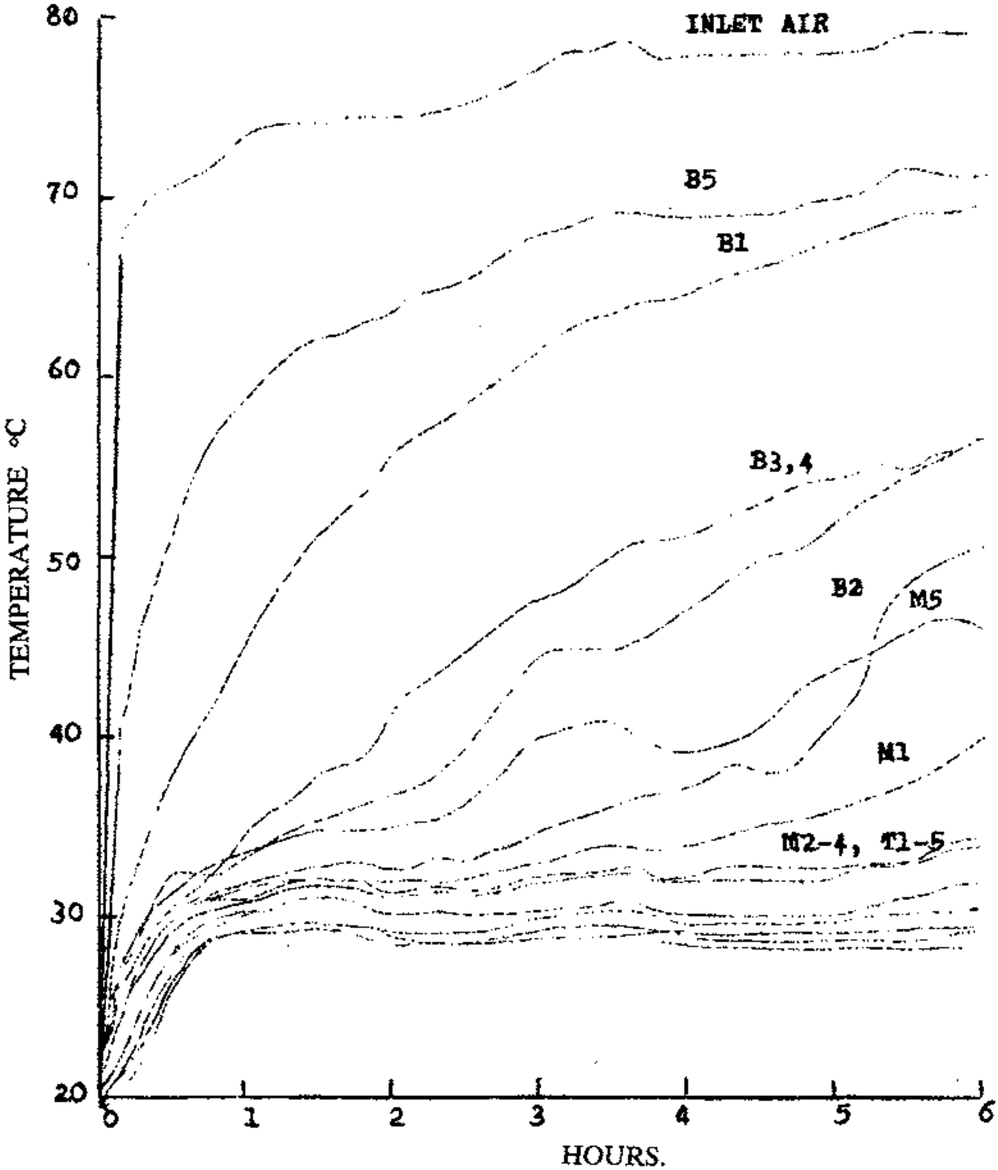


Fig. 3a. Drying time—temperature, Sweet potatoes. Initial moisture 60.61%, Inlet air 3509 ft. min —1

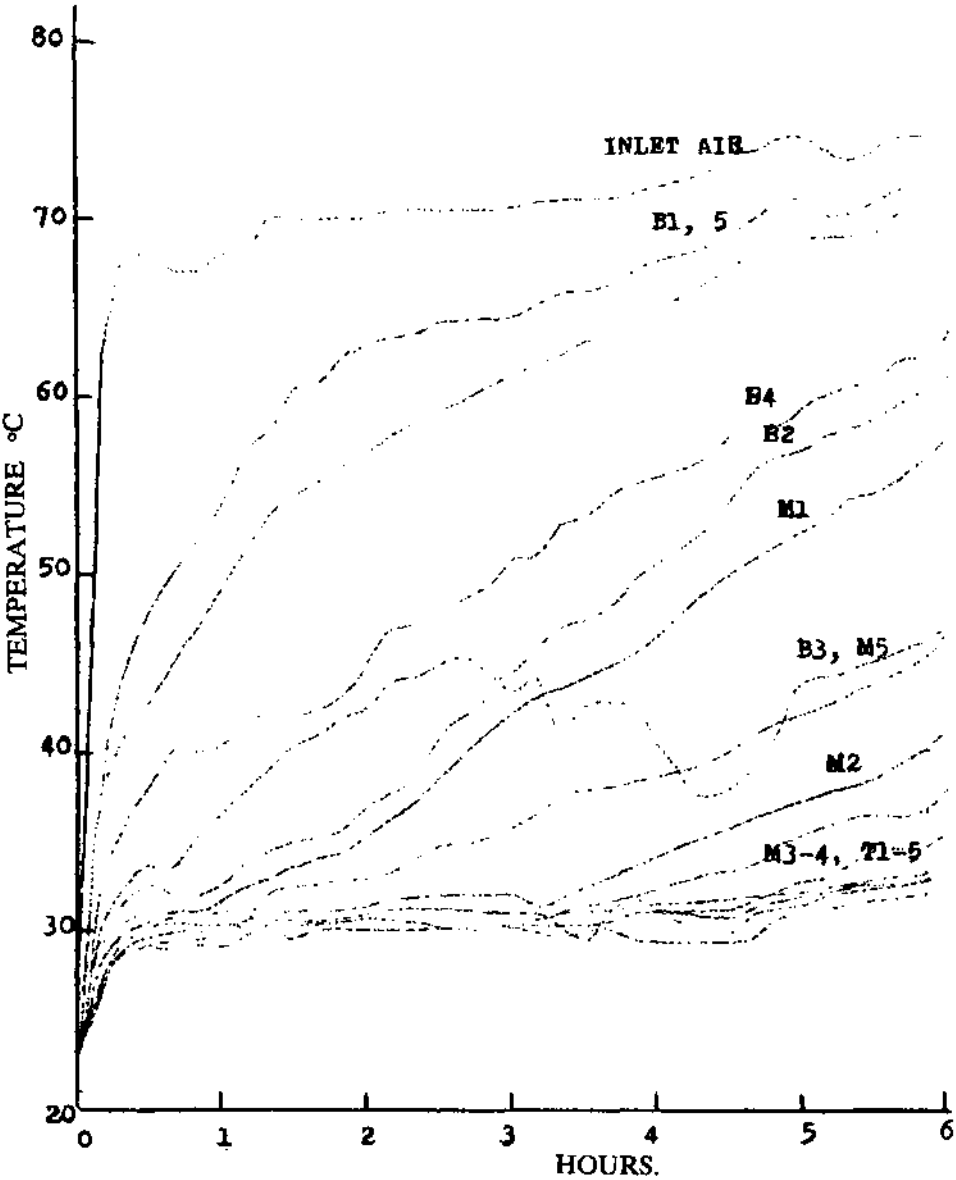


Fig. 3b. Drying time—temperature, Sweet potatoes. Initial moisture 60.11%, Inlet air 5481 ft. min —1

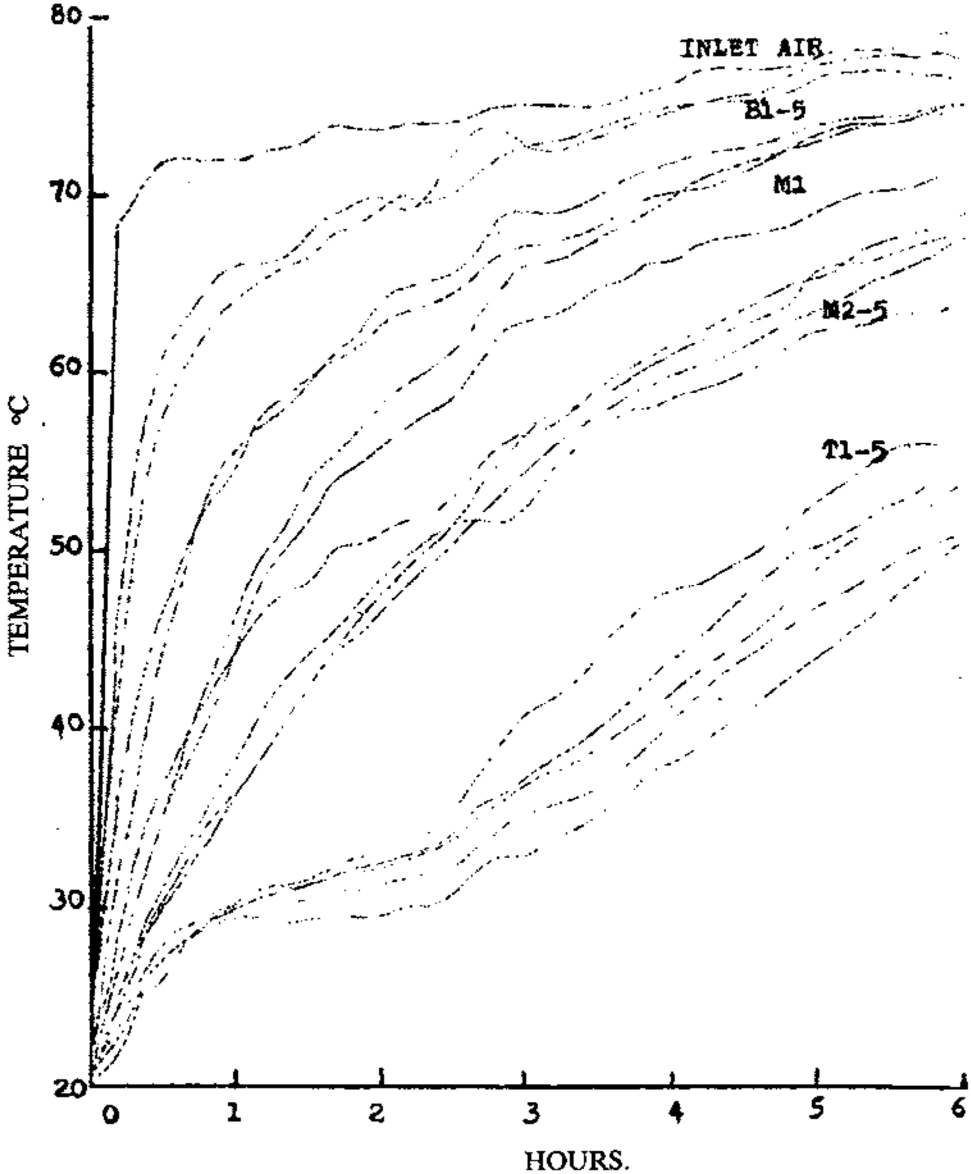


Fig. 3c. Drying time—temperature, Sweet potatoes. Initial moisture 35.91%, Inlet air 5665 ft. min $^{-1}$

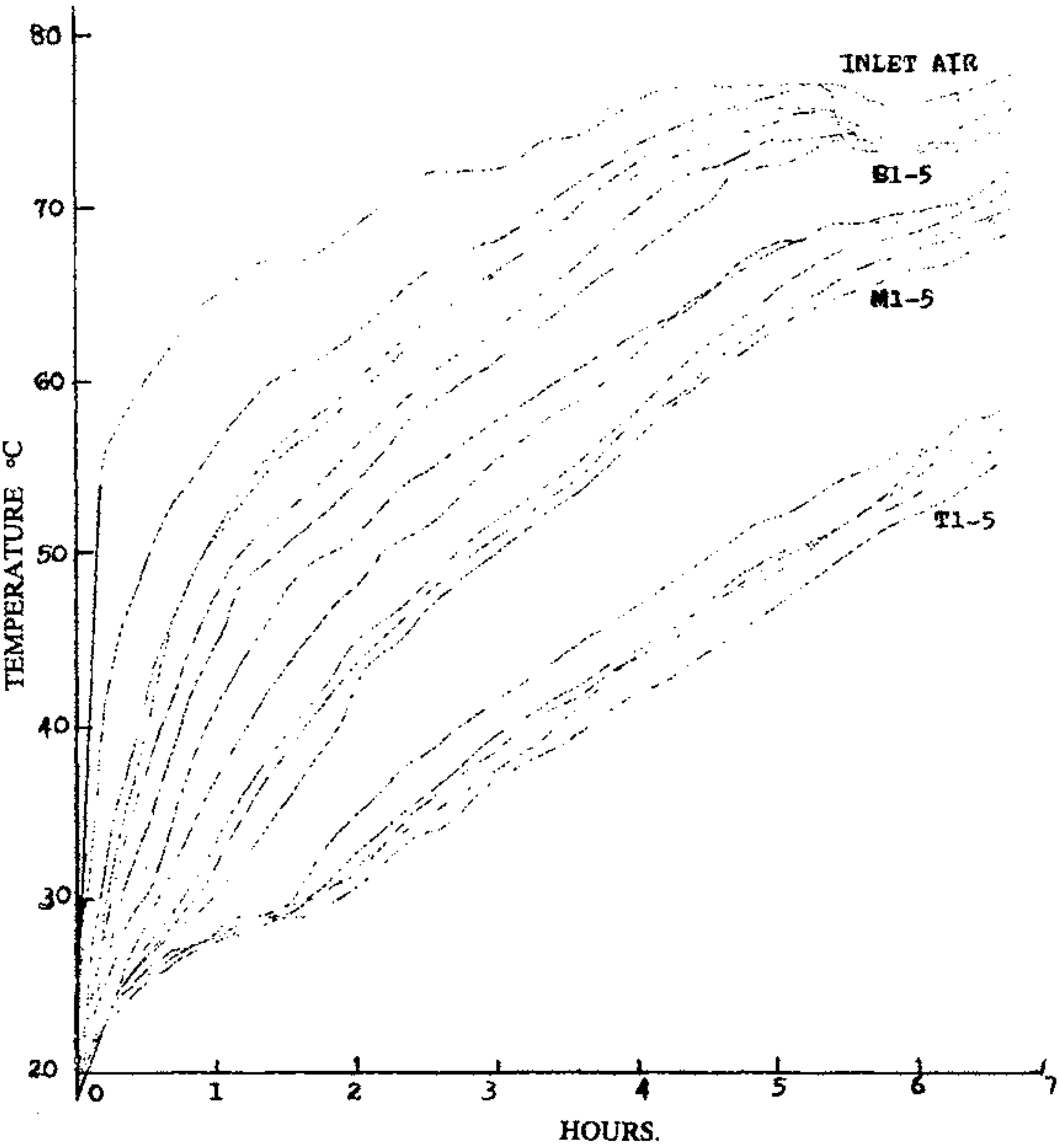


Fig. 4a. Drying time—temperature, Groundnuts in shell. Initial moisture 14.38%, Inlet air 2019 ft. min $^{-1}$

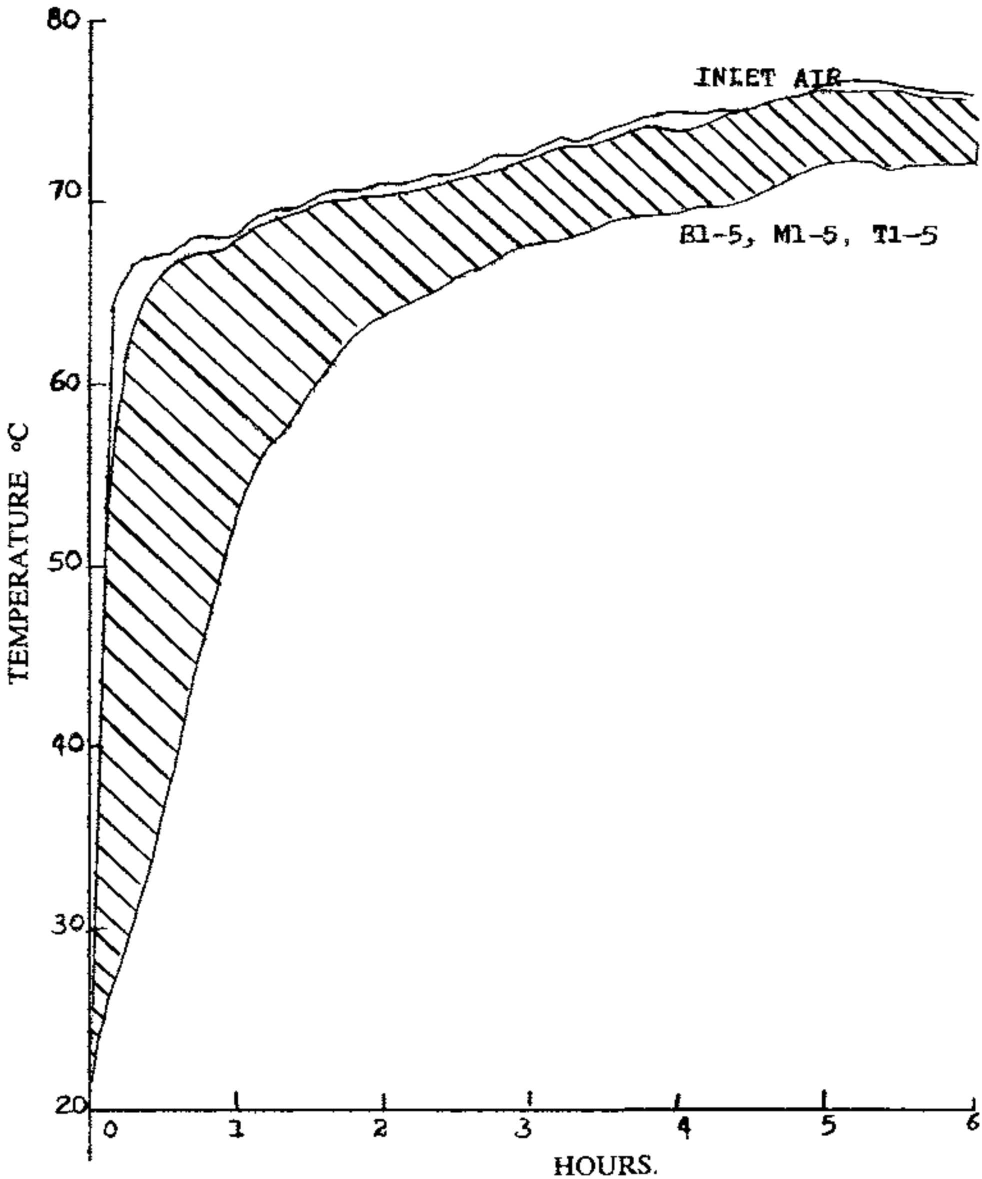


Fig. 4b. Drying time—temperature, Groundnut in shell. Initial moisture 10.14%, Inlet air 5390 ft. min $^{-1}$

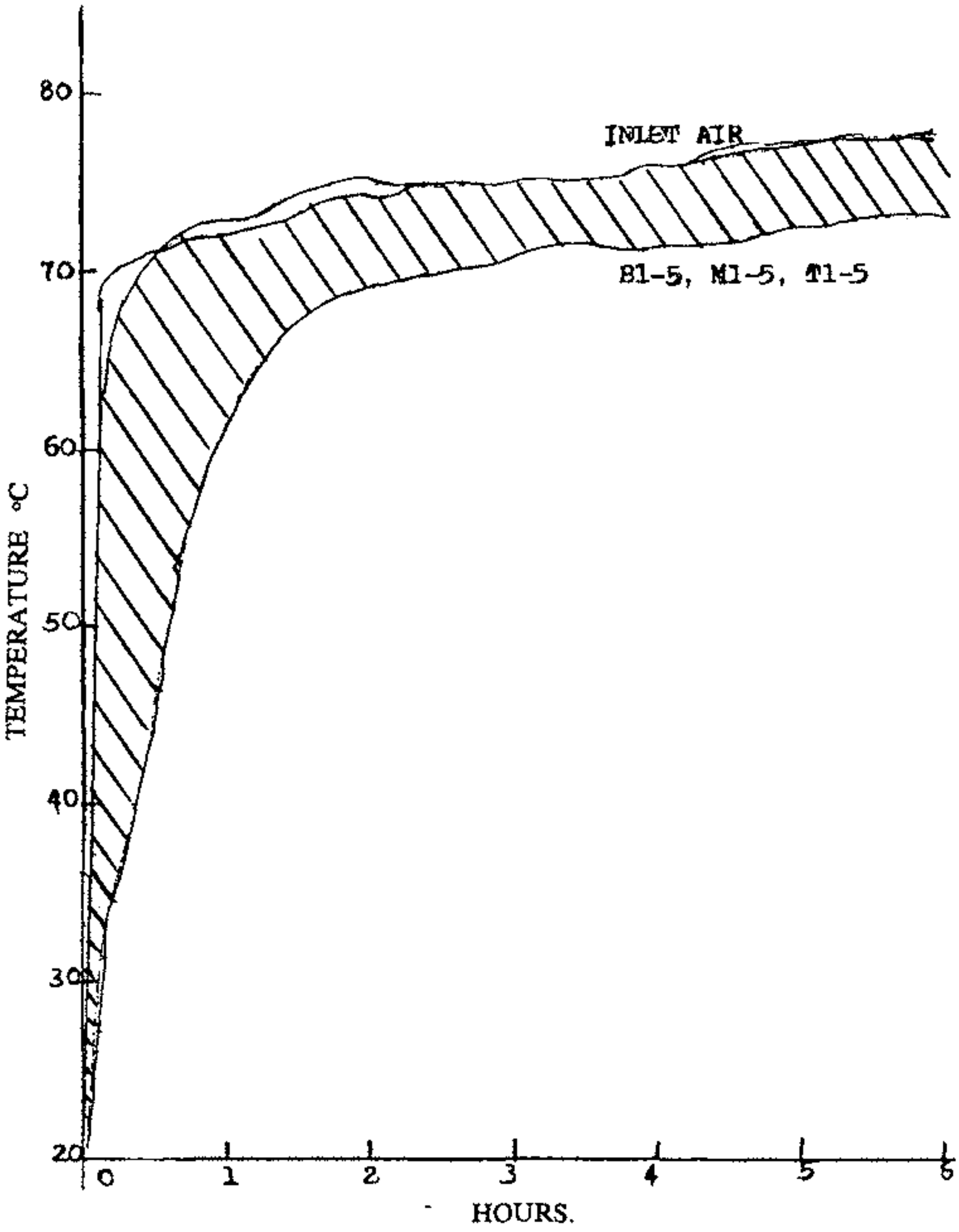


Fig. 4c. Drying time—temperature, Groundnut in shell Initial moisture 3.99%, Inlet-air 3604 ft. min —1

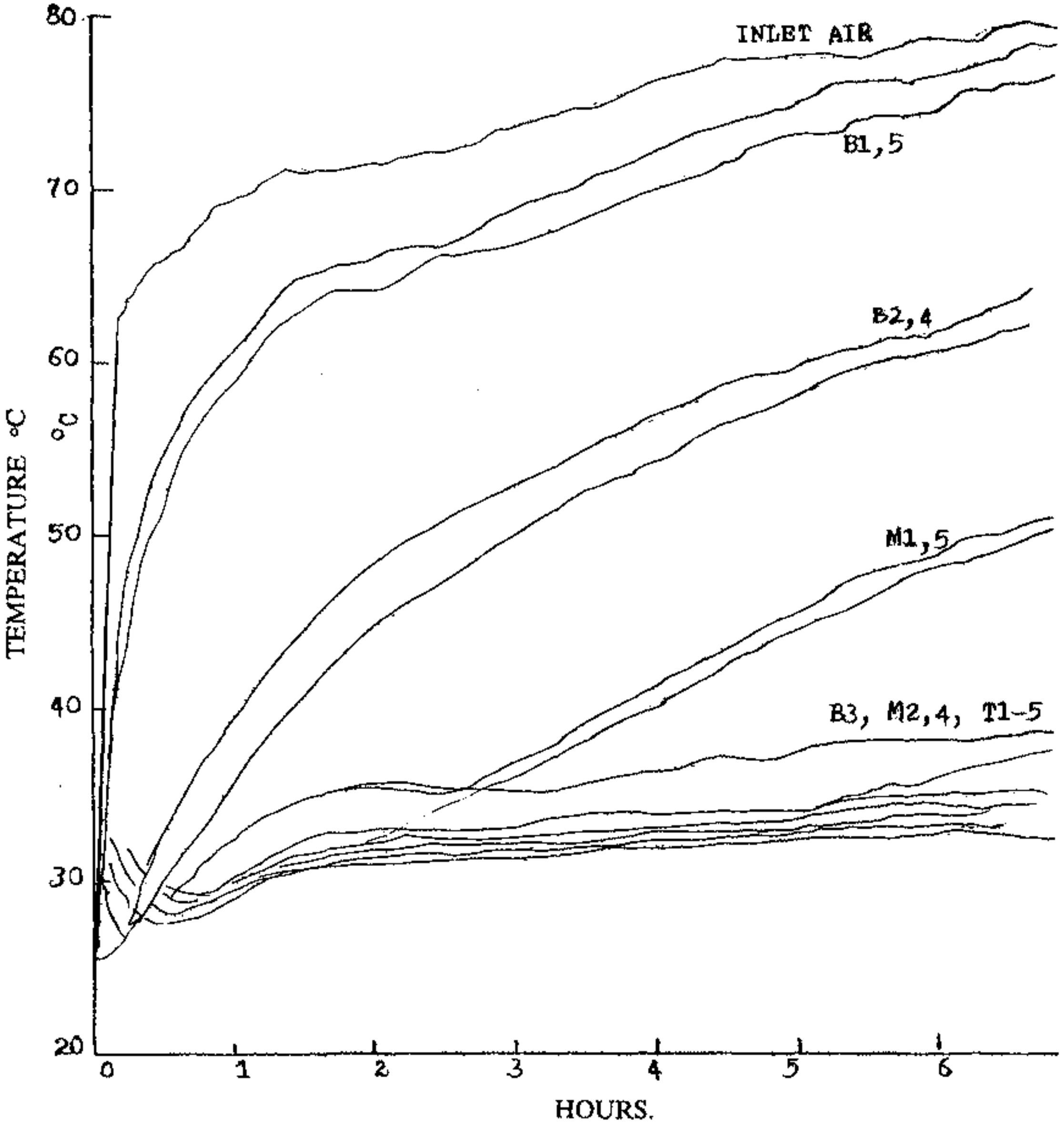


Fig. 5a. Drying time—temperature, Cherry coffee. Initial moisture 39.48%, Inlet air 1970 ft. min $^{-1}$

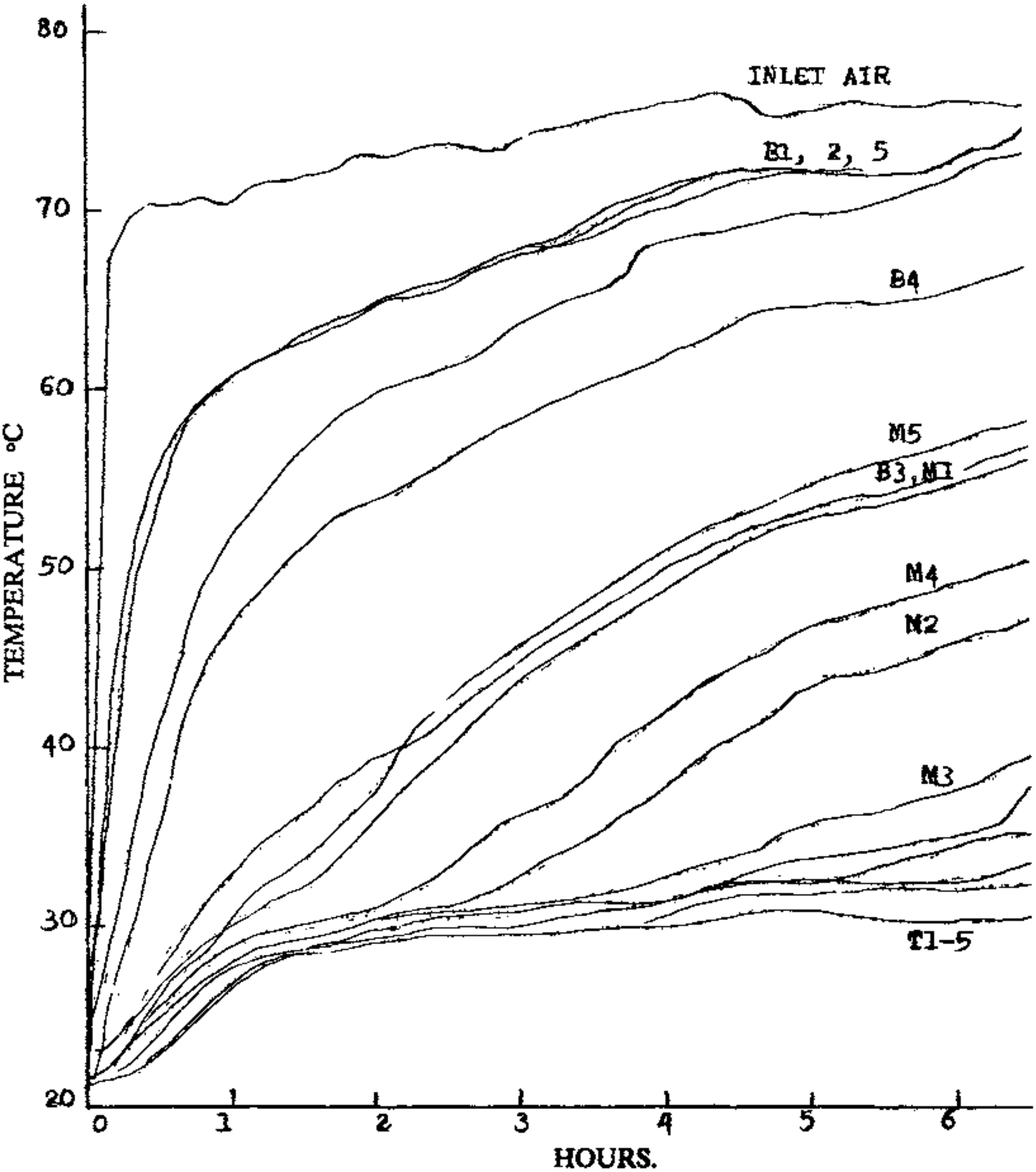


Fig. 5b. Drying time—temperature, Cherry coffee. Initial moisture 33.96%, Inlet air 1970 ft. min $^{-1}$

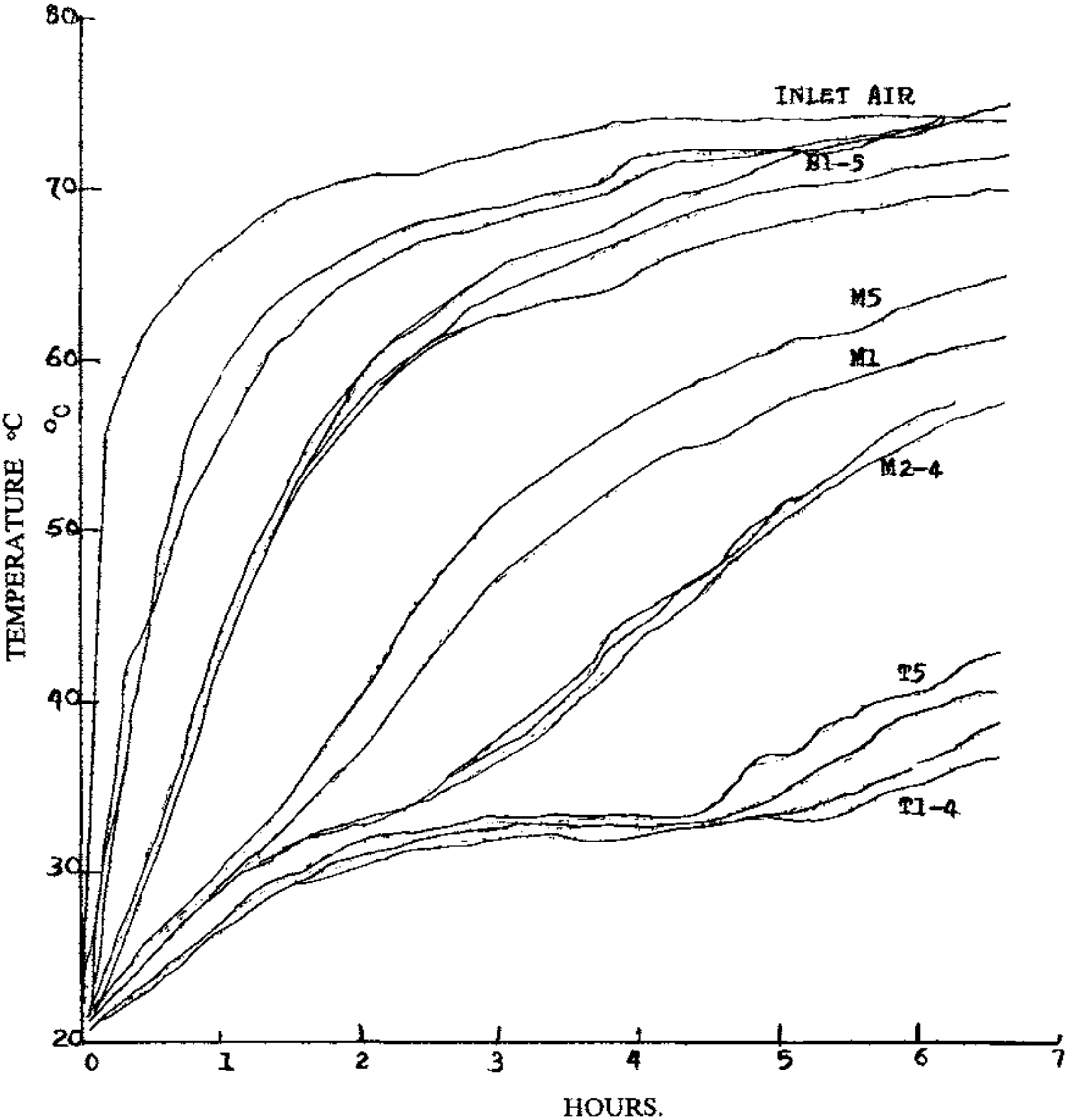


Fig. 6a. Drying time—temperature, Haricot beans. Initial moisture 18.15%, Inlet air 2085 ft. min —1

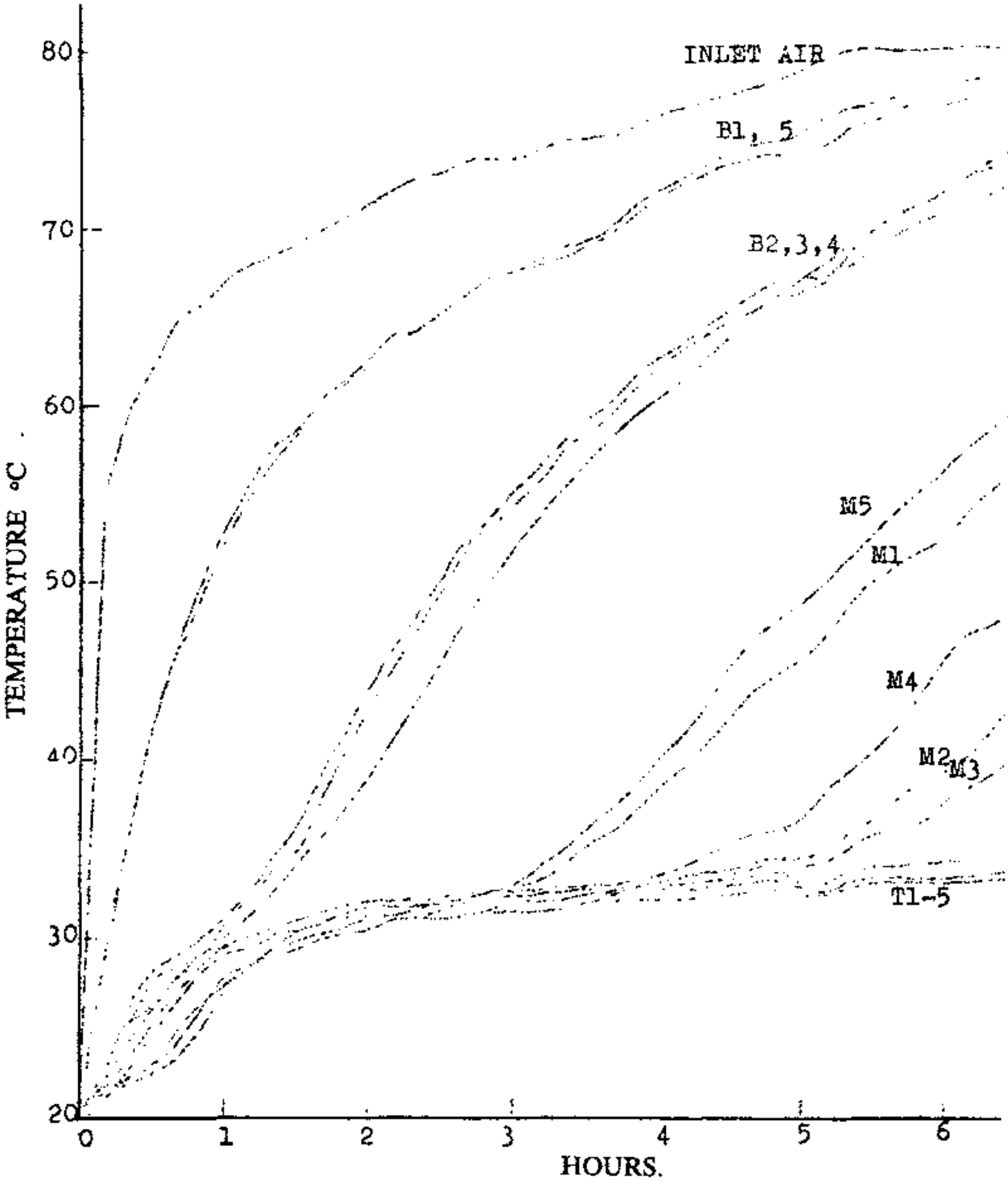


Fig. 6b. Drying time—temperature, Haricot beans. Initial moisture 11.69%, Inlet air 2085 ft. min —1

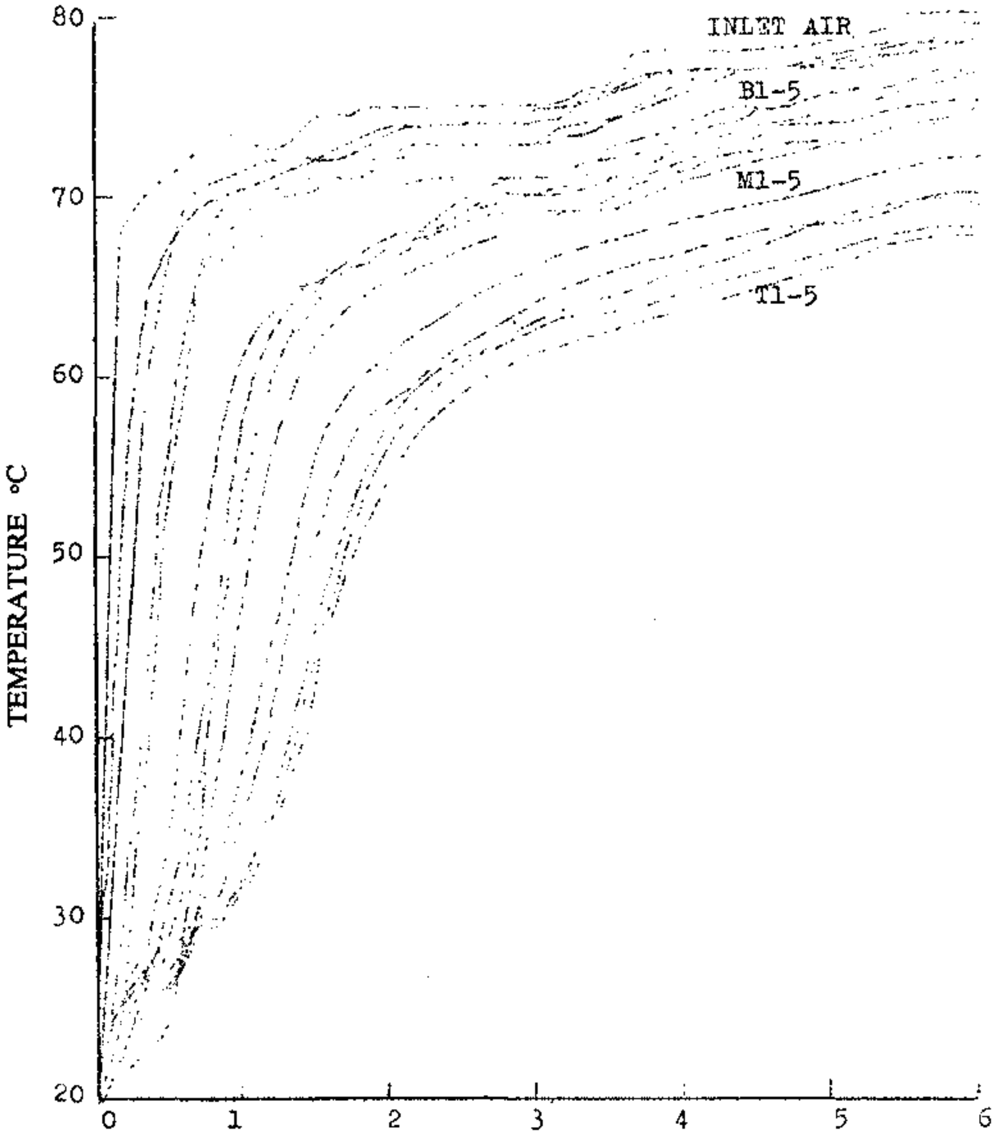


Fig. 6c. Drying time—temperature, Haricot beans. Initial moisture 7.68%, Inlet air 3518 ft. min —1

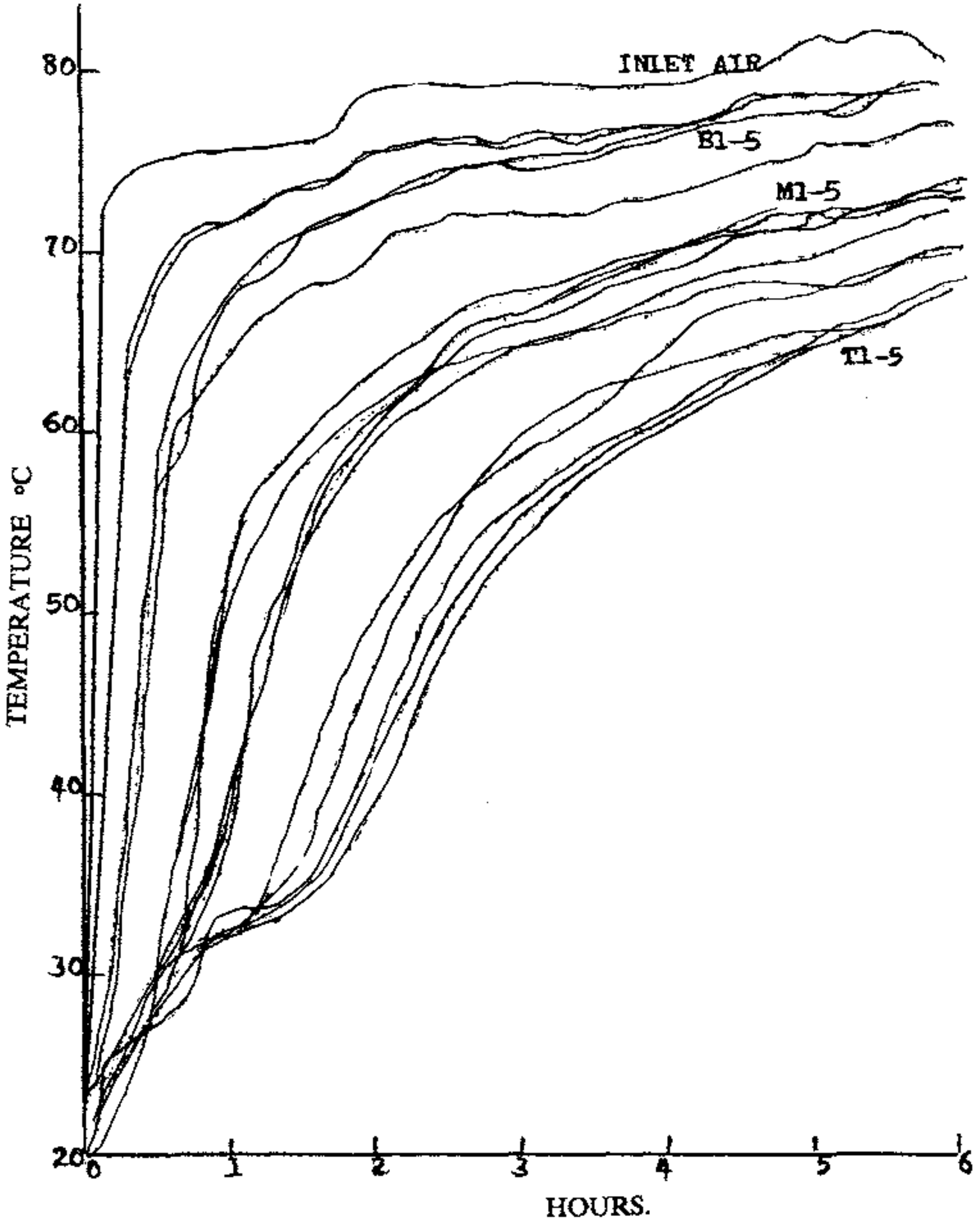


Fig. 6d. Drying time—temperature, Haricot beans. Initial moisture 14.61%, Inlet air 5680 ft. min —1

Table 1. Exhaust air velocity

Initial Moisture % (w.b.)	Inlet-air velocity ft. min—1)	Average exhaust air velocity (ft. min —1) at points shown in Fig. 1 (top-view)							
		X1	X2	X3	X4	X5	X6	X7	X8
Cassava									
58.21	3500	250	370	433	320	310	306	340	380
59.98	5410	218	520	540	510	464	560	520	500
34.22	5430	396	580	560	488	424	420	580	474
Sweet potato									
60.61	3509	286	365	335	268	370	356	354	322
60.11	5481	306	552	552	344	505	529	594	481
35.91	5665	376	560	431	444	507	573	578	525
Ground nut									
14.38[1]	2019	125	180	242	193	168	160	254	214
3.99[1]	3604	150[2]	330	380	347	370	348	360	331
10.14[1]	5390	464	573	600	504	540	444	520	504
Cherry coffee									
33.96	1970	116	198	132	173	139	175	145	154
39.48	1970			Reading unobtainable [3]					
Haricot beans									
18.15	2085	84	172	200	145	82	143	129	100
11.69	2085	80	128	171	140	125	154	180	147
7.68	3518	250	322	348	291	240	234	302	291
14.61	5680	451	527	516	414	406	340	404	446

1. Moisture content of whole nut in shell. (See Table 3).

2. Reading suspect.

3. At the higher moisture content the exhaust air contained too much moisture for velometer readings to be obtained.

(3) *Moisture content*

The post-drying moisture content of cassava, sweet potatoes, cherry coffee and haricot beans (Table II) clearly indicate that drying at the top layers is slower than that at the bottom, as expected from a study of the temperature rise through the material during drying. At the lower inlet velocity ground nuts show a similar trend, while for the higher velocities the drying rate is more or less constant throughout the bed.

With haricot beans, at an initial moisture content of 18.15%, condensation takes place at the top layer after 7.5 h. of drying, as evidenced by a slight increase in the final moisture content. Similar trends were also noticed by Woodforde and Lawton (10), working with wheat in 6 in. deep bed.

Table II also gives the total drop in the level of some of the material inside the hopper at the end of the drying period. As the thermocouples at the top layer were located at a depth of 2 in. in certain cases they could only measure the temperature of the exhaust air as the level of the drying material dropped beyond this value.

Figs 4b and 4c clearly indicate that the rather low initial moisture of 3.99% for groundnuts in shell, compared to that of 10.14% does not materially alter the drying characteristics of the crop.

Table II. Moisture content of dried material

Drying time (hour)	Drop in level after drying (inch)	Percent moisture content (w.b.) Initial	After drying Hopper top	Hopper bottom
	Cassava			
6.0	4.0	58.21	56.54	16.81
6.0	5.3	59.98	53.74	18.96
6.0	5.0	34.22	24.66	6.37
	Sweet potato			
6.0	4.8	60.61	57.76	25.53
6.0	7.0	60.11	52.99	20.56
6.0	6.0	35.91	31.14	3.77
	Cherry coffee			
7.0	1.5	39.48	37.22	30.46
6.5	1.5	33.96	30.78	23.77
	Haricot beans			
7.5	0	18.15	18.18	12.08
6.5	0	11.69	10.83	5.84
6.0	0	7.68	6.42	4.92
6.0	0	14.61	8.48	6.27

The moisture content of the groundnut is difficult to express in one figure as there is a considerable difference between the values of nuts in shell, nuts only, shell only and nuts in shell with the shell split open (Table III.). The unsplit shell surrounding the nut tends to mask the true content of the nut. At the end of the 7 h drying period, the level of material in the hopper had dropped by 2in.

Table III. Moisture content of various portions of groundnut

Portion of groundnut	Percent moisture content (w.b.) Initial	After drying Hopper top	After drying Hopper bottom
Inlet-air velocity 2019 ft. min^{-1}, drying time 7 h			
Nuts in shell	14.38	8.74	7.21
Nuts only	15.63	7.69	6.54
Shell only	13.84	9.58	9.77
Nuts and shell, split open	11.85	10.70	6.53
Inlet-air volocity 3604 ft. min^{-1}, drying time 6 h			
Nuts in shell	3.99	1.79	1.96
Nuts only	3.73	1.38	1.29
Shell only	6.01	2.11	1.48
Nuts and shell, split open	4.01	3.11	1.33
Inlet-air velocity 5390 ft. min^{-1}, drying time 6 h			
Nuts in shell	10.14	2.68	2.69
Nuts only	6.80	2.41	2.47
Shell only	14.00	2.90	2.32
Nuts and Shell, split open	9.52	2.50	2.10

CONCLUSIONS

The heat—and air-flow characteristics during drying of the five materials, reported in this paper, indicate that the drying rate and temperature rise at the top layers is considerably lower than that at the bottom. In order to ensure even drying in a deep bed, therefore, it is necessary to turn or invert the material well during drying. Higher inlet-air velocities for a given drying temperature increases the drying rate to an appreciable degree. The drying characteristics of the two root crops, cassava and sweet potatoes, are found to be very similar to each other, while they differ somewhat from other crops like ground nuts, cherry coffee or haricot beans. The drop in level of the material during drying appears to be related to the initial moisture content.

ACKNOWLEDGEMENT:

The Rockefeller Foundation of U.S.A. provided funds for part of the experimental work. Professor D.M. Thomson of the Physics Department at Makerere helped with recording equipment and P.R. Patel, an undergraduate student at the Faculty of Agriculture carried out a number of observations.

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DISCUSSION

Chairman :

If there are any brief comments or questions, you may ask them now.

Dr. Smith :

It is obviously, extremely important with these experiments to know what the relative humidity of the air, to start with, is. Did you measure this?

It's perfectly obvious that if you dry anything the rate of drying will depend enormously on the relative humidity of the air before you start. Did you measure this ?

Dr. Ghosh :

Yes, measurements were taken.

Dr. Maner :

Did you take into account the particle size of yuca (cassava) and sweet potato in your drying experiments? Does particle size have any effect on drying intensity?

Dr. Ghosh :

I am almost certain that particle size will have an effect, because in the comparative study which we have done between cassava and halitose beans, halitose beans had the smallest grains which were used in these experiments, and the drying rate was comparatively faster than others.

Now the reason why we used a standard value for cassava and sweet potato is that it is about the size to which it will be prepared for drying. It was beyond the scope of this experiment to study the effects of particle size. We know that as particle size is reduced, drying will change, but we kept that as a standard value for these two root crops.

Prof. Stephanson :

Two of the questions which I had, have already been asked. What conditions are optimum for storing these crops ? What is the moisture content of the crop, the temperature condition, the rate of ventilation, used for this kind of root crops? And if we know the optimum environmental condition, how much different is that from the ambient condition that they are now stored at in the shed or outdoors? Do you have to provide some drying, or do you have to provide some cooling? How much drying has to take place after a crop is harvested? How far down do you have to take the moisture content? And then, how does this compare with the actual environmental conditions that you are storing it under natural temperature conditions? Will the moisture continue to go down, or will it go up again?

Dr. Ghosh :

With cassava and sweet potato (we shall confine ourselves mainly to those two) the moisture content is in the region of about 60%. For safe storage, the moisture has to be reduced to a value of about 12% to 14%, so there is a considerable amount of water which has to be got rid of for storage in chips.

Prof. Stephanson :

In other words, once you get the temperature down to 12% or 14% it will stay at that. You don't have to provide any more drying.

Dr. Ghosh :

No. It will stay at that provided that you have a certain minimum amount of air flowing through the material.

Prof. Stephanson :

In other words if the air is dry enough it won't add moisture to the material.

Dr. Richardson :

What was the source of energy to move the air through this experimental set up? And what temperature did you use for air that was pumped through the dryer?

Dr. Ghosh :

This is very much of a laboratory experiment, and therefore how much it cost us to heat the air is not of primary importance. We used electrical heaters, and the air was moved by electrically operated plants. The drying temperature was in the region of 75° to 80°C.

Dr. Richardson :

Did you take any information on the economics of drying under this system?

Dr. Ghosh :

Not at this stage of the work, but drying is usually carried out at those temperatures. But when we try to convert these figures into actual drying, then we have to consider what is the best source of getting that heat (of heating them). It may not necessarily be electricity. It is very unlikely that in most countries it will be electricity.

Dr. Richardson :

Just one brief question. What is the use of these dried chips of cassava, sweet potatoes and yams in Uganda?

Dr. Ghosh :

In Uganda, as Dr. MacDonald has pointed out yesterday, we have a peculiar situation where cassava is of no use really. In the second paper which I shall be presenting a little later on today, I have tried to describe a use for this cassava, which is in excess of requirements normally. And it is being used for the production of starch.

Mr. Gooding :

The last speaker has asked the question which I was going to ask. What was the ultimate fate of this material intended to be, because I have serious doubts as to whether it would be suitable for use as human food dehydrated, because when you dehydrate a piece of potato ¾" thick you never, never rehydrate it into its form again. But of course, if it is to be made into starch it makes sense.

Dr. Ghosh :

Some of the materials of dried sweet potatoes and cassava is converted into flour, and three-quarters of an inch is somewhere near the standard that is used.

Dr. Jeffers :

I would like to known how optimistic you are about the commercial possibilities of dehydrating root crops — not necessarily as a source of starch but possibly as flour or meal for use in human food or as stock feed.

Dr. Ghosh :

Personally I think that there are a lot of root crops, like any other crops, which, having been grown, is wasted because of bad storage and bad processing. And when we take an overall picture of how much malnutrition and hunger there is in the world, it is a shame to have to grow something and throw it away. If we can establish an industry, economically by which root crops can be converted into flour and then used, there is no reason why it cannot be done. In the actual economics of it, I would not suggest for one minute that we do anything like what I have done for commercial use. The source of energy in most of these cases, should be solar, and as most of these crops are grown in tropical countries where solar energy is available, we are, in fact, trying to develop a programme for studying the use of solar energy in the drying of these crops.

Mr. Wilson :

I would like to ask if there is any direct experimental evidence to substantiate the statement that to ensure even drying in a deep bed it is necessary to invert the material, it's extrapolation in this paper as I see it. I'm not asking this so much as a quibble, but from the practical difficulty as agitation of the type of material used with the root crops.

Dr. Ghosh :

Yes, there is experimental evidence and there is also practical and commercial evidence, in saying that. In East Africa itself a lot of even high quality coffee is dried mechanically, and almost invariably there is a means by which the crop is inverted. Because if you do not mix the materials well, you are creating a condition whereby the whole crop is likely to be spoilt. There will be too much heat at the bottom, and too little heat at the top and you will spoil the quality completely.

Dr. Maner :

Just a comment. I think that his studies here indicate the necessity of using less deep or shallower layers of drying material and possibly that a flow type drying apparatus, if you are using artificial energy, such as petroleum, heat not using sun, this might be indicated since your particle size and your exposure of your particle to drying in the entire surface, will determine the length of drying and energy required.

Dr. Ghosh :

That is correct, and I think that if one is using deep drying, one should restrict to about 18" to 20", not very much more than that , because you are going to use too much extra energy for the same drying effect with a deeper depth.

Chairman :

Thank you Dr. Ghosh.

POST-HARVEST PROBLEMS OF THE YAMS (*DIOSCOREA*)

— *by* —

D. G. Coursey
Tropical Products Institute, England.

Introduction.

Yams are major food crops in many tropical countries. The name "yam", although often applied to other tropical "root" crops, such as the sweet potato, correctly refers to the edible tubers of members of the genus *Dioscorea,* the principal genus of the family. Dioscoreaceae of the monocotyledonous Order, Liliales. The principal edible species are:—

D. alata L.	The Greater, Water or Winged Yam	(S.E. Asia)
D. rotundata Poir.	The White or Guinea Yam	(W. Africa)
D. cayenensis Lam.	The Yellow of Guinea Yam	(Africa)
D. opposita Thunb.	(=*D. batatas* Decne) The Chinese Yam	(China)
D. esculenta (Lour.)	Burk. The Lesser Yam (often known as Chinese Yam)	(S.E. Asia)
D. bulbifera L.	The Aerial or Potato Yam	(Africa and Asia)
D. trifida L.	The Cush-cush or Yampi	(Tropical American)

but numerous other species are utilized for food to a minor degree (Cobley, 1956; Coursey, 1965; 1967 b; Waitt, 1963). Other species are of use for the production of steroids for pharmaceutical use.

World production of food yam is of the order of 20 million tons/annum, about half of this total being derived from the "Yam Zone" of West Africa — a belt extending over both high forest and Guinea savannah country from the central Ivory Coast to the Cameroon mountains — and the remainder from various parts of S.E. Asia, India, Indonesia, Oceania and the Caribbean area.

Like many other tropical food crops, yams are still cultivated largely by peasant farmers, in individually small quantities, using manual methods. Although some varieties of yam are capable of yielding heavily — 10 tons/acre or more— under these conditions yields are often poor, at about one to three tons/acre. The cost of yam production, in terms of labour requirement is also exceedingly high, when compared, say, with that of potato production in Europe. Few figures are available, but those in Table 1 (a) and (b) illustrate this point well:—

Table I. (a) Costs of Yam Production

Country	Labour Requirement Man-hours/ton	Animal-hours/ton	Reference
Nigeria	360	—	Brown (1931)
Ghana	440	—	Hunter and Danso (1931)
Ghana	456	—	Bray (ca. 1958)
Trinidad	280	20	Paterson (1942)

Table I. (b) Costs of Potato Production.

Country	Labour Requirement Man-hours/ton	Animal hours/ton	Tractor hours/ton	Reference
United Kingdom (average)	14.5–16.0	—	?	Clift (1966)
United Kingdom (ideal)	7.6	—	3.2	"
Poland (small-holders)	33	15	—	Sackiewicz (1966)
Poland (state farms)	20.4	4.6	1.7	"

Yam production, using existing simple techniques involving negligible capital investment, is thus economic only where the labour force is prepared to accept a very low standard of living, which it is becoming progressively less prepared to do. It may be noted that in Trinidad, where yams have long been a staple food, they can no longer compete in price with potatoes imported from Europe during the greater part of the year (Chapman, 1965). It appears likely that a similar situation could develop in West Africa in the near future, as already, yams in urban markets in both Ghana and Nigeria fetch a price comparable with that of potatoes in Europe.

If yam production is to continue to be feasible in the changing socio-economic matrix of the present day, much needs to be done, in the improvement of cultural techniques, the selection and breeding of better strains ,and other agricultural changes, and in particular, mechanisation. These topics are beyond the scope of this paper.

However, in addition to the problems of actual economic production, there are a number of post-harvest problems connected with yams, which affect the economics of their use for food. These problems have to date received much less attention than their magnitude appears to warrant. The main object of this paper is to indicate some of these problems, and a few of the major lines of investigation in this field that can profitably be investigated. These fall conveniently into the main headings of storage, transport and processing.

Storage.

The majority of textbooks of tropical agriculture which mention the subject of yam storage at all, state merely that "yams store well", with little if any comment. There is a modicum of truth in this statement, in so far as yams can be kept for long periods without elaborate precautions or pest control measures, under the conditions of a tropical peasant's farm, without total loss occurring. Nevertheless, the few experiments which have been conducted to date (e.g. Anon, 1937: Gooding, 1960; Coursey, 1961) all indicate that very substantial losses in weight occur during storage, even when the tubers are not afflicted by any form of decay. These weight losses, although arising in part from simple water loss by transpiration, also involve a major destruction of dry matter—i.e. of food material—as a result of the natural metabolic processes of the dormant tuber. The respiration of this organ, although naturally slower when in the dormant condition than when active growth is taking place, appears still to be extremely rapid, in comparison with that of other "root" crops, such as the potato or sweet potato. The few experiments so far conducted on the use of respiratory inhibitors to reduce this high respiration rate have met with little success, although similar techniques have worked well with the potato. Gamma irradiation is another possibility, which has not been investigated, so far, in the case of the yam.

In addition to this high natural rate of loss, a number of storage rots are known (Dade and Wright, 1931; Baudin, 1956; Okafor, 1966) to affect yams. Amongst them, *Botryodiplodia theobromae* Pat. appears to be the most widespread, but several others, *Rhizopus, Fusarium, Hendersonula, Macrophomina* and *Penicillium* spp. among the fungi, and a bacterium believed to be *Serratia* sp. have also been reported. Although it is known that several types of storage decay are of major economic importance in connection with yam storage, much further work needs to be done on the incidence of the various biodeteriogens responsible, in different species and varieties of yam, and in different parts of the world, and on the correlation of visually distinct types of rot with specific organisms.

The yam tuber in store is, of course, a living organism, and its storage behaviour is therefore likely to be modified by factors giving rise to physiological stress. Adequate ventilation is a primary essential in successful yam storage, in order that oxygen be available for the metabolic processes of the tuber. Extremes of heat and cold can also disturb the metabolism. It is commonly supposed throughout West Africa that exposure to the sun adversely affects the storage behaviour of yams; it is known that when so exposed, the internal temperature of the tubers can reach 45° or even 50°C (Coursey and Nwankwo, unpublished work), which temperatures may well be high enough to induce biochemical lesions, comparable to the defect "black heart" of potatoes. Reduced temperatures also, although they result in lowered respiration rates (Coursey *et al,* 1966) also appear to produce some form of irreversible change at about 5°C. Such "chilling damage" is well known in the sweet potato (Lauritzen, 1931; Cooley *et al,* 1954) and many other tropical crops, but is only currently receiving detailed investigation in the case of the yam (Coursey, unpublished work), although first reported some time ago (Anon 1937; Czyhrinciw and Jaffe, 1951).

The post-harvest effects of nematodes—essentially a field pest—are but little understood, although the interactions of the lecions caused by these organisms with fungal invasion have long been recognised (West, 1934). A preharvest disease, believed to be caused by a virus, has recently been reported in Barbados as causing lesions in the tubers which become progressively more severe during post-harvest storage (Harrison, 1966). The available information on yam storage has recently been reviewed in detail elsewhere (Coursey, 1967 a).

Transport

Problems of transportation are, to a degree, linked with storage problems, in that, during transport, produce may often be exposed to unfavourable storage conditions. In the case of yams, these usually take the form of inadequate ventilation, or of undesirably high or low temperatures. The breakdown of the yam tissue caused by the stresses so induced appears to lead to invasion by rotting organisms to a greatly enhanced degree, and to susceptibility to attack by a wider range of organisms than normal. The mechanisms concerned are not, however, fully understood as yet.

Transport of yams in their natural condition is a basically difficult operation. Being in most species large and irregularly shaped they are difficult to pack conveniently or effectively. They contain a high proportion of water (ca. 60% to 75%) and a substantial amount of waste (ca. 15% to 20%) in the form of peel and unpalatable "heads". Thus, only a quarter or less of the bulk transported represents actual foodstuff, and that food is predominatly carbohydrate i.e. food of low nutritional quality. The large size and awkward shape of the tubers also renders them very liable to mechanical damage during transport, especially when transported by road and the damage inflicted can lead to enhanced decay. Nevertheless, on account of the strong attachment of the peoples of certain ethnic groups to yams, rather than alternative carbohydrate foods, very substantial quantities of yams are transported for long distances, especially in West Africa, even though it has been estimated (Hill, 1966) that in urban markets in this region, about a third of the price of the yams represents the cost of transport. The build-up in European countries, especially Great Britain, of immigrant populations derived from areas which are traditionally yam-eating, has stimulated a considerable international trade in yams. The problems arising in this trade, especially in terms of the market diseases associated with adverse holding conditions during transit, require urgent attention. Some investigations in this field have recently been initiated at the Tropical Products Institute.

Processing

In most parts of the world where yams are grown, the manufacture of some form of "yam flour" occurs in traditional culinary practice. The techniques of preparation vary somewhat in different districts, but consist essentially of cutting the yam tubers into slices, drying the slices in the sun, often after an initial parboiling process, and grinding the hard, dry pieces so formed with a mortar and pestle or, in more recent times, with a corn mill. The resultant flour, dried to a moisture content of a few percent, can be stored almost indefinitely, although it is liable to attack by insects and rodents.

Similar techniques, following prolonged soaking or boiling of the tubers, can be used to manufacture edible products from many of the toxic species of yam, and this is commonly done in times of famine (e.g. Corkill, 1948). The toxicity of many of the *Dioscorea* is due to alkaloids of the *dioscorine* type, which are water-soluble, and are so removed by this processing.

To date, processed food products based on the yam have been manufactured only on the domestic scale. One attempt to manufacture a form of yam flour in Western Nigeria on a small industrial scale was not successful, although this failure was due, at least in part, to the use of aluminium vessels for the parboiling process, which caused a browning reaction to take place in the yam giving rise to a dark coloured, unacceptable product. In India, as part of a campaign to alleviate food shortage, the semi-industrial processing of wild toxic yams (*D. hispida Dennst.*) into an edible flour has been proposed, and an outline for the process given (Rao and Beri, 1952).

Owing to the low moisture content of the product, the fact that peel, etc. has been eliminated during the processing, and the durability of the product, considerable reduction in transport costs of actual food material could be achieved if acceptable dehydrated yam products were readily available, especially in urban markets. Proposals for improvements in yam flour production, on a semi-industrial scale, and also for the small scale industrial manufacture of more sophisticated dehydrated products, based on traditional West African culinary practices have recently been put forward (Coursey, 1966). No very serious difficulties are envisaged in the development of such processes, although further studies of the rheological properties of the food products are needed, if the texture of the processed and reconstituted product is to correspond sufficiently closely to that of the well-known domestic product to be acceptable, in such conservative market.

It has been shown (Rasper and Coursey, 1967) that there is substantial variation in the viscous and other properties of the starches between different species and varieties of yam, which are reflected in the texture of food prepared from them.

Another aspect of the processing of yams that requires further study is the technique of peeling the large, irregularly shaped tubers by other than manual methods. Experiments on cassava—whose rhizomes are similarly shaped to many yams—have shown that when peeled by tumbling with water in a rotating drum, the peeling loss is as high as 25 to 30 per cent, and a number of small areas of skin remain, which need to be removed manually. Recently, however, it has been found (Matthews, 1966) that in the case of the long cylindrical tubers of *D. rotundata,* successful peeling, with a loss of only 15 per cent, may be achieved by chopping the tubers into pieces approximately equal in length to their diameter, and peeling in a normal rotating disc type potato peeler.

Packing of the processed product in insect-proof containers such as polythene-lined sacks, which is desirable for marketing reasons, would automatically lead to greatly enhanced storage life.

Suggestions have been made at different times for various industrial applications of yams, such as the production of power alcohol by fermentation, (Cook, 1927) and of surface-active additives for stabilizing the froth of beer (Hollo, 1964) while small quantities of yam starch sometimes appear in international trade under the name of "Guyana Arrowroot". However, the high cost of production of yam compared with that of other carbohydrate materials appears likely to preclude the use of yams for industrial applications, other than the manufacture of specialized food products, on any extensive scale.

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DISCUSSION

Chairman :

The meeting is open for discussion.

Prof. Stephanson :

The question I have is on the matter of storage and it is really somewhat connected with the first paper. In your paper you mentioned the tremendous loss or some losses during storage due to evaporation and also some high temperatures. I would gather that if this yam could be kept at a lower temperature in a condition where is would not lose its moisture it may result in a higher quality. Is this true?

Dr. Coursey :

The high temperatures which I have mentioned were recorded in West Africa in conventional type of driers which consists mainly of hanging the yams up on an open wooden framework. There is certainly little doubt that if the yam can be conserved at lower temperatures both the loss of water and the respirational losses of dry matter could be reduced. This is one of the things on which I am working at the moment. I might mention that it is a strong condition in West Africa in the yam growing areas, that yam in store should be shaded from the sun, and this yields very strong results.

Prof. Stephanson :

Has this ever been tried to use a spray cooler to increase the humidity of the air and lower the temperature and blow this through the stored yam?

Dr. Coursey :

This has never been tried as far as I am aware. It certainly might be worth trying but one of the troubles of course is, can material which is only carbohydrate bear the costs of expensive and sophisticated storage techniques?

Porf. Stephanson :

This would require a pan of some kind to move the air but the spray cooling would be done very easily.

Dr. Coursey :

Yes.

Dr. Iton :

Mr. Chairman, in your opening remarks you said that we, as scientists, could dream and build what we like, but sooner or later we have to come to reality and the practical problems. Both yesterday afternoon and this afternoon I heard speakers referring to the tendency on the part of people who live away from their original homes to persist in buying imported food. And one of the root crops which certainly comes into this category is the Irish potato. Some people said it has snob value; maybe it does. I think that here we have to grapple with a really serious economic problem. I should say it has exercised my mind, privately, as to whether all this talk we are having about increased food crop production in the tropics is as sound as it appears to be. I often wonder if we would not do better to expend less money in buying things like Irish potatoes and things which don't spoil which cost less on the market here than most of our locally produced root crops.

I make this comment in view of the original comment you made and the statement made by Dr. Coursey, that some people will continue to pay exhorbitant prices for imported foods. We must bear in mind that these foods are not always more expensive than locally produced ones.

Dr. Coursey :

My feelings about the shipment of yams from one country to another are rather stimulated perhaps by the absurd situation I observed in West Africa of ships coming out bringing potatoes for Europeans living in West Africa and going back with yams for West Africans living in Europe. Well, I cannot help feeling that either this is a very exceptional substitute for the other.

Dr. Maner :

I think that what is being discussed here, is also true with many other root crops in other areas of the world. But isn't this true that it is not because it cannot be produced more economically, but it is because of agronomic practices that are presently being employed, does not allow for a more economic production and therefore it has to be sold at a higher price. I know that in Colombia such exists with cassava, which we refer to as yuca, because on the market yuca is very expensive. It is not because yuca is so difficult to grow, but because it is consumed only by a very few people basically and its supply is expensive and the market is limited. There are I think if we can increase the demand for yuca (cassava) — I think if we can increase the production and utilise it in other things, then the price of these root crops will be lowered, much lower than we can bring in food from outside.

Chairman :

Are there any more economical questions? We can delay them until later.

Dr. Martin :

It is a common practice among native people to store some of their root crops in the soil mainly by not harvesting them and as the yams come into maturity at the beginning of the dry season, it may be that conditions in the soil are particularly favourable for storage over a period of time — 2 or 3 months' time. Have you got any idea what happens to the yam under such conditions and perhaps if the yams do not deteriorate so rapidly in the soil, then by studying the natural storage in the soil we can learn a little bit more about storage conditions.

Dr. Coursey :

From a scientific point of view, it will be most interesting to investigate this type of storage practice. This practice is followed to some extent in most parts of West Africa. I have the impression that very serious deterioration of yams in the soil takes place, but what perhaps is more important is the great danger of surreptitious harvesting, shall we say, or even another kind of storage pest — harvesting by monkeys, which is not unknown in some areas and also I think the human race is a more serious pest than the monkey; but both can be quite severe and this practice, though it is still adopted, is certainly tending to decline in favour of hanging in racks in the open under shade. It certainly is a scientific point of view.

RECENT DEVELOPMENTS IN THE MANUFACTURE OF STARCH FROM CASSAVA ROOTS IN UGANDA

— by —

B. N. Ghosh

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The cassava is an important root crop throughout the tropics, and it is cultivated extensively by the peasant farmers as a source of starchy food and as a famine relief crop. Both the "bitter" and "sweet" varieties of cassava are grown in East Africa under varying soil and climatic conditions. Due to its high starch content it is considered suitable as a raw material for the manufacture of industrial starch, and in the present paper the broad details of a starch-extraction plant being set up in Uganda to supply the local market is described.

The results of a market survey indicate that the pre ent annual East African consumption of starch and glucose is of the order of 1500 and 1200 tons respectively. These figures, however, are likely to increase to 2400 and 1600 tons respectively by 1970. The bulk of the present demand is met by imports, notably from Europe and Far East and by a small plant in Kenya producing manioc starch. The Uganda plant would, in the first instance, manufacture only starch from cassava, although the possibility of starting glucose production at a later date is under investigation.

In considering the extraction of starch from cassava, the effects of maturity on the yields of cassava tuber and starch, the presence of poisonous prussic acid, enzyme action and the relative advantages of procuring raw cassava either from peasant farmers or from a plantation crop specially grown for the purpose is discussed. The results of a laboratory analysis carried out on a sample of locally grown cassava is given.

The background to the establishment of the Uganda plant and the viability of the starch project is discussed. It is felt that Government protection from imports would be necessary for the first few years to enable the plant to break even financially. The details of the modern extraction process to be followed is given, along with the specification sheet of the product to be manufactured.

The cassava plant (*Manihot esculenta* Crantz), also known as *ubi kettella* or *kaspe* in Indonesia, *manioca, mandioca* or *yuca* in Latin America and *manioc* in Madagascar (Holleman and Aten 1950), is second in importance only to the sweet potato as a root crop throughout the tropics (Cobley 1956). Of South American origin, it is now grown in every tropical country, including E. Africa, where it is believed to be introduced by the Portuguese (Vesey-Fitzgerald 1950). It is grown either as a famine relief crop or processed in various ways to form traditional articles of food, while due to its very high starch content, it is also considered suitable as a raw material for the production of industrial starch. The present article describes the plant being set up in the Lango District of Uganda for this purpose.

The cassava belongs to the Euphorbiaceae family, with over 150 known species of this genus (Cobley 1956) and a large number of varieties are known to exist in East Africa (Nichols 1950). Cassava varieties can be classified either as "bitter" or "sweet," the former containing the poisonous prussic acid. In the starch-extraction plant being set up in Uganda, the supply of raw material in the first instance would be by peasant farmers only, and hence a large number of varieties are likely to be included.

Cassava is propagated almost exclusively by vegetative means from stem cuttings, approximately 10 in long. It requires a warm humid climate and in tropical regions some varieties grow at altitudes of up to 5500 ft. It is usually planted at the beginning of the rainy season either as a single crop or inter-cropped with maize, legumes or vegetables. The crop is ready for harvest from about 10—12 months onwards, although Nigerian experience indicate a growing period of 22—24 months (U.S. AID 1965). The effect on yields of harvest at other than optimum age is discussed later. Harvesting is a manual operation: stems are cut and the roots pulled or dug by hand, sometimes with the help of a simple implement like a crowbar (Holleman and Aten 1950), although fairly elaborate harvesting equipment for a possible plantation crop for the Uganda plant is being considered (Fig. 1—2). Krochmal (1966), in a recent article has described some of the machinery used in South America in the farming of cassava.

East African market for cassava starch

A survey of the East African market for starch, modified starch, dextrin and glucose was carried out in June 1964 (Patel 1966), in order to establish manufacturing facilities for some or all of these products at the Lira plant in Uganda. An annual production rate of about 1000 tons of starch is envisaged in the first instance with effect from 1967, and the production of glucose at a later date is under consideration. In view of the low level of local consumption of dextrin it has been omitted from the present production programme.

The estimates of market size for starch (Table I) are based on information provided by the principal endusers. The annual average growth rate in the demand for starches is also estimated to be 12%, leading to a demand of some 2400 tons by 1970.

Table I. East Africa: current annual starch requirements of the principal consuming industries

Industry	Quantity (Ton)	Percent of Total
Textiles	1140	76
Paper/packaging	250	16
Bags and cordage	100	6
Laundry	25	2
Total	1515	100

Source : *East Africa: The market for starch, modified starch and glucose.* Marketing Section, U.D.C., Kampala.

The principal sources of supply for starches at present are Europe, Indonesia and a plant in Kenya with an annual production of 400—450 tons of manioc starch. The imported starches are maize starch, sago and modified starch. The delivered price in East Africa varies widely between £32 to £130 per ton, while the Kenya produced starch sells at £35 per ton.

Glucose, a by-product in the production of starches, is used in East Africa mainly by the confectionery industry, and to a very limited extent by the pharmaceutical industry. Present annual consumption are 1200 and 13 tons respectively. The confectionery industry's demand is likely to rise to about 1600 tons per annum by 1970. The principal sources of supply for glucose is Europe, at a c.i.f. Mombasa port price varying between £45—58 per ton.

SOME BASIC CONSIDERATIONS IN EXTRACTING STARCH FROM CASSAVA

Optimum starch content

From the standpoint of starch production, the most profitable planting time is at the beginning of the wet monsoon, and harvesting either before or after the optimum age may lead to a loss of starch content to the extent of 40% or more (Holleman and Aten 1950). Fig. 3 shows the effect of maturity on the yields of cassava tuber and starch.

Poisonous acid

Cassava tubers contain a highly poisonous prussic acid, both in the free state and in a chemically bound form; when the cells are crushed the latter is set free through enzymic action. The amount of acid varies from a few mg up to 250 mg per kg of the fresh root. The presence of prussic acid is easily recognised by a 'bitter' taste, but the 'sweet' varieties may also contain appreciable amounts of acid which is not easily recognised. Most of the acid can be got rid of, however, during the processes used for the extraction of starch.

Time lapse between harvest and processing

Cassava should be procured within relatively short distances from the processing plant to allow processing within 24 hours after harvesting, and also to avoid excessive transport cost. If the tubers are left unprocessed for any length of time, enzyme action occurs in the cassava root and reduces the quality and yield of the starch.

Plantation crop vs. procurement from farmers

Procurement of the cassava from peasant farmers is likely to be more cumbersome and costly than a plantation crop specially grown for processing to extract the starch. The former needs proper arranging and scheduling of harvest and a possibly higher cost of transport from the farms, as they may not be located near by. Further, without a plantation crop being available as an alternative source of supply, the farm prices are unlikely to be stable.

Analysis of cassava chips

A laboratory analysis of locally available cassava was carried out to ascertain the percentages of the various constituents (Anon 1963). Circular discs, 5—8 mm in thickness were obtained by slicing the root perpendicular to the longitudinal axis. The chips were predominantly dead white in colour with occasional traces of coloured impurities on the root surfaces (faint yellow). The chips were free from coloured surface moulds, adhering soil and sand particles and also free from extensive 'browning' products as were displayed by sun-dried untreated whole roots. Milling to a fine powder gave a bright white flour comparable in brightness to a superior grade potato or maize starch. The flour had a faint pungent odour characteristic of all cassava flours.

ANALYSIS

Moisture	—	13.6 %		
Ash	—	0.31%		
Surface sand	—	nil		
Water soluble material	—	4.3 %	(d.b.)	
Soluble reducing sugars	—	0.16%	(„)	
Ether solubles	—	0.39%	(„)	
Crude Fibre	—	1.93	— 2.35%	(d.b.)
Starch	—	93.4 %		(„)
Nitrogen	—	0.48%		(„)
Ferricyanide Number	—	2.08%		(„)

Mass composition balance :

Starch	—	80.8 %
Fibre	—	1.8 %
Water solubles (ash, soluble sugars and most of the nitrogen containing constituents)	—	3.7 %
Ether solubles	—	0.3 %
Moisture	—	13.4 %
	Total :	100.0 %

THE STARCH FACTORY AT LIRA

Background

The Lango Development Company Ltd. was formed as a subsidiary of the Uganda Development Corporation Ltd. in November 1962 for commercial utilization of the large surplus cassava crop grown as a famine reserve in the Lango District of Uganda. The three-fold programme of work set up for the Company is (a) to process and export dried cassava roots and chips, for which there is a substantial market in Western Europe, the object being to build up a regular and substantial flow of cassava from farmers and co-operative societies; (b) to manufacture other cassava products like flour, animal food stuffs, starch and starch derivatives for which there is an assured but limited domestic market in E. Africa; and (c) to investigate the feasibility of manufacturing fuel alcohol for local use (Anon 1963).

Viability on the starch project

A viability study of the starch project was carried out during early 1966 to determine the future cash requirements of the L.D.C. and to decide whether Government protection from imports should be sought (Anon 1966). An analysis of capital and operating costs, profitability and estimated cash flows indicated that at current prices and envisaged rates of production, the company is likely to run at a loss for the first 6 to 7 years. The Uganda Government is being approached to provide necessary protection to the industry from imports for the duration of this period.

Plant description and flow-sheet

The starch extraction plant at Lira is designed to carry out the following sequence of operations, shown diagrammatically as a flow-sheet in Fig. 4.

(a) *Root cleaning* : The cassava tubers are prewashed to separate the coarse soil and then passed through a combined washing and peeling unit.

(b) *Grinding and washing* : The peeled tubers go through a selecting conveyor to remove damaged or diseased tubers, before being ground to a pulp by a mill equipped with scraping and breaking rotors. A generous addition of raw starch milk water, obtained from the process at a later stage (e), is fed to the pulping mill so that the fibrous material present in the pulp is left undamaged. The pulp is then washed before being passed through a wet, fine mill for fine-grinding and separating the starch grains. The free, milky, starch grains are re-washed on a counter-flow bed, while the pulp obtained from fine-grinding is pressed and sold as provender, after sun drying on open concrete floors.

(c) *Refining sieving* : The washed milky material is then pumped over a Rostant-sieving machine to separate the fine fibres from the starch milk. The extracted fine fibres are re-washed to separate further quantities of starch grain, and the cleaned starch milk is led over parallel, coupled, special, Rostant sieves to the separators.

(d) *Separation and concentration* : The processed starch milk, freed to a great extent from the fine fibre, is then passed through a multi-stage separator. In the first stage, a further amount of washing is carried out and the gluten is separated, during which the starch milk of about 3°Be is concentrated to about 10°Be. It is important to separate the gluten quickly and effectively in order to avoid decolorization of the starch. By adding fresh water, the starch milk is diluted to about 5°Be before being passed through the second stage of the separator, where a concentration up to about 21°Be is obtained.

(e) *Starch pre-desiccation* : The starch milk concentrate of about 21°Be has a dry substance content of about 415 kg/1000 litres. It is passed through a dewatering centrifuge, equipped with automatic, discharging devices and control gear for timing the charging and centrifuging operation, to reduce the water content to about 37%. The water freed by the centrifuge is repassed to the washing process (b) mentioned earlier.

(f) *Starch drying:* The starch output from the centrifuge is led by a worm conveyor to a pnematic rapid dryer, which reduces the final moisture content to a value between 10 and 13%. Drying is effected by hot air, produced by a set of 3 special oil burners working on atomized burning principle, and compressed air. The burners are designed for the food industry and they burn with a gas-like flame which does not contaminate the starch in anyway, provided a special grade of extra light oil is used. The required quantities of fresh air is sucked into the hot-air generator through an air filter and heated to about 150°C. During the drying process, the starch is pneumatically conveyed from the bottom to the top of the drier and then deflected downwards. Starch particles which are not quite dry are returned to the drying unit located at the bottom, while the dry starch is separated in the cyclone from the conveying air, and is led through a rotary pocket seal, by means of a worm conveyor, into a starch powder sifter equipped with two exchangeable screens. The first sifter has a 100 mesh screen and the second a 140 mesh screen. The resulting starch powder which is of high purity and fineness, is then packed in bags, weighed, and the bags sealed. The dried starch powder failing to pass through the sieve is treated by an attrition mill to grind the powder to the required size.

Sulphuric acid required for the starch production is obtained by burning raw sulphur in a sulphur burning installation consisting of a kiln, air filter, compressor, sublimator, water coller and gas absorption column. The acid is added to the process mentioned above during the stages (a) and (c).

Plant power-consumption and capacity

The total motor-capacity of the plant, required to drive the various machines, is about 24,000 kw. The total water consumption is of the order of 40 cubic meter/hour (24 cu. ft/min.) and the total sulphur consumption 0.8 kg/hour for a maximum starch capacity of 7.5 tons/24 hours.

The plant is designed to produce approximately 5 tons of cassava starch daily with a final moisture content of 10-13%, working on a two-shift basis of 16 hrs/day. The starch content of the cassava tubers varies between 18 and 36%, and affect the amount of tuber treated per day (Fig. 2). The plant can also be operated on a continuous 3 shifts/day basis, thus increasing the output to 7.5 tons/day or approximately 2,100 tons/year.

Starch specification

The analysis of the final product to be manufactured should be as follows:

Appearance	:	Low speck count, clean odour, uniform white colour although a trace of yellow colour would be acceptable for average requirements.
Mesh	:	99% to pass through 100 mesh screen 95% " " " 140 " "
Moisture	:	10—13% maximum
Ash	:	0.35% maximum
Pulp	:	0.8% "
Protein	:	0.4% "
pH	:	4.5 to 5.5
Acidity	:	2.5 ML of N/10 acid to reach pH 3.0 for a 25 gm sample.
Viscosity	:	(a) Inherent viscosity (one point) 2.80 — 3.00 (fresh roots). Inherent viscosity (one point) 2.40 — 2.60 (processed dry roots). (b) Corn Industries Viscometer: Fresh root, at maximum peak, at least 270 gm/cm; less in viscosity on holding at 92°C for 15 min. Less than 35% of max. value. Concentration 4% (dry basis).
Sulphur dioxide	:	Less than 45 p.p.m.
Speck count	:	5 cm sq. decimeter—min. 100.

Cassava starch of the quality mentioned above is also suitable for the production of glucose, dextrose, couleur and dextrin.

Acknowledgement:

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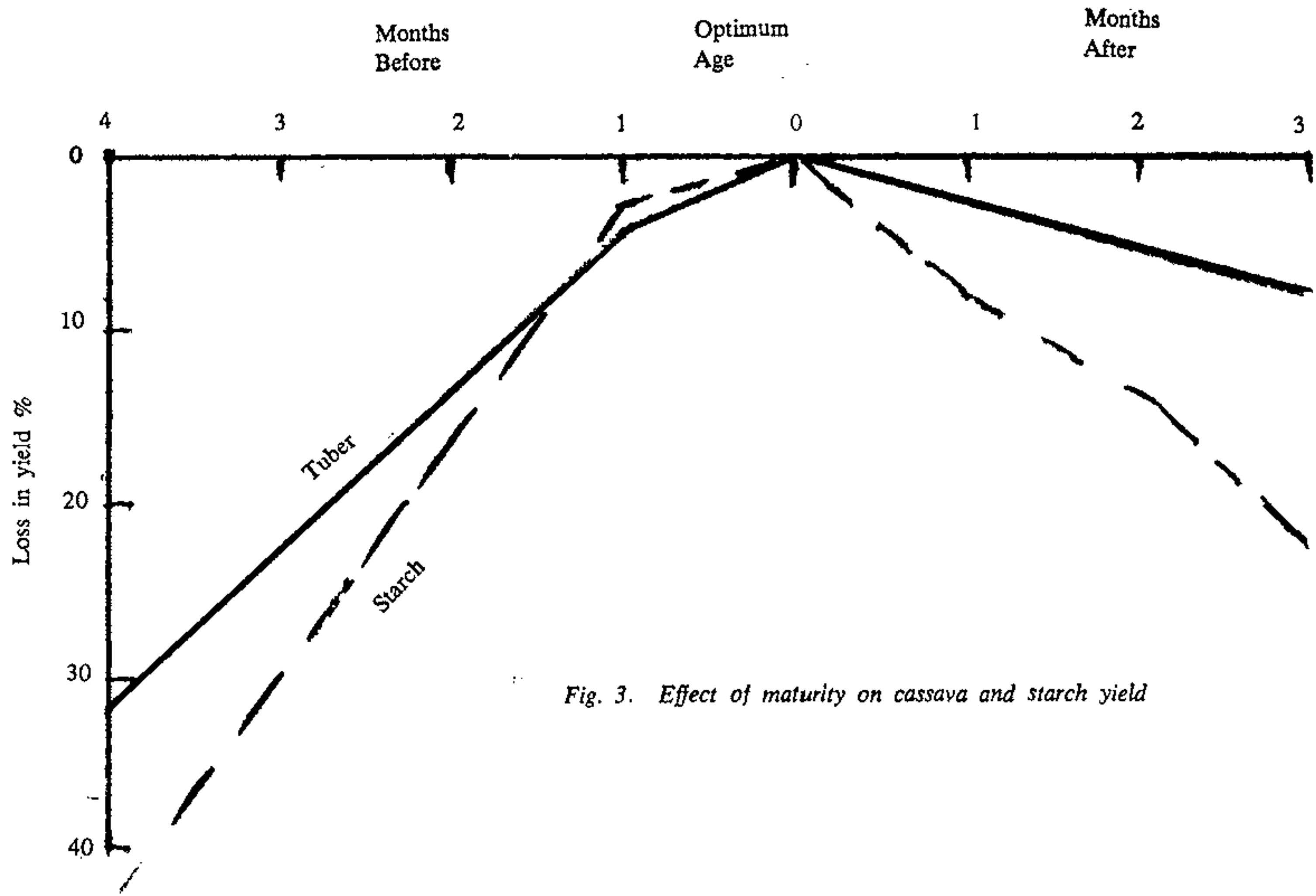

Fig. 3. Effect of maturity on cassava and starch yield

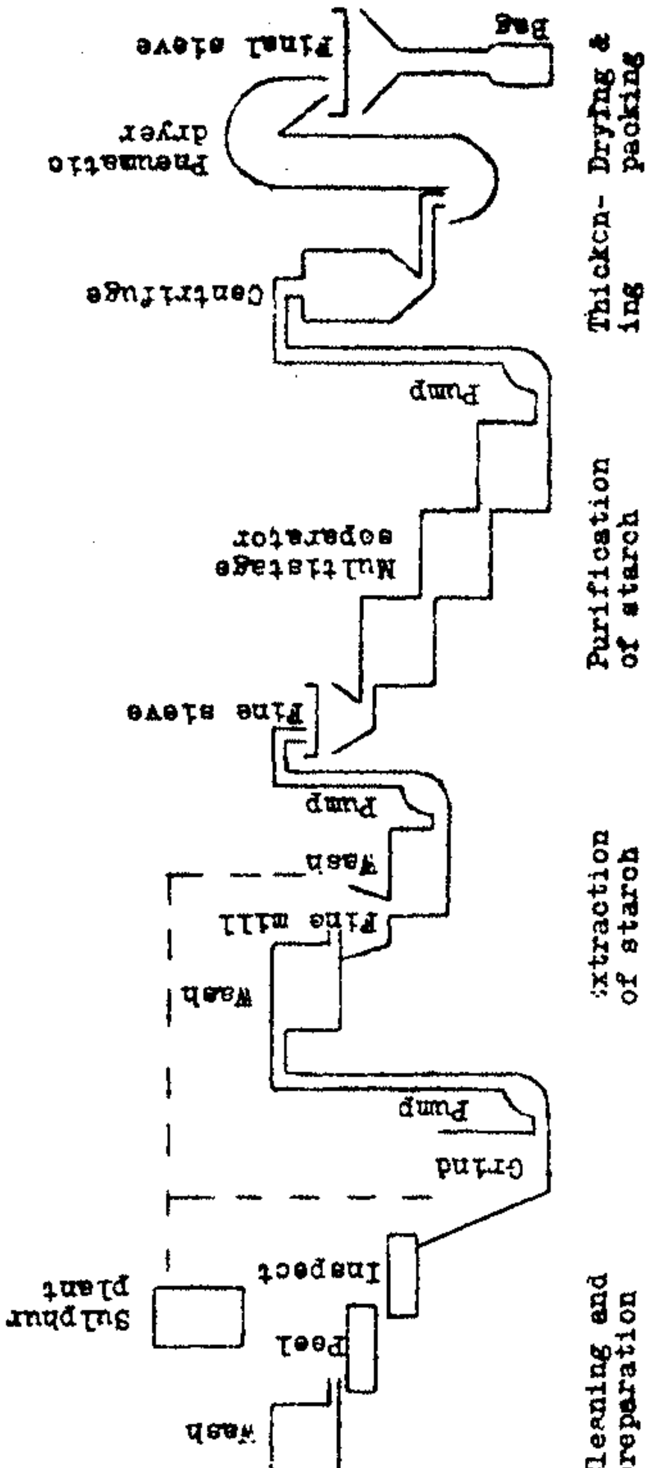

Fig. 4. Flow sheet for manufacture of cassava starch

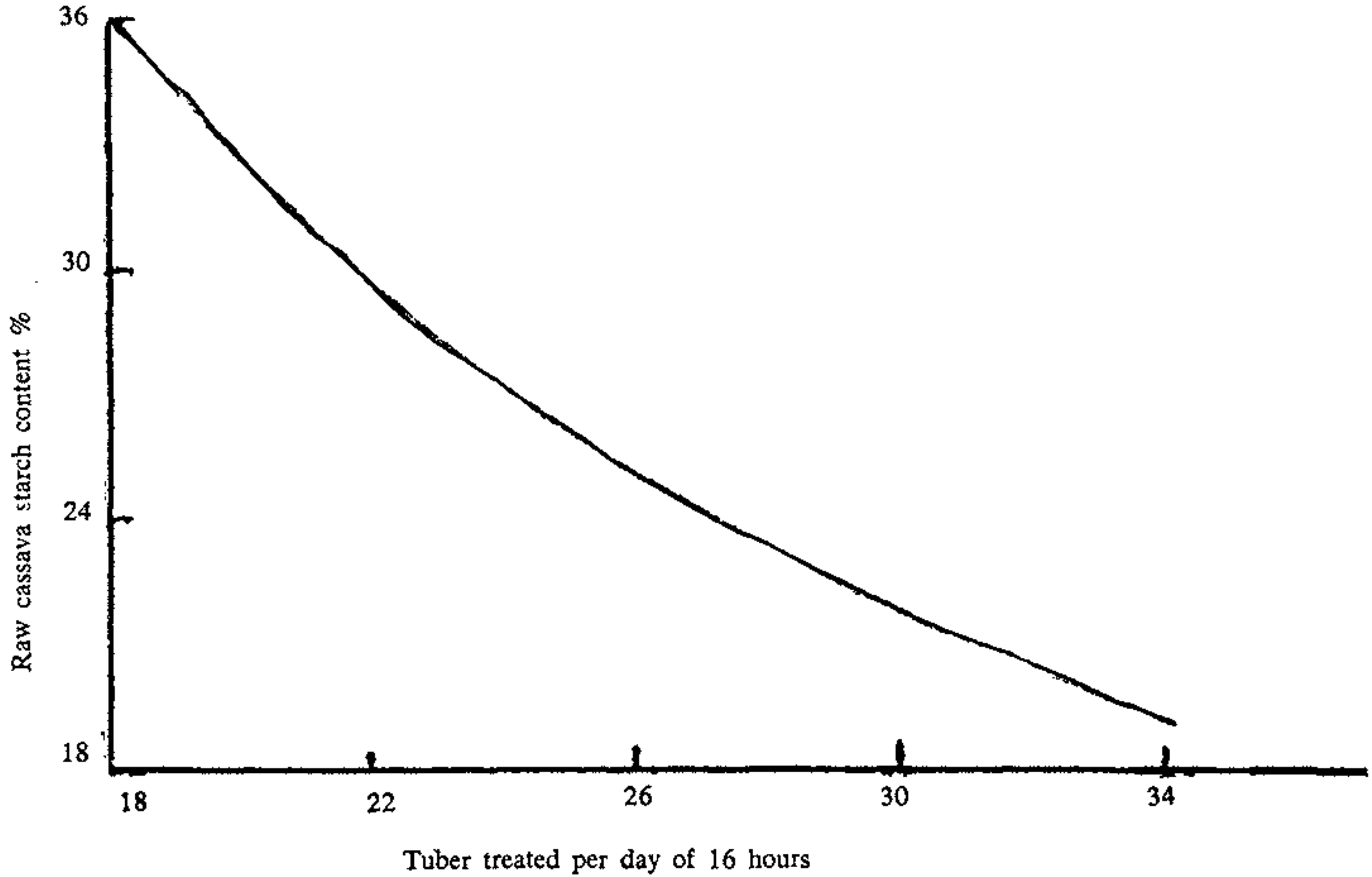

Fig. 5. Effect oj cassava starch content on quantity treated per day.

INVESTIGATIONS ON STARCHES FROM SOME WEST AFRICAN ROOT CROPS

by

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Starch crops including the starch root crops, play a very important role in the diet of the West African population. Hitherto, they have been utilised in this area almost entirely for the preparation of food at the domestic level. Therefore, in spite of their importance as tropical food crops, comparatively little is known about the properties of their starches. In general, very little information is available in the literature on the properties of those starches which have not been of any commercial use. However, with the development of food processing industries that is beginning to take place in West Africa much more detailed knowledge of the technological qualities of the materials processed is needed. Recently, a project on the mechanisation of the processing of a very popular traditional West African dish — fufu — has been started in Ghana and this project attracted attention to the study of the rheological properties of starches prepared from starchy materials used for fufu making. The general aim of this study was to find out whether there is any relationship between the quality of the final product and the qualities of the starches involved in the process of fufu making.

In the traditional way, fufu is prepared by pounding peeled and boiled yam, cassava or cocoyam tubers or plantain fruits either alone or as a mixture in a wooden mortar until an elastic and somewhat glutinous dough is formed. Yams *(Dioscorea L)* are preferred for fufumaking — especially in the yam zone of Africa — as it is believed that yam fufu is the most palatable, having the optimum texture. Amongst the other starch crops which can be used for fufu pounding, the most serious competitor of yam is cassava. The displacement of yam by cassava has been accelerated during the last ten years mostly as the result of increasing urbanisation in West Africa with the concomitant evolution of the urban proletariat, creating a higher demand for the cheapest food even if it is less acceptable and less nutritious (Coursey, 1965). On the other hand, recent dietary surveys made in Ghana suggest that the so called new cocoyam *(Xanthosoma sagittifolium)*, the cormels of which are also used for fufu making, is now less common in diets than it used to be. It is, however, still a very important starch crop, typical for the forest area, whereas the so called old cocoyam *(Colocasia esculenta)* is grown to a small extent, chiefly by the older people. As the old cocoyam cormels become too soft when boiled, they are quite unsuitable for pounding fufu (Irvine, 1961).

Finally, the last starchy material used in fufu making is the fruit of plantain. The fruits of some cultivars contain a considerable amount of starch. To complete the study of starches present in materials used for fufu making, the results of the investigations on plaintain starches have been included in this paper, in spite of the fact that plantains do not belong to the class of root crops.

Except from cassava starch which is commercially used, very little is known about starches of all other crops mentioned. Up to now, some attention has been paid to the study of *Dioscorea* starches, since yams are food crops of major importance in many tropical countries, most notably in West Africa, the Caribbean area, and parts of South-East Asia and Oceania. The most important yam species in West Africa is the indigenous *Dioscorea rotundata* Poir (White Guinea Yam), which exists in a very wide range of cultivars. The Asiatic *D. alata L.* (Water Yam), introduced to West Africa some hundreds of years ago, is also fairly widely grown as well as *D. cyanensis Lam.* (Guinea or Yellow Yam). In West Africa these three species predominate and account for at least 95 per cent of the total production (Coursey, 1965). In addition, *D. bulbifera* L. (Potato of Aerial Yam), *D. esculenta* (Lour.) Burk. (Chinese Yam) are also grown to a very limited extent while a number of wild species, e.g. *D. dumetorum* Pax., are only occasionally collected for food.

Both white and yellow yams are generally used for fufu making, while water yams are generally not used for this purpose; they are considered of poorer quality than either white or yellow yams.

The starches of several Asiatic species have been described in a series of articles by Rao and Beri (1952, 1955, 1964, 1965). Of the species discussed, only *D. alata* and *D. bulbifera* are cultivated in West Africa. The starch of *D. esculenta* as grown in the Ivory Coast has been figured by Miege (1948) and the particle size distribution given. A later paper by the same author (Meige, 1957) describes briefly some investigations on the starches of *D. cyanensis* and *D. alata* grown in that country. Single samples of each of the major West African species grown in Nigeria, have been described in an unpublished report by Greenwood-Barton (1961); this report includes studies with the Amylograph on the viscosities of the starches, and notes very considerable variation between species. An amylogram and some other data for *D. opposita* Thunb. starch are given by Hollo (1964). A recent review article by Seidemann (1964) illustrates the microscopical structure of a number of *Dioscorea* starches, and also gives some data on their viscous and other properties. The information on other starches concerned is far more limited.

The present study describes an examination of some rheological properties of the starches prepared from the representatives of the major West African *Dioscorea* species, from several cultivars of old and new cocoyams and from several cultivars of plantain. One starch sample was prepared from the tubers of *Coleus dysentericus* Baker, var. nigra Chev. (Salaga or Fra-Fra Potatoes). (This plant is grown as a food tuber in the savannah part of tropical Africa. In Ghana, it is grown in the northern part; the tubers are either boiled and eaten alone or cooked in soup). The amylose content of these starches have also been investigated. The study has been completed by microscopic examination of individual samples.

MATERIALS

Most of the *Dioscorea* tubers used in these investigations were grown on the University Farm at Legon, a few miles north of Accra. The last two varieties of *D. rotundata* were collected at Ejura about 200 miles northwest from Legon. The species and varieties studied were :

D. rotundata var. "Puna"
var. "Labreko"

var. "Kplinjo"
var. "Tantanpruka"
var. "Tempi"

D. alata
D. esculenta
D. dumetorum

Two local cultivars of *Xanthosoma sagittifolium*, two local cultivars of *Colocasia esculentum* and seven local cultivars of plantain were grown at the Agricultural Research Station, at Kade, about 80 miles north of Accra. The tubers of *Coleus dysentericus* var. *nigra* Chev. were collected from a private farmer in the Northern Region of Ghana.

Some well-studied starches were used as standards for comparison : two samples of corn starch, white potato starch and cassava starch prepared from *Manihot utilissima* var. Ankra.

The starches were prepared by peeling the tubers (with plantains by peeling the fruits), grating, extracting with water and allowing the starch to settle out. The soluble impurities were removed by repeated washings and settlings in water. Some difficulty was experienced in obtaining the starch from *Dioscorea* tubers which on grating produced very sticky and mucilagineous pulp (*D. rotundata* var. "Kplinjo," *D. alata* and *D. esculenta*). Because of the very high viscosity of the slurries prepared from these tubers, the settling velocity of the starch granules was very low and the settling process took a very long time. In the case of *Dioscorea dumetorum* and *Colocasia esculentum* the starch granules were so small that centrifuging instead of settling was necessary to separate the starch. Starch after purification was carefully dried at temperatures not exceeding 35°C.

METHODS

The consistency of starch pastes referred to as "viscosity" during the entire course of the gelatinisation process was derived from curves obtained by means of the Brabender Viscograph, using the following procedure : A weighed amount of starch equivalent to 25.0 g. dry weight was suspended in 450ml. of distilled water at 25°C, and the suspension poured into the measuring vessel of the Viscograph. The viscosity was recorded at a constant rotational velocity of 75 r.p.m. using the 500 cmg. measuring box with the temperature rising uniformly at 1.5°C/minute. After reaching a temperature of 95°C the starch paste was maintained at this temperature with constant stirring for a further 30 minutes; after this "holding period" the paste was cooled uniformly at 1.5°C/minute for a further 30 minutes, i.e. until the temperature reached 50°C. The viscosity was expressed in Brabender Units (BU).

The *pasting temperature* was read off from the viscosity curves as the temperature at which the viscosity started to rise. This pasting temperature is often referred to as gelatinisation temperature; this, however, is incorrect as the starch granules start to gelatinize before this point is reached. The pasting temperatures obtained with different samples are relative only since it has been shown that the pasting temperature depends on the concentration of the suspension (Pagenstedt, 1951).

The *gel strength* was measured using F.R.I.A. Jelly Tester on starch gels prepared as follows Starch equivalent to 25.0 g. dry weight was suspended in 450 ml. distilled water and starch paste was prepared from this suspension using Brabender Viscograph (as described above) to ensure constant heating and stirring conditions. As soon as the paste reached its maximum viscosity, the heating and stirring was continued for a further five minutes. Similar samples of starch gels were prepared by heating the starch pastes for twenty minutes at 95°C. The samples thus prepared in the form of a hot solution were poured into boxes (5 x 5 x 6.25 cm.) and allowed to set at an ambient temperature of 25°C. To prevent evaporation and consequent skin formation, a thin film of liquid paraffin was poured on to the surface of the paste. The strength was tested after a period of 2, 4 and 7 days and was expressed as the number of mls. of water required to be run into the counterpoised bucket of the Jelly Tester to bring about 10° and 20° rotation of the spade immersed in the gel. The iodine absorption and *amylose content* were determined by an amperometric titration according to Hollo and Szejtli (1956) taking the theoretical iodine absorption of pure amylose to be 26.1. Other determinations were done according to A.O.A.C. methods.

RESULTS

The results of viscosity measurements, characterising the gelatinisation process of individual starches are summarised, together with data on gel strengths in Tables 1, 2 and 3.

No great differences were observed among the viscosities derived from the viscograms of *D. rotundata* starches; the maximum viscosities ranged between 600 and 780 BU, except for starch extracted from vat. "Tantanpruka," yielding a paste of relatively very high viscosity (895 BU), which ranked second to white potato starch only. On further heating and stirring after attaining the maximum viscosity, the pastes thinned down only slightly so that the curves had no distinct peaks. On cooling, however, the viscosity increased very distinctly which indicated the formation of a very firm gel. The strength of gels prepared from these starches varied with the source of the starch, being relatively very high when compared with other starches examined. With the samples of gels prepared from var. "Tempi" and "Kplinjo" by boiling the pastes for 5 minutes after attaining the maximum viscosity, the retrogradation after 4 days standing was observed followed by a very distinct decrease of gel strength.

The pasting of *D. alata* starch resulted in a paste with considerably lower viscosity (410 BU) when compared with *D. rotundata* starches. However, the gel produced from this paste was of an exceptionally high gel strength and of a very"brittle" nature, so that it was not possible to avoid splitting the sample by the rotating spade of the F.I.R.A. Jelly Tester when the samples were tested after more than 4 days standing.

A slightly higher viscosity was shown by paste prepared from the *D. esculenta* starch (500 BU), while *D. dumetorum* starch yielded paste of an extremely low viscosity (180 BU). This starch did not form any gel, the strength of which could be measured under the given conditions.

The transition temperatures of all *Dioscorea* starches at the concentration given ranged from between 77 and 83°C.

Xanthosoma sagittifolium starches produced pastes less viscous than

D. rotundata, D. esculenta or cassava starches, but more viscous than corn starch pastes. The viscosity curves at given concentration have the same character as the curves of *Dioscorea* starches; there is no distinct decrease of viscosity after attaining the maximum viscosity. The gels have roughly the same gel strength as the corn starch gels. Unlike the *Dioscorea* starch gels, the strength of these gels does not show any measurable increase on standing. Heating the pastes for 20 minutes after the attainment of maximum viscosity did not increase the gel strength; a very slight decrease was observed. The viscosity of *Colocasia esculenta* starch pastes was very close to the viscosity of corn starch pastes; the strength of the gels produced from this starch, however, was very low.

The starches of all the cultivars of plantains examined did not show any significant differences either in viscosity of gel strength. The maximum viscosity ranged between 550 and 730 BU, which is relatively very near the range of the viscosities of *D. rotundata* starches. The pasting temperatures of all the starches under given conditions lie betwen 75.5°C and 77°C. The gels have been found to be in the range as the strength of gels prepared from *D. rotundata,* var. "Puna" and "Labreko."

The results of chemical analysis of starches are given in Table 4. These results indicate that samples were of sufficient purity for further investigations. The starches of very small particle size (*D. dumetorum, C. esculenta*) were found to have relatively higher "non-starch" content than other samples. This was presumably caused by difficulties in the separation of the starch granules from the slurry, resulting in incomplete removal of the impurities.

The starches examined vary in the proportion of amylose as shown in Table 4. Evidently, gel formation is facilitated by the presence of amylose. However, it would be very difficult to find out any general relationship between the amylose content and the theological properties of starches from various botanical sources, since the amylose content is only one of the many factors affecting these properties.

The results of the microscopic examination of the starches are summarised in Table 5, which includes a brief description and the results of granules size measurements.

CONCLUSIONS

The rheological properties of the starches extracted from several West African starch crops, grown in Ghana, have been investigated. Considerable variations between the different *Dioscorea spp.* (yam) have been found. The indigenous West African *D. rotundata* with large granules (the longitudinal diameter of the granules varies from 35—50 u, the majority being about 40 u), and the Asiatic *D. alata* (the diameter of the granule varies from 17—26 u), form gels of considerable strength, but the viscosity of the starch of the former species is much higher. The starch from *D. esculenta* and wild species *D. dumetorum,* both with very small granules (1—5 u and 1—3 u respectively), produce gels with lower strength, the latter being so soft that no measurement could be taken.

The viscograms of all *Dioscorea* starches at the concentration given have the same character. After attaining the maximum, the viscosity does not fall appreciably, even when the solutions are heated for 30 minutes at 95°C on constant stirring. In this respect, the *Dioscorea* starches resemble corn and rice starches and differ from cassava and white potato starches.

The viscograms of cocoyam, plantain and *Coleus* starches have also the same character. The paste, prepared from *Coleus* starch is found to be relatively very viscous; the gel formed resembled the white potato gel. The plantain starches are found to be very near the range of the viscosity of corn starch. The gels prepared from cocoyam starches do not change their consistency appreciably during the period of seven days, thus resembling the corn starch gels.

All these results, however, must be taken as relative, since the course of gelatinisation depends on the pretreatment of the starch, the rate of heating, the pH of the suspension and many other factors.

The *Dioscorea* starches, except from those prepared from *D. esculenta* and *D. dumetorum*, have been found to have relatively high amylose content when compared with other starches. This explains the very high increase of the viscosity of the pastes on cooling, since amylose facilitates the gel formation. Any unambiguous relationship between the amylose content and the intensity of gel formation with all the samples can hardly be expected, as other factors affecting the process of gel formation must be considered.

As far as the relationship between the quality of fufu and the rheological properties of the starch present in the material used is concerned, it has been shown that there must be some other factors, too, which determine the suitability of the plant for fufu making. For example, no significant differences have been found between plantain starches. Nevertheless, some of the cultivars investigated are preferred, while some cannot be used for fufu making at all. These other factors involved are the subject of further study.

Table 1. Rheological Properties of Dioscorea Starches

Sample	Viscosity in BU					Gel Strength/mls/											
	Pasting temperature °C	At 95°C	Maximum viscosity	At the end of the 'holding' period	At the end of the 'cooling' period	Boiled 5 minutes after attaining the maximum viscosity						Boiled 20 minutes at 95°C					
						2 days		4 days		7 days		2 days		4 days		7 days	
						10°	20°	10°	20°	10°	20°	10°	20°	10°	20°	10°	20°
Dioscorea rotundata																	
var. "Tantanpruka"	79.5	895	895	870	1430	10.0	21.1	14.6	23.6	20.5	32.8	10.5	19.5	15.5	24.0	22.0	33.5
" "Kplinjo"	78	640	780	780	1520	15.2	23.0	11.8	16.2	——	——	17.9	27.0	22.0	34.0	23.3	39.2
" "Tempi"	80	740	740	620	1180	11.3	19.5	11.6	18.8	11.7	18.5	12.0	20.0	15.0	24.0	19.5	31.0
" "Puna"	77.5	730	750	705	1310	9.5	17.2	13.0	23.5	18.0	27.0	10.2	18.5	13.6	23.8	19.0	29.0
" "Labreko"	78	550	600	540	1010	5.7	11.2	7.7	14.5	9.5	16.7	6.2	14.5	10.1	18.0	11.3	22.2
Dioscorea alata	83	250	410	410	600	18.5	27.8	28.6	50.2	**	**	20.0	29.5	30.0	54.0	**	**
Dioscorea esculenta	78.5	415	500	510	670	——	——	6.3	14.5	7.5	15.7	6.9	13.5	8.3	15.7	9.2	17.0
Dioscorea dumetorum	82	180	180	185	210	*	*	*	*	*	*	*	*	*	*	*	*

(*) The strength was too low for any measurement.

(**) The sample was too brittle to avoid splitting in measuring.

Table 2. Rheological Properties of Plantain Starches

Sample	Viscosity/in BU/					Gel Strength/in mils/					
						Boiled 20 min. at 95°C					
	Pasting temper-ature °C	At 95°C	Maxi-mum visco-sity	At the end of the hold-ing' period	At the end of the 'cool-ing' period	2 days		4 days		7 days	
						10°	20°	10°	20°	10°	20°
Cultivar "Soboaso"	76.5	550	550	475	700	6.7	14	8.5	16.6	9.2	15.2
"Csabum"	77	580	620	540	810	9.1	15.9	10.0	18.0	11.0	20.0
"Assamiensa"	77	490	565	540	740	8.8	17.8	9.2	19.2	10.3	20.5
"Apantum"	77	480	585	570	730	9.8	17.5	10.1	19.0	12.0	25.0
"Brodewio"	77	480	520	515	710	8.6	16.7	10.7	17.1	11.0	20.0
"Assamienu"	75.5	600	630	585	860	8.7	16.5	10.0	17.0	11.8	20.5
"Onieba"	77	595	730	660	900	10.0	18.0	13.3	22.0	14.1	25.2

Table 3. Rheological Properties of Various Starches

Sample	Pasting temperature °C	Viscosity in BU: At 95°C	Maximum viscosity	At the end of the 'holding' period	At the end of the 'cooling' period	Gel Strength/in mls/: Boiled 5 minutes after attaining the maximum viscosity: 2 days 10°	2 days 20°	4 days 10°	4 days 20°	7 days 10°	7 days 20°	Boiled 20 minutes at 95°C: 2 days 10°	2 days 20°	4 days 10°	4 days 20°	7 days 10°	7 days 20°
Xanthosoma spp. I	78	370	380	330	610	8.0	13.3	9.0	14.5	—	—	7.0	13.2	7.0	13.5	7.0	13.0
,, ,, II	82.5	360	360	340	650	8.2	14.5	8.4	16.6	8.6	16.6	7.5	14.0	7.4	15.8	7.5	15.6
Colocassia spp. I	77	220	260	260	420	2.7	4.4	3.6	7.5	2.9	5.8	2.2	5.0	3.0	5.4	Liquified	
,, ,, II	76	160	160	140	200	—	—	—	—	—	—	1.8	3.6	1.7	4.0	Liquified	
Coleus dysenterious	74	760	770	715	930	4.5	—	5.2	—	5.8	—	—	—	—	—	—	—
Corn +	84	200	210	190	280	7.5	13.6	7.9	14.7	7.5	14.7	8.0	15.5	8.3	15.5	8.3	15.6
Corn ++	85	250	290	265	370	8.0	14.0	8.5	14.0	9.0	14.2	9.5	17.0	9.2	17.0	9.6	17.0
Cassava	69	540	630	280	440	1.8	3.5	2.0	3.6	2.0	3.6	*	*	*	*	*	*
White potatoes	63	1920	1180	460	580	6.2	11.8	6.0	12.8	6.1	12.0	*	*	4.6	3.0	1.7	3.4

(+) The sample was kindly supplied by Hercules Powder Company, Inc., U.S.A.

(++) The sample was kindly supplied by Corn Products (Sales) Ltd., Great Britain.

(*) The strength was too low for any measurement.

Table 4. Chemical Composition of Starch Samples Investigated

Species and Variety	Water %	Ash %	Ph	Protein (N x 6.25) %	Iodine Absorption	Amglose %
D. rotundata var. "Puna"	17.9	0.26	6.9	—	6.5	24.9
var. "Labreko"	16.7	0.30	6.4	0.14	6.1	23.0
"var. "Kplinjo"	18.6	0.17	7.3	0.14	6.6	25.3
var. "Tantanpruka"	16.8	0.19	7.5	0.07	6.3	24.0
var. "Tempi"	16.7	0.19	7.4	0.05	6.0	23.0
D. alata	18.2	0.26	7.2	0.16	5.9	22.4
D. esculenta	16.8	0.46	6.2	0.08	4.0	15.3
D. dumetorum	16.5	0.30	4.4	1.55	3.9	15.0
Xanthosoma sagittifolium I	16.5	0.22	5.9	—	6.0	22.9
— ,, — II	15.4	0.19	—	—	6.1	22.4
Colocassia esculentum I	16.6	0.81	6.4	—	3.8	14.5
— ,, — II	17.4	0.92	5.8	—	3.9	14.9
Coleus dysenterious	15.1	0.27	6.5	0.12	5.7	22.0
Corn +	7.4	0.21	6.5	—	4.7	18.0
Corn ++	14.0	0.29	5.9	—	5.2	19.9
White potatoes	17.4	0.38	6.8	—	5.5	21.0
Cassava	14.8	0.32	7.2	—	5.1	19.5
Plantain, cultivar "Soboaso"	15.6	0.21	6.9	—	5.1	19.5
"Osabum"	16.8	0.17	7.3	—	5.4	20.7
"Assamiensa"	15.2	0.29	6.6	—	5.3	20.3
"Apantum"	18.0	0.23	6.8	—	5.7	21.8
"Brodewio"	16.2	0.19	7.0	—	5.4	20.7
"Assamienu"	16.4	0.25	7.1	—	5.8	22.2
"Oniaba"	18.8	0.22	6.9	—	5.9	22.8

Table 5. Microscopic Characteristics of Starches Investigated

Species and Variety	Granule shape	Granule size	
		Length	Width
D. rotundata var. "Puna"	long-oval, mostly flattened at one end (sack shaped)	52 (20 — 70)	23 (10 — 35)
var. "Kplinjo"	long-oval, mostly sack-shaped some granules slightly bent	43 (15 — 55)	26 (10 — 35)
var. Tantanpruka	long-oval (some sack-shaped) or rounded-triangular	40 (20 — 50)	27 (15 — 35)
var. "Tempi"	rounded-triangular or oval	35 (15 — 45)	25 (10 — 35)
		Diameter	
var. "Labreko"	shell or pear shaped	40 — 50	
D. alata	irregular, oval or eliplical very few rounded-triangular	17 — 26	
D. esculenta	polyhedral, mostly compound	1 — 5	
D. dumetorum	very small, polygonal	1 — 3	
Xanthosoma sagittifolium	round shaped	9.3 (2.8 — 22)	
Colocasia esculentum	very small, round shaped	9.3 (0.6 — 3.3)	
		Length	Width
Plantain	long-oval, or pear shaped, oval	27 (5 — 50)	12 (28 — 33)

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DISCUSSION

Dr. Magoon :

I wish to make the following comments:—

1. You have indicated in your paper that cassava is definitely of South American origin, but have given no data to support your conclusion. On the other hand, Rogers (1963) proposed that cassava first became an important element in the diet of low-land tropical people, somewhere in the Meso-American complex, and was distributed from there to other parts of its present day range. This proposal is well supported by sound arguments.

2. You have pointed out that the genus **Manihot** contains over 150 species. I do not know what makes you so sure that each one of them deserves the rank of a species. Although there are certain 'species' groups in the genus, the species are very difficult to delimit taxonomically, because, as pointed out by Rogers, hybridization occurs and recombination of characteristics destroys sharp delimitations among many of the so-called species. The progress of speciation among forms of the same group, is comparatively weak, so that related species are connected by intergrades. Considerable amount of work will be required in this genus, before one is in a position to categorically state the number of species it contains. Only a few 'species' have so far been used in the breeding programme, and, in fact, very little is known to the breeder concerning the various other wild forms, in spite of the fact that the genus is a large one.

3. You have emphasised that cassava tubers contain a highly poisonous prussic acid in the free state. What evidence do you have, if any, to support this statement? As far as I know, the living plant probably contains no free prussic acid, but like other members of the Euphorbiaceae, it exudes latex from small sacs beneath the peel or bark, when it is cut or bruised. The latex contains a cyanogenetic glucoside that begins to break down into prussic acid, acetone, and glucose, once the plant is harvested. The prussic acid is present in roots, branches, and leaves of the plant, after they are harvested in quantities that vary from harmless to lethal. It is highly soluble in water, and is reported to get decomposed when heated to a temperature of 150°C. The freeing of prussic acid from the glucoside appears to be accomplished by the action of linase — an enzyme which is present in the growing plant — and hydrolysis, under the influence of linase can be speeded up by soaking the roots in water, by heating, by cutting or grafting them, since it facilitates contact between enzyme and cyanogenic glucoside. The enzyme, linase, has been shown to get destroyed above the temperature of 75°C. and therefore, great care must be exercised in keeping the temperature below 75°C, in preparing cassava products. Hardly anything definite is known regarding the toxicity of cassava roots, and the influence of external factors on it, and much more critical work will have to be done before the effect of soil, climate, age of the plant, moisture, temperature, altitude, potassium deficiency etc., which have been shown to influence prussic acid content, by different workers, can be fully acceptable to all.

4. The next point is optimum starch content. If the graph shown here is taken into consideration, it appears that no consideration is made of the time whereby the maximum period of starch content will be available in the tuber. Actually experience has shown that there is a considerable variation in the starch content at various stages of the tuber and the maximum period of starch content is really from variety to variety. Apart from this, potassium has shown to have considerable effects on the formation of carbohydrates. Even though potassium is not a constituent of carbohydrates, it appears to play a part in the creation of tubers, starches and cellulose. So such factors have not been taken into consideration in drawing this graph. Probably it has been taken only on one variety.

Dr. Ghosh :

I am indeed thankful to Dr. Magoon for pointing out these various things. As I do not profess to be an expert on cassava, by any means. We have had discussions on the subject, and what I have tried to do here is to show what we are doing in the industrial stage. I take his criticism about the number of species with an open mind. My knowledge is on the books I have read or which I have available, and if that is wrong there is no question asked about it.

Going back to the graph showing the optimum age and the effect of maturity of cassava on starch, I think if the graph is looked at carefully it is self-explanatory. It does not refer to any particular variety, but I think that I am right in saying that it applies to a large number of varieties. Similar studies, if carried out, will show that as you move away from the optimum stage, either minus or plus, you will lose in the yield. Therefore, this graph is only an indication as to the importance of establishing the optimum age of the varieties which are under consideration. It is not for a particular variety.

Mr. Doku :

Could you describe the peeling unit in a bit more detail, because I believe that peeling could affect the efficiency of production of starch?

Dr. Ghosh :

Unfortunately I forgot to mention this, but I have a few photographs with me of the plant. Most of the photographs were not very successful, and if you are interested, I can show them in much more detail to you.

Mr. Kennard :

The information you gave concerning this plant is of considerable interest to us, because we were looking into the possibility of manufacturing cassava starch as a substitute in the refining process in bauxite. What is of interest to me is the fact that the plant will operate for six to seven years at a loss. Could you give me some information as to the cost of establishing such a plant?

Dr. Ghosh :

I am afraid that this is going to be a very tricky question to answer, because the Uganda government, who is responsible for it is not particularly keen to show how much they are losing. I think that this is more of a political project than an economic one, and it is difficult to answer this question.

Dr. Maner :

Just one comment. In Colombia there is a pilot plant being run by the United Starch Company from the United States, and I understand that they did not decide to go into commerical production because of the excessive cost of producing starch.

Prof. El Mohandes :

Going back to the project, it would be successful to establish a plant in your country, providing that you do not import starch from outside. In other words, you have to have protective measures because the competitive prices between corn starch and other starches are very high, and tuber starches cannot compete with the modified starches of corn, so before you think, you have to take these protective measures. One statement in that paper said that they had to have protective measures in Uganda, because the South East Asian production is so deep that nobody can compete with it. Corn starch is cheaper because it is produced for five cents a pound. The cost of production is five cents a pound and that is very cheap.

UTILIZATION OF YUCA IN SWINE FEEDING

—*by*—

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The ever expanding world population demands a continued interest in increasing the quantity and quality of food produced to feed these new generations and to reduce the widespread pains of malnutrition that exist among much of the present population. The development and expansion of an animal industry must take this fact into consideration, and every attempt must be made by animal nutritionists to reduce competition between the human and animal population for available protein and energy sources.

Swine require large quantities of energy and moderate quantities of protein for their growth and development. In the leading pork producing countries of the world there exist large supplies of grains that are available for animal feeding. In other countries the annual production of all classes of grains is not great enough to satisfy the needs of existing human population ; however, many of these countries have the potential or are already producing large quantities of other food sources that are available for livestock feeding if they can be incorporated into efficient and economical rations.

A good example of an energy source that has great potential in many countries is *Manihot* or in more common terms yuca or cassava, whichever is preferred. Large quantities of this crop are now being produced and future potential feeding and especially in swine rations is limited. Experimental results reported by Oyenuga and Opeke, (1957) and Modebe, (1963) of West Africa indicate that up to 50 to 55% of the diet of growing-finishing pigs can be supplied by either wet or dried yuca. Noland, *et al,* (1957) from very limited data suggest that pigs will grow well when fresh yuca is included in the diet but must be fed a controlled quantity protein supplement in order to prevent over-consumption.

The utilization of yuca, basically a carbohydrate source with very little protein, in swine feeding requires that special attention be given to protein, vitamin and mineral supplementation, to toxicity caused by the presence of hydrocyanic acid, and to feeding management. Therefore experiments were conducted to study these factors of protein, vitamins, minerals and feeding management as they are related to yuca utilization by the pigs.

PROCEDURE AND RESULTS

The yuca utilized in the studies was a mixture of several varieties commonly used for human consumption and was produced at the Palmira Experiment Station of the Colombian Agricultural Institute (ICA). The fresh yuca utilized was harvested two or three times weekly to prevent spoilage. After harvest the yuca was washed to remove the adhering soil and chopped daily as it was needed. Yuca for the first studies was chopped by hand using a large knife (machete) ; a soil shredder was later utilized for chopping. The yuca meal utilized was produced by drying the chopped yuca at 180°F in a forced-air oven for 24 to 36 hours.

The yuca and protein supplements of all studies utilizing fresh, chopped yuca were fed in automatic metal feeders and all yuca not consumed within 24 hours after feeding was collected, weighed and discarded.

Experiment 1.

Fifteen weanling Duroc pigs weighting an average of 18.1 kgs. were used in an experiment with a completely randomized design. The pigs were maintained on pasture which was equipped with a shade over a concrete slab. Automatic feeders and waters were used. The rations fed were (1) a basal diet of corn, soybean meal, cottonseed meal, bone meal and vitamin-trace mineral premix; (2) raw, chopped yuca *ad libitum* and a protein supplement also offered *ad libitum,* and (3) raw, chopped yuca *ad libitum* and a protein supplement fed in quantities sufficient to supply the pigs minimal daily requirement. The composition of the basal diet and the protein supplement are presented in Table 1. Upon analysis the basal diet contained 19.81% protein and the protein supplement contained 42.88% protein (Table 2). The yuca contained 63.76% moisture and only 1.04% protein.

The performance of the pigs in all lots was very satisfactory and very similar (Table 3). The pigs fed the control diet gained an average of 0.765 kgs. daily during the 112-day experimental period as compared to 0.774 kg. daily gain by the group consuming both yuca and the 42.88% protein supplement free choice. Group 3 which received a controlled amount of protein supplement (average daily intake 0.69 kgs.) gained 0.730 kgs per day. Average daily intakes of fresh yuca was 3.66 and 3.84 kgs. respectively for groups 2 and 3. For convenience of comparison the feed intakes were also calculated on a dry basis . The basal group consumed more dry feed daily and required 11.8% more feed to produce a unit of gain when compared to those receiving yuca and protein supplement.

Table 1. Composition of Basal Diet and Protein Supplement utilized in Experiments Nos. 1 and 2

Ingredients	Basal Diet (%)	Protein Supplement (%)
Soybean Meal	10.59	61.50
Cottonseed Meal	3.53	20.53
Corn	81.33	—
Bone Meal	2.00	7.90
Vitamins-Trace Mineral Premix[a]	2.55	10.07
Total	100.00	100.00

[a] Contributed 2500 I.U. vitamin A ; 250 I.U. vitamin D ; 2.5 mg. riboflavin ; 12.5 mg. niacin ; 7.5 mg. pantothenic acid ; 125 mg. chlorine choloride ; 16.5 mg. vitamin B 50 mg. chloratetracycline ; 51.5 mg. Mn ; 2 mg. Co ; 4. 4. mg. Cu ; and 45.5 mg. Zn per kg. of finished feed in the control diet ; approximately 4 times this amount was added to the protein supplement.

Table 2. Proximate Analysis of Basal Diet, Protein Supplement and Yuca utilized in Experiments Nos. 1 and 2

Analysis	Basal Diet (%)	Protein Supplement (%)	Yuca (%)
Moisture	10.84	8.60	63.76
Protein	19.81	42.88	1.04
Fiber	3.86	4.40	1.06
Ether Extract	4.64	1.67	0.26
Ash	6.57	14.85	0.86
Nitrogen-Free Extract	51.11	20.74	32.02

Table 3. Performance of Pigs Fed basal Diet or Raw-yuca and protein supplement – Experiment No. I

	(1)	(2) Raw-yuca + Supplement ad lib	(3) Raw-yuca Supplement Controlled
		kilograms	
Av. daily gain[a]	0.765	0.774	0.730
Av. daily intake, wet yuca	–	3.66	3.84
Av. daily intake, dry yuca	–	1.33	1.38
Av. daily intake, supplement	–	0.84	0.69
Av. daily intake, supplement[b]	2.40	2.17	2.07
Feed/unit gain	3.13	2.80	2.83

[a] Five pigs per treatment; 112-day experiment; Av. initial wt., 18.1 kg.

[b] Total intake expressed on a dry matter basis.

Experiment 2.

This experiment was a replication of Experiment 1 except that the pigs were housed in confinement. Fifteen weanling Duroc pigs were randomly allotted to the three treatments previously described in Experiment 1. The performance of the pigs (Table 4) was similar to those of Experiment 1. The growth rates of the basal group and the yuca group offered protein supplement free choice were very similar, 0.843 and 0.834 kg. daily gain, respectively. The efficiency of feed utilization was not different for the two groups. The group receiving yuca plus a controlled amount of protein supplement (Lot 3) consumed slightly less wet yuca daily and only 0.67 kg. of supplement daily as compared to 1.06 kg. consumed by the free choice group. As a result this group had 4.7% less daily gain but required 20.5% less total feed to produce a kilo of gain.

Table 4. Performance of Pigs Fed Basal Diet or Raw-yuca and Protein Supplement – Experiment No. 2

Item	Basal	Raw-yuca + Supplement Ad-Lib	Raw-yuca † Supplement Controlled
	....	kilograms	....
Av. daily gain[a]	0.843	0.834	0.794
Av. daily intake, wet yuca	–	4.05	3.89
Av. daily intake, dry yuca	–	1.47	1.40
Av. daily intake, supplement	–	1.06	0.67
Av. daily intake, total[b]	2.58	2.53	2.07
Feed/unit gain	3.05	3.03	2.61

a
Five pigs per treatment; 98-day experiment; Av. initial wt. 17.8 kg.
b
Total expressed on a dry matter basis.

Experiment 3.

Ninety-six Duroc and Duroc-Landrace crossbreed pigs weighting an average of 23.0 kgs. were divided according to weight, sex, litter and condition to 12 outcome groups of 8 pigs each. These outcome groups were then allotted to six treatments, each with two replications. Each group was fed fresh, chopped yuca daily to allow voluntary consumption, and the excess was removed, weighed and discarded each morning before offering additional yuca. It was of interest to compare two basic protein supplements with two levels of vitamin-trace mineral supplementation (Table 5). A combination of cottonseed meal and soybean meal was compared with only soybean meal, both with a normal level of vitamin-trace mineral supplementation and with two times this normal level. Supplements 2 and 4 were offered *ad libitum* and in daily rations calculated to exceed the pigs' daily protein requirements by 10%. (National Research Council, 1964)

Table 5. Composition of Protein Supplements fed with Raw-yuca to growing – finishing pigs – Experiment No. 3

Ingredients/Treatments	(1) %	(2) %	(3) %	(4) %	(5) %	(6) %
Soybean Meal (SOM)	65.00	64.00	90.00	88.00	64.00	88.00
Cottonseed Meal (CSM)	25.00	24.00	—	—	24.00	—
Bone Meal	8.00	8.00	8.00	8.00	8.00	8.00
Vitamin-Trace Mineral Premix[a]	2.00	4.00	2.00	4.00	4.00	4.00
Total	100.00	100.00	100.00	100.00	100.00	100.00

a

Contributed 3 mg. riboflavin; 11 mg. pantothenic acid; 25 mg. niacin; 125 mg. chlorine chloride; 16.5 mg. vitamin B 250 I.U. vitamin D, 2500 I.U. vitamin A; 51.5 mg. of Mn; 4.4 mg. Cn; 2 mg. Co; 45.5 mg. Zn; and 5 mg. chlorate'ra'ycline per kg. of finished feed.

The pigs were grown in concrete lots 2.5 x 8 meters and body weights and protein supplements consumption were recorded at weekly intervals. Yuca consumption was recorded daily.

The performance data for this trial is presented in Table 6. The average daily gains were very similar for all groups fed either of the basic protein supplements free choice. There was no consistent advantage of adding higher than recommended levels of vitamins and trace-minerals. The average gains obtained from the groups fed controlled daily rations of protein supplement were not different between treatments, but were inferior to those produced by pigs receiving *ad libitum* quantities of either supplement.

Average daily intakes of wet yuca were very similar varying an average of only 480 gms. between the highest and lowest daily consumption (3.89 to 3.41 kg.). Higher daily intakes of protein supplement were observed among the groups fed *ad libitum* the combination of cottonseed meal-soybean meal (CSM and SOM) when compared to the groups offered voluntary consumption of the supplement containing only soybean meal (SOM). As a result of this higher daily consumption the CSM and SOM groups required more total feed (yuca and supplement) to produce a unit of gain. Feed required to produce a unit of gain was not different among the S O M groups nor between the groups receiving controlled quantities of either supplement.

Table 6. Influence of protein source and vitamin-trace mineral level of growing –finishing pigs fed raw-yuca ad-lib – Experiment No. 3

Protein	SOM + CSM			SOM		
Vitamin-Trace – mineral Supplement	Normal Ad-Lib	2 x Normal Ad-Lib	2 x Normal Control	Normal Ad-Lib	2 x Normal Ad-Lib	2 x Normal Control
	.... kilograms					
Av. daily gain[a]	0.687	0.657	0.614	0.627	0.661	0.618
Av. daily intake, wet yuca	3.89	3.65	3.50	3.41	3.67	3.60
Av. daily intake, dry yuca[b]	1.38	1.30	1.25	1.21	1.31	1.28
Av. daily intake, supplement	0.83	0.93	0.67	0.70	0.73	0.61
Av. daily intake, total	2.21	2.23	1.92	1.91	2.04	1.89
Feed/unit gain	3.22	3.38	3.10	3.03	3.07	3.06

[a] Sixteen pigs per treatment ; 84-day experiment ; Av. initial wt., 23.0 Kg.

[b] Yuca calculated on 10% moisture basis.

It was observed that pig does an acceptable job of balancing his own diet when offered fresh, chopped yuca and protein supplement *ad libitum*. It was, however, observed that the pig tends to slightly overeat protein when calculated over the entire experiment. This is basically due to excessive consumption during the early stages of the feeding trial. In general, the daily voluntary consumption of wet yuca increases progressively from weaning to market weight, and the daily voluntary consumption of protein remains almost constant over the entire period.

Experiment 4.

It was of interest to measure the performance of growing-finishing pigs fed complete-balanced diets with varying levels of dried yuca. Yuca, chopped in a soil shredder and dried in a forced-air oven at 180°F to a final moisture content of approximately 10%, was substituted for 33.66 or 100% of the corn in the basal, 16% protein, corn-cottonseed meal-soybean meal diet (Table 7), and the protein level equalized in these diets by increasing the level of soybean meal. The level of cottonseed meal was held constant at 7% in all diets to avoid problems of gossypol toxicity. These four treatments were repeated adding 10% cane molasses to increase palatability by reducing the dustiness of diets caused by the powdery nature of the dried yuca.

Table 7. Composition of Experimental Diets – Experiment No. 4

Diet	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	%	%	%	%	%	%	%	%
Dried ground yuca[a]	—	25.72	48.65	69.25	—	21.70	41.04	58.26
Ground yellow corn	81.31	51.43	24.33	—	69.00	43.38	20.52	—
Soybean Meal	7.69	11.85	16.02	19.75	10.00	13.92	17.45	20.74
Cottonseed Meal	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00
Cane Molasses	—	—	—	—	10.00	10.00	10.00	10.00
Bone Meal	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
Vitamin-Trace – Mineral Premix[b]	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00

[a] Dried in forced-air oven at 180° F.

[b] Contributed the same concentration of vitamins and trace minerals as in premix of Table 5.

The summary of performance data is presented in Table 8. Each increase in level of dried yuca caused a corresponding decrease in average daily gain with or without 10% molasses. These decreases in gains were not caused by decreased feed intake as the average daily voluntary consumption among treatments without added molasses was not different. Adding 10% molasses increased daily feed consumption by 13.7% and supported a 9.8% increase in average daily gains when treatments with and without molasses were compared. As contrasted to the treatments without molasses, increasing the yuca level in the presence of molasses caused a decrease in average daily consumption. Feed conversion was not greatly different among treatments.

Table 8. Influence of level of dried-yuca on growing-finishing pigs' performance Experiment No. 4

Treatments/Results[a]	Av. daily gain,	Daily feed intake	Feed/unit gain,
	....	kilograms	......
1 Basal	0.773	2.68	3.47
2 25.72% yuca	0.744	2.66	3.57
3 48.65% yuca	0.743	2.79	3.76
4 69.25% yuca	0.708	2.48	3.49
5 Basal + 10% molasses	0.888	3.38	3.84
6 21.70% yuca + 10% molasses	0.827	2.95	3.56
7 41.04% yuca + 10% molasses	0.777	3.00	3.85
8 58.26% yuca + 10% molasses	0.767	2.73	3.54

[a] Six pigs per treatment; 111-day experiment; Av. initial wt. 18.5 Kg.

Experiment 5.

In view of the results obtained in the previous experiment, reduced gains as the level of dried yuca was increased, an experiment was conducted to evaluate the influence that additions of animal protein (fishmeal) and double vitamin-trace mineral fortification might have on growing-finishing pig performance when dried yuca was used to completely replace corn in the diets (Table 9.) Forty weanling Duroc and Duroc x Landrace pigs weighting an average of 19.3 kg. were alloted to the 2 x 2 x 2 factoral experiment using a randomized design. The variables of the experiment were two levels of fishmeal, two levels of vitamin-trace mineral fortification and two levels of molasses. Feed was supplied *ad libitum* in automatic metal feeders. The pigs were housed in 4 x 5 mt. concrete lots of all which were sheltered.

Table 9. Composition of Experimental Diets — Experiments 5 & 6

Diet	(1) %	(2) %	(3) %	(4) %	(5) %	(6) %	(7) %	(8) %
Dried ground yuca[a]	69.25	69.03	66.25	66.03	58.26	58.04	55.26	55.04
Fishmeal	—	—	3.00	3.00	—	—	3.00	3.00
Soybean Meal	19.75	19.75	19.75	19.75	20.74	20.74	20.74	20.74
Cottonseed Meal	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00
Cane Molasses	—	—	—	—	10.00	10.00	10.00	10.00
Bone Meal	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
Vitamin-trace Mineral Premix[b]	2.00[c]	2.22[d]	2.00	2.22	2.00	2.22	2.00	2.22

[a] Dried in forced-air oven at 180°F

[b] Supplies the same level of vitamins and trace minerals as premix in Table 7

[c] Normal vitamin-trace mineral fortification

[d] Double vitamin-trace mineral fortification

The second day after the initiation of the 28-day experiment, diarrhoea developed in all lots and by the third day all pigs in all lots had developed the same symptoms. All drugs and antibiotics used were ineffective in controlling the diarrhoea. As would be expected all pigs grew very poorly as can be seen in Table 10. The experiment was terminated after 28 days, and the pigs changed to another diet. The diarrhoea stopped almost immediately and the pigs began to make acceptable gains. Yuca toxicity was suspected. A close check of the yuca source, revealed that two rows of yuca variety (H-34) known to be very high in hydrocyanic acid had been accidently included in the dried yuca. Heating this yuca for 24 to 36 hours at 180°F did not eliminate the hydrocyanic acid toxicity and this small quantity included in the mixture was sufficient to cause the severe diarrhoea.

Table 10. Influence of vitamin-trace mineral level, molasses and fishmeal on dried yuca utilization by growing-finishing pigs — Experiment No. 5

Treatments/Results[a]	Av. daily gain, (Kg.)	Daily feed intake, (Kg.)	Feed/unit gain, (Kg.)
	...... (0% molasses)		
1 Basal	0.246	1.30	5.28
2 Basal + 2 x Vit. Tr. Min.	0.225	1.19	5.29
3 Basal + 3% Fishmeal	0.335	1.37	4.09
4 Basal + 2 x Vit. Tr. Min. + 3% Fishmeal,	0.375	1.58	4.21
	(10% Molasses)		
5 Basal	0.201	1.02	5.07
6 Basal + 2 x Vit. Tr. Min.	0.104	0.89	8.56
7 Basal + 3% Fishmeal	0.257	1.13	4.40
8 Basal + 2 x Vit. Tr. Min. + 3% Fishmeal,	0.227	1.07	4.71

[a] Five pigs per treatment ; 28-day experiment ; Av. initial wt. 19.3 Kg.

Experiment 6.

The same experiment was then repeated using a new batch of dried yuca. The performance data of the pigs are presented in Table 11. As can be seen from the data the pigs performed very satisfactorily. Doubling the vitamin-trace mineral supplementation in the diet tended to increase gains and feed efficiency. Contrary to the results obtained in Experiment 4, molasses had no effect on either rate of gain or feed efficiency. The addition of 3% fishmeal was not of value in improving gains or feed conversion; however, in the presence of 10% molasses and a double vitamin-trace mineral fortification, 3% fishmeal did support faster gains.

Table 11. Influence of vitamin-trace mineral level, molasses and fishmeal on dried yuca utilization by growing-finishing pigs — Experiment No. 6

Treatments/Results[a]	Av. daily gain, Kg.	Daily feed intake, Kg.	Feed/unit gain Kg.
	...... (0%	molasses)	....
1 Basal	0.714	2.03	2.84
2 Basal + 2 x Vit-Tr. Min.	0.748	2.27	2.99
3 Basal + 3% Fish Meal	0.672	2.19	3.26
4 Basal + 2 x Vit-Tr. Min. + 3% Fish Meal,	0.710	2.17	3.06
	...... (10%	molasses)	....
5 Basal	0.708	2.16	3.05
6 Basal + 2 x Vit-Tr. Min.	0.716	2.03	2.84
7 Basal + 3% Fish Meal	0.714	2.63	3.68
8 Basal + 2 x Vit-Tr. Min. + 3% Fish Meal,	0.780	2.25	2.88

[a] Five pigs per treatment ; 57-day experiment ; Av. initial wt. 22.3 Kg.

DISCUSSION

The satisfactory daily feed consumption, gains and feed efficiency of pigs fed fresh, chopped yuca in combination with a well fortified protein supplement, demonstrate that yuca can be used as the only energy source in growing-finishing pig rations. It is essential that yuca be fresh and free from spoilage and that varieties with low hydrocyanic acid (HCN) content be utilized as even small quantities of HCN have severe effects on the growth and condition of pigs.

Although young pigs tend to overeat protein supplement probably to satisfy drymatter and energy needs until their stomachs are large enough to allow for consumption of large quantities of fresh yuca, older pigs are able to consume sufficient yuca to satisfy their daily energy needs and consume only enough supplement to meet their daily requirements for protein and vitamins.

The dusty-powdery nature of dry ground yuca could possibly cause a problem in ration palatability although it was not shown to be a problem in the present studies. In addition to its very low protein and vitamin content which requires that special care be given to proper supplementation, yuca is almost void of other extract. It is possible that additions of small quantities of fat or oil would be useful in improving pig performance.

These studies only represent the first phases in research that needs to be conducted to study how to better utilize yuca in complete life-cycle feeding of swine.

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A PRELIMINARY STUDY OF THE NUTRITIVE VALUE OF SOME DEHYDRATED TROPICAL ROOTS

— *by* —

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Root crops including cassava (*Manihot esculenta*); dasheen and eddoes (*Colocusia esculenta*); sweet potatoes (*Ipomoea batatas*) and yam (*Dioscorea spp.*) are commonly grown throughout the West Indies for food and contribute a major proportion of the total caloric intake (F.A.O. 1962). Despite their relative ease of propogation and high energy-yielding potential, research efforts on these crops has been negligible in comparison with that of the export crops, and cultivation has remained largely in the hands of peasant farmers (Campbell and Gooding 1962). Being highly perishable and of limited transportability, consumption is largely limited to domestic markets. Unlike other tropical countries where they constitute valuable sources of feed for all classes of livestock (Oyenuga 1955 and 1961) their use for this purpose in the West Indies is often associated with subsistence farming. The wastage and neglect which occurs needs little emphasis.

Recent investigations have demonstrated the possibilities for mechanical cultivation (Gooding and Campbell 1964; Chapman 1965) and the feasibility of commercial production (Haynes 1966) under Trinidad conditions. However little attention has been paid to problems involved in the transportation or utilization of these bulky high-carbohydrate, poor-protein foodstuffs. Although processing methods have long been developed (Martin and Leonard 1949, Holleman and Aten 1956), possibilities for the industrial utilization of roots for production of human livestock food have hardly been explored here.

Recognition that a deficiency of dietary protein is a major nutritional problem in this area suggests the urgent need for sources of high quality protein foods (F.A.O. 1962). Since a large proportion of our animal protein is now imported and is often too expensive for many in the lower income groups other sources must be sought. The development of low-cost protein-enriched foods based on dehydrated roots has been demonstrated (Tape 1963), and could be of value in augmenting the supply of dietary protein. On the other hand the use of dehydrated root flour or meal in stockfeeds, in place of cereals which are mainly imported, could aid the expansion of the local livestock industry.

Dehydrated sweet potatoes and cassava have long been used as a source of carbohydrate in rations for poultry and livestock (Holleman and Aten 1956; Mather *et al.* 1948; Singletary 1948 and Tillman and Davis 1948) but despite some reference to the suitability of the edible aroids (Barrett 1910) less is known about the value of these roots and yams for this purpose.

The present study was therefore designed as a preliminary attempt to determine and compare the feeding values of some commonly grown root crops when dehydrated and used as a major carbohydrate source in the diet of laboratory rats.

MATERIALS AND METHODS

Roots used in this study included cassava *(Manihot esculenta)*, dasheen and eddoes (*Colocasia esculenta*), sweet potatoes (*Ipomoea batatas*), tannia (*Xanthosoma sagittifolium*) and yam (*Dioscorea alata*).

Samples were obtained from the Central Experiment Station, Ministry of Agriculture, Centeno; the Central Marketing Agency, Port of Spain and the Texaco Food Crops Demonstration Farm and local retail outlets.

Preparation of materials

Fresh roots were cleaned, chopped and dehydrated in a force-draft oven at 80°C. and ground in a laboratory hammer-mill. Sub-samples were sieved and placed in glass bottles with plastic covers and stored in an air conditioned room until later analysis.

Proximate analysis and gross energy determinations

Moisture, ether extract, crude fibre and ash analyses in duplicate were determined according to A.O.A.C. (1960) methods and nitrogen as described by Metson (1956). Gross energy determination were done using a Ballistic Bomb Calorimeter.

Feeding trials

All ingredients were ground through the same sieve and mixed in a Hobart mixer. Rations were fed to groups of four weanling albino rats which were kept individually in wire mesh cages housed in an air conditioned room maintained at 75°F. All rations were fed *ad libitum*. a period of at least one week being allowed for rats to adjust to each ration. Fresh water was available at all times. Sub-samples of each ration were collected throughout the trials and composited for later analysis. Weekly liveweight and feed consumption data were recorded,

Experiment 1

A total of 48 rats was used in this experiment. Groups of male rats matched for initial weight were used to determine the effect of substituting cassava, sweet potato and yam meals at levels of 10, 20 or 30% in a commercial grower ration (Appendix Table II), during three consecutive five week periods.

Experiment 2

In this experiment groups of rats matched for initial weight were assigned at random for five weeks to a commercial grower ration alone or substituted with 10, 20 or 30% dasheen meal (Appendix Table III).

Experiment 3

Balanced rations containing dehydrated roots (60%) and supplemented with a commercial "concentrate mix," fortified with fish flour, were compared with a balanced whole wheat ration when fed for four weeks as the sole nutrient source. Groups of rats matched for initial weight were assigned at random to each of the six rations (Appendix Table IV).

Experiment 4

In this experiment the proportions of dehydrated roots were reduced from 60 to 55% and the level of commercial "concentrate" increased from 30 to 37%. These rations were compared with a supplemented corn diet when fed to rats as the sole ration for a period of four weeks (Appendix Table V).

Experiment 5

In this experiment mixed rations of dehydrated roots (48 or 50%) or corn (50%) and wheat middlings (30%) were compared. The protein supplement consisted of a fixed level of fishmeal (5%) with soybean meal being adjusted roughly in accordance with the crude protein contents of dehydrated roots. Groups of rats matched for initial weight were randomly assigned to the various ration treatments (Table 6) for a period of three weeks.

RESULTS

Composition of dehydrated roots (meals)

Proximate composition and gross energy data for different dehydrated roots are presented in Appendix Table 1. It is apparent that crude protein contents of dehydrated cassava in particular and dasheen meals were quite low when compared with the other dehydrated roots. While the levels of crude protein in sweet potato (6.3%) and tannia (6.5%) meals were lower than those of eddoe (8.5%) and yam (8.6%) meals,they compared favourably with levels usually reported for yellow corn (8.9%). Ether extract (.18 — 87%) and crude fibre (1.6 — 2.8%) contents were generally low as were levels of ash in cassava (1.3%) and sweet potato (1.6%). As estimated by difference nitrogen-free extract contents of all dehydrated roots were of a high order (82 — 92%) and levels of gross energy were fairly similar (3.92 — 4.20 k cals/gm).

Experiment 1

Appendix Table VII shows that the substitution of the commercial ration with 10 or 20% dehydrated roots apparently had little adverse effect on feeding value of the ration as indicated by the small magnitude of difference in weight gains and feed conversion efficiency. At the 30% level of substitution weight gains of rats fed dehydrated roots were depressed and efficiency of feed conversion lower, particularly in the case of sweet potato and cassava.

Experiment 2

A progressive decline in weight gain and efficiency of feed conversion occured with each level of substitution of dasheen meal for the commerical ration (Appendix Table VIII). Although these effects were quite marked at the 30% level, except for reduced growth, no gross deficiency symptoms were evident.

Experiment 3

When dehydrated roots were used as major (60%) basal ingredients in balanced rations and supplemented with a commercial "concentrate mix," fortified inferior to that of rats fed a supplement whole wheat diet (Appendix Table IX).

The poor performance of rats fed dasheen meal was particularly apparent in this trial.

Experiment 4

When the level of dehydrated roots was reduced to 55% and that of commercial "concentrate" increased in both the control and test rations, the general level of performance, as measured by gain in weight and efficiency of feed utilization was slightly improved (Appendix Table X). Performance of rats fed dasheen meal was worse than the previous trial.

Experiment 5

The addition of Wheat middlings and supplementation with a mixture of soybean meal and fishmeal resulted in some improvement in general performance. Weight gains and efficiency of feed conversion of rats fed sweet potato meal were superior to all others including the control ration. In order of average daily gains, sweet potato fed rats were followed by the control (2.9); yam (2.4); tannia (2.3); cassava (2.2) and dasheen (1.1) grams per day. In terms of efficiency of feed conversion sweet potato (4.5) were best with controls (5.3); cassava (5.6); tannia (6.8); yam (7.0) and dasheen (10.8) grams of feed per gram weight gained, in that order.

Although performance of dasheen fed rats was still poor, there was a marked improvement over previous trials.

DISCUSSION

Dehydrated roots were generally of inferior feeding value to corn or wheat, but to what extent this was attributable to specific nutrient deficiency is not certain. It appeared that supplementation with fishmeal and soybean meal improved feeding values of all roots except dasheen and could render these feed-stuffs suitable as carbohydrate substitutes for a major proportion of the cereals in balanced rations. Other studies have emphasized the importance of high quality protein supplementation. Evans (1960) indicated the need for fishmeal or its equivalent of other high quality protein food when feeding pigs on roots and other bulky foods. Waugh (1963) also noted remarkably improved weight gains when sweet potato diets for pigs were supplemented with fishmeal or skim milk.

Studies of the amino acid composition of tropical roots (Close *et al.* 1953 and Concepcion and Cruz 1961) would suggest that because of the poor quality of protein, supplementation of tropical roots with the deficient amino acids is the obvious method for improving the nutritional value of these starchy foodstuffs. However, Adams *et al.* (1958) found that a condition resembling kwashiorkor, in adult rats fed high cassava diets, was corrected only when complete protein containing essential amino acids was fed. This is in accordance with observations by Friend *et al.* (1963) that the use of an easily digested source of animal protein may be an essential feature of the supplementation necessary for improving the feeding value of potato pulp.

It would also seem that the efficiency of utilization of nutrients is influenced by method of processing which could therefore determine the extent to which roots can be used as ration components for livestock and poultry. It is recognized (Holleman and Aten 1956; Oyenuga 1955) that boiling or heat treatment destroys enzyme action and accomplishes hydrolysis of certain toxic principles in some tropical roots. Inadequate pretreatment may therefore have been responsible for the poor performance observed when dasheen meal was fed. This could also have accounted for the poor growth and impaired feed utilization (Susaki and Hamakawa 1959; Tillman and Davis 1948; Vogt and Penner 1963; Yoshida and Morimoto 1955, 1960 and Yoshida *et al.* 1963) and even mortality (Yoshida and Morimoto 1957 and 1959) when dehydrated sweet potato and cassava were fed to rats and chickens. Toxic principles have been isolated from some species of yams which could prove fatal. In a recent study Gilbert and Gillman (1963) observed that when bioassays with *Dioscorea alata, D. cayenensis* and *D. rotundata* and *D. Xanthosoma sagittifolium* (Tannia) were carried out in weanling rats, none of these roots promoted growth nor was survival prolonged beyond 100 days. However, it was not determined whether the acute necrosis observed in rats fed yam was due to a toxic principle or was a consequence of sulphur containing amino acid deficiency. Although these workers deduced that the necrosis became manifest only in young rats, other studies (Adams *et al.* 1958) with adult rats and mice fed cassava gari, have shown physiological and morphological abnormalities which did respond to supplementation with complete protein containing essential amino acids.

Wood (1967) has recently suggested that for a food that plays such an important part in nutrition of large numbers of the human race, surprisingly little is known about cassava. Observations in particular about the paucity of knowledge which exists about amounts of toxic factors which may be consumed or of the long-term metabolic effects of ingesting them, may well apply to other tropical roots.

It is beyond the scope of this paper to determine whether commercial dehydration or other forms of processing tropical roots would be feasible. Certainly, indications are that these popular foods could become valuable carbohydate substitutes for cereals in stockfeeds or enriched as "instant" or other foods for improving general nutritional levels. Increased utilization of roots could make certain developing countries less vulnerable to emergencies which could curtail imports (ICNND 1962) and warrants a far greater research effort to solve some of the problems which exist.

SUMMARY

Meals were prepared by grinding artificially dehydrated whole roots and tubers of cassava (*Manihot esculenta*), dasheen (*Colocasia esculenta*), sweet potato (*Ipomoea batatas*), tannia (*Xanthosoma sagittifolium*) and yam (*Dioscorea alata*). Groups of weanling albino rats matched for initial weight were used to determine feeding values of dehydrated roots as a replacement for 10, 20 or 30% of a commercial feed or as basal ingredients in balanced rations.

Dasheen meal was markedly inferior at all levels of substitution. Cassava, sweet potato and yam differed little from each other and produced satisfactory growth and performance at levels up to 20%.

When dehydrated roots were supplemented with a commercial "concentrate" mix (36%) all were inferior to controls containing corn or wheat; dasheen being particularly poor. Dehydrated roots (48 — 50%) when mixed with wheat

middlings (30%) and supplemented with fish meal (5%) and soybean meal (8 — 14%) produced generally better weight gains and efficiency of feed conversion than when supplemented with a commercial "concentrate." In particular it was noted that weight gains and Feed/gram Gain (gms) with respect to the sweet potato diet (3.2 and 4.5) were superior to the control ration (2.9 and 5.3) with cassava (2.2 and 5.6) being slightly inferior. Although some slight improvement occured, dasheen rations were quite poor.

It was concluded that with high quality protein supplementation dehydrated cassava, sweet potato, tannia and yam could satisfactorily replace cereals as main carbohydrate components of balanced rations. The poor performance of dasheen meal may have been attributable to the presence of calcium oxalate and other irritants and suggested that boiling or other treatment may be a prerequisite to dehydration.

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Appendix Table I. Composition of some Dehydrated Tropical Roots

No.	Common Name	Scientific Name	Mean chemical composition as determined per cent of dry matter						
			Dry Matter	Crude Protein	Ether Extract	Crude Fibre	Nitrogen Free Extract	Total Ash	Energy Gross k cals/gm
1.	Cassava—sweet, whole	*Manihot esculenta (utlissima)*	32.2	2.4	.87	2.8	92.6	1.3	4.20
2.	Cassava farine	,,	88.3	1.9	.39	2.2	82.6	1.3	3.94
3.	Dasheen—whole	*Colocasia esculenta*	23.7	3.1	.24	2.0	91.5	4.1	3.92
4.	Eddoes—whole	,,	——	8.5	.42	1.6	85.7	3.8	——
5.	Sweet Potato	*Ipomoea batatas*	30.0	6.3	.51	1.9	89.7	1.6	4.11
6.	Tannia	*Xanthosoma sagittifolium*	31.5	6.5	.18	2.4	87.0	3.9	4.02
7.	Yam—lisbon	*Dioscorea alata*	21.9	8.6	.42	2.5	83.7	4.7	4.15

Appendix Table II. Ration Formulation and Composition.
(Experiment I)

		Dehydrated Roots								
		10%			20%			30%		
Ingredients (%)	Control Ration	Cassava Farine	Sweet Potato Meal	Yam Meal	Cassava Farine	Sweet Potato Meal	Yam Meal	Cassava Farine	Sweet Potato Meal	Yam Meal
Commercial Grower (16%)	95	85	85	85	75	75	75	65	65	65
Cassava Farine	—	10	—	—	20	—	—	30	—	—
Sweet Potato Meal	—	—	10	—	—	20	—	—	30	—
Yam Meal	—	—	—	10	—	—	20	—	—	30
Cod Liver Oil	5	5	5	5	5	5	5	5	5	5
	100	100	100	100	100	100	100	100	100	100
Analysis %										
Crude Protein	15.2	13.5	14.3	14.5	11.8	13.3	13.7	10.0	11.9	12.2
Ether Extract	7.5	7.5	6.6	7.3	7.3	7.4	6.7	7.0	7.1	6.8
Crude Fibre	2.9	3.0	2.9	3.0	2.3	2.7	2.4	3.0	2.9	3.0
Ash	4.9	4.7	4.8	5.0	4.6	5.0	5.5	3.8	4.0	4.7

Guaranteed Analysis : Crude Protein, Min. 16.0%; Crude Fat, Min. 3.0%; Crude Fibre, Max. 5.0%; Active drug ingredient Chlortetracycline.

Appendix Table III. Ration Formulation and Composition (Experiment 3)

Ingredients	Control Ration	Dasheen Meal (%) 10	20	30
Commercial Grower Ration (16%)*	95	85	75	65
Dasheen Meal	—	10	20	30
Cod Liver Oil	5	5	5	5
	100	100	100	100
Analysis %				
Crude Protein	14.9	13.9	12.8	11.6
Ether Extract	11.3	10.6	10.0	9.0
Crude Fibre	2.9	5.6	5.4	5.3
Ash	8.5	8.8	8.0	7.6

* Guaranteed Analysis : Crude Protein, Min. 16.0%; Crude Fat, Min. 3.0% Crude Fibre, Max. 5.0%. Active drug ingredient Chlorotetracycline.

Appendix Table IV. Ration Formulation and Composition (Experiment 3)

Ingredients	Control Ration	Dehydrated Roots Cassava Meal	Dasheen Meal	Sweet Potato Meal	Tannia Meal	Yam Meal
Commercial Concentrate*	10	30	30	30	30	30
Whole Wheat Flour	80	—	—	—	—	—
Cassava Meal	—	60	—	—	—	—
Dasheen Meal	—	—	60	—	—	—
Sweet Potato Meal	—	—	—	60	—	—
Tannia Meal	—	—	—	—	60	—
Yam Meal	—	—	—	—	—	60
Fish Flour	2	2	2	2	2	2
Cod Liver Oil	3	3	3	3	3	3
Molasses	5	5	5	5	5	5
	100	100	100	100	100	100
Analysis %						
Crude Protein	16.6	12.7	12.6	14.3	15.4	16.9
Ether Extract	2.7	2.2	3.6	3.4	3.8	4.3
Crude Fibre	2.3	5.3	4.8	3.8	4.3	4.4
Ash	2.7	6.6	7.4	6.4	7.3	7.1

* Guaranteed Anaysis : Crude Protein, Min. 36.0%; Crude Fat, Min. 1.5%; Crude Fibre, Max. 9.0%; Ca. Min. 3.0%; Phosphorus, Min. 1.2%; Iodine, Min. 0.0002%; Salt (NaCl), Min. 1.5%; Max. 2.5%.

Appendix Table V. Ration Formulation and Composition (Experiment 4)

Ingredients	Control Ration	Dehydrated Roots: Cassava Meal	Dasheen Meal	Sweet Potato Meal	Tannia Meal	Yam Meal
Commercial Concentrate*	35	37	37	37	37	37
Ground Yellow Corn	60	—	—	—	—	—
Cassava Meal	—	55	—	—	—	—
Dasheen Meal	—	—	55	—	—	—
Sweet Potato Meal	—	—	—	55	—	—
Tannia Meal	—	—	—	—	55	—
Yam Meal	—	—	—	—	—	55
Molasses	5	5	5	5	5	5
Cod Liver Oil	—	3	3	3	3	3
	100	100	100	100	100	100
Analysis						
Crude Protein	15.6	13.7	13.7	14.9	15.1	16.2
Ether Extract	3.8	4.3	4.4	5.2	3.8	3.8
Crude Fibre	2.8	3.9	4.4	4.0	4.7	4.4
Ash	5.5	8.2	9.3	8.1	8.9	8.4

* Guaranteed Analysis : Crude Protein, Min. 36.0%; Crude Fat, Min. 1.5%; Crude Fibre,Max. 9.0%; Ca. Min. 3.0%; Phosphorus, Min. 1.2%; Iodine, Min. 0.0002%; Salt (NaCl), Min. 1.5%; Max. 2.5%.

Appendix Table VI. Ration Formulation and Composition (Experiment 5)

Ingredients	Control Ration	Dehydrated Roots: Cassava Meal	Dasheen Meal	Sweet Potato Meal	Tannia Meal	Yam Meal
Wheat Middlings	30	30	30	30	30	30
Ground Yellow Corn	50	—	—	—	—	—
Cassava Meal	—	48	—	—	—	—
Dasheen Meal	—	—	48	—	—	—
Sweet Potato Meal	—	—	—	50	—	—
Tannia Meal	—	—	—	—	50	—
Yam Meal	—	—	—	—	—	50
Fish Meal	5	5	5	5	5	5
Soybean Meal	8	14	14	12	12	8
Molasses	5	0	0	0	0	4
Vegetable Oil	—	1	1	1	1	1
Premix*—Mineral-Vitamin	2	2	2	2	2	2
	100	100	100	100	100	100
Analysis (%)						
Crude Protein	14.0	12.0	13.0	13.6	13.8	15.0
Ether Extract	2.8	1.8	1.1	1.3	1.2	1.9
Crude Fibre	2.6	4.7	4.2	3.9	4.5	4.1
Ash	6.2	7.7	7.7	6.7	8.0	7.7

* A Mixture of 88% "Churn" minerals and 12% vitamin premix, the latter supplying: Vit. A. USP units 10,570; Vit. D_2 , USP units 352, 420; Vit. E. I.U. 1,100; Riboflavin, mgs. 880; Calcium pentothenate mgs. 2,880; Choline chloride mgs. 31, 700; Vit. B_{12} mgs. 4,400; Zinc bacitracin mgs. 4,400, Iodine mgs. 760; manganese mgs. 24,430; Iron mgs. 19,220; Copper mgs. 1,460; Cobalt mgs. 520; Zinc mgs. 20,020. per kg.

Appendix Table VII. Weight gain, feed consumption and efficiency of feed utilization data

(Experiment 1)

RATIONS

	Level of Substitution	Control	Cassava Farine	Sweet Potato Meal	Yam Meal
No. of Rats		4	4	4	4
Av. Initial Weight (gms)		91.2	90.7	91.5	92.5
Av. Final Weight "		207.5	211.0	192.2	196.5
Av. Weight Gain "	10%	116.3	120.3	102.7	104.0
Av. Daily Gain "		3.3	3.4	2.9	3.0
Av. Feed Consumed "		466.5	424.4	464.5	433.2
Feed/gm Gain "		4.0	3.5	4.5	4.2
No. of Rats		4	4	4	4
Av. Initial Weight (gms)		78.2	78.0	79.0	79.7
Av. Final Weight "		192.7	189.2	176.7	196.7
Av. Weight Gain "	20%	114.5	111.2	97.7	117.0
Av. Daily Gain "		3.3	3.2	2.8	3.3
Av. Feed Consumed "		450.5	422.7	466.7	456.2
Feed/gm Gain "		3.9	3.8	4.6	3.9
No. of Rats		4	4	4	4
Av. Initial Weight (gms)		78.0	78.5	76.7	78.5
Av. Final Weight "		194.0	159.0	156.0	164.7
Av. Weight Gain "	30%	116.0	80.5	79.3	86.2
Av. Daily Gain "		3.3	2.3	2.3	2.5
Av. Feed Consumed "		510.0	376.2	485.7	396.0
Feed/gm Gain "		4.4	4.7	6.1	4.6

Appendix Table VIII. Weight gain, feed consumption and efficiency of feed utilization data.
(Experiment 2)

	RATIONS			
		Dasheen meal (%)		
	Control	10	20	30
No. of Rats	4	4	4	4
Av. Initial Weight (gms)	65	66	66	66
Av. Final Weight "	136.8	125.2	115.8	86.5
Av. Weight Gained "	71.5	59.5	49.8	86.5
Av. Daily Gain "	2.0	1.7	1.4	.58
Av. Feed Consumed "	460.0	380.2	336.5	247.0
Feed/gm Gain "	6.4	6.4	6.8	12.1

Appendix Table IX. Weight gain, feed consumption and efficiency of feed utilization data.

(Experiment 3)

		RATIONS				
	Control (Whole Wheat)	Cassava Meal	Dasheen Meal	Sweet Potato Meal	Tannia Meal	Yam Meal
No. of Rats	4	4	4	4	4	4
Av. Initial Weight (gms)	89.7	96.5	95.0	98.0	97.3	99.5
Av. Final Weight "	149.7	130.3	100.7	143.7	136.5	149.8
Av. Weight Gain "	60.0	33.8	5.7	45.7	39.2	50.3
Av. Daily Gain "	2.9	2.2	.27	1.6	1.9	2.4
Av. Feed Consumed "	233.5	215.0	203.0	257.5	365.0	355.0
Feed/gm Gain "	3.9	6.4	35.6	5.6	9.3	7.0

Appendix Table X. Weight gain, feed consumption and efficiency of feed utilization data.

(Experiment 4)

		RATIONS				
	Control	Cassava Meal	Dasheen Meal	Sweet Potato Meal	Tannia Meal	Yam Meal
No. of Rats	4	4	4	4	4	4
Av. Initial Weight "	65.8	66.0	66.0	65.8	66.0	66.0
Av. Final Weight "	162.2	119.8	70.0	120.2	130.2	133.0
Av. Weight Gain "	96.4	53.8	4.0	54.4	64.2	67.0
Av. Daily Gain "	3.4	1.9	.14	1.9	2.3	2.4
Av. Feed Consumed "	343.5	375.5	219.8	297.8	367.6	408.0
Feed/gm Gain "	3.6	7.0	54.9	5.5	5.7	6.1

Appendix Table XI. Weight gain, feed consumption and efficiency of feed utilization data.

(Experiment 5)

		RATIONS				
	Control	Cassava Meal	Dasheen Meal	Sweet Potato Meal	Tannia Meal	Yam Meal
No. of Rats	4		4	4	4	4
Av. Initial Weight (gms)	80.5	82.0	81.8	81.2	81.0	80.3
Av. Final Weight "	142.0	127.8	105.8	147.5	129.8	131.0
Av. Weight Gain "	61.5	45.8	24.0	66.3	48.8	50.7
Av. Daily Gain "	2.9	2.2	1.1	3.2	2.3	2.4
Av. Feed Conusmed "	323.4	254.5	259.8	299.8	331.6	392.3
Feed/gm Gain "	55.3	5.6	10.8	4.5	6.8	7.7

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DISCUSSION

Chairman :

The floor is open for questions on Dr. Maner's paper.

Prof. Mahadevan :

I am not trying to be patronising when I say that I have been impressed by both Dr. Maner's and Dr. Jeffers' contributions this afternoon. However, I have also had some cause for concern by the total absence of any statistical analyses of the results. Of course, one can see that a completely randomised design has been used in these experiments, but I fail to see whether the experimental results have, in fact, been subjected to statistical analysis. For instance, average daily gains in one experiment have been cited as ranging from 0.672 for one treatment to 0.748 for another. Now, without any knowledge of the within treatment and between treatment variability in the experiment, it would be impossible to determine whether these differences are real differences or might be attributable to experimental error. Perhaps Dr. Maner or Dr. Jeffers might like to comment on this.

Dr. Maner :

I purposely left many of these statistical analyses of the experiment out of the paper here because I was not trying, in this paper to give actual differences between some of these treatments. My main interest here was to demonstrate to the symposium that they can be used efficiently and economically. We used our standard diets only to compare and give an indication of how well they were performing. Some of these have been subjected to statistical analysis. I think that approximately four out of six have been subjected. Within treatment variation usually is very small; variation within groups is very small. These experiments were run over a period of 3 years and we do have some differences between experiments. For instance, the first three experiments were conducted using pigs that were produced at the Palmora Station; three of the other experiments were conducted using pigs which were reared at an altitude of 8600 feet, about 2600 metres, down on the Palmora Station which is about 1000 metres so there are differences within strains and between animals used. I appreciate your comment.

Dr. Richardson :

In your experiments, what are the economic advantages or disadvantages of using root crops as a substitute for maize? If you have the data at hand can you give us a general statement on it.

Dr. Maner :

As far as economic advantages go, I do have the data available in my brief case, but it would be easier just to give a general statement on it. In every case where we have used cassava (yuca) in our experiments we have tried to compare. We do not have good data to show the actual cost of producing cassava or yuca per hectare or per kilo. In many of our experiments where we measured the actual production, we have produced as much as 10 tons dry matter per hectare or 30 tons of wet yuca per hectare and this was with unimproved varieties, with very poor cultural practices, because we, as animal scientists, had to grow the yuca in order to utilise it. In this case we used no fertilizer and also no mechanical cultivation methods. We only used the machines to control the weeds and we got as much as 30 tons per hectare. When we compare on our experiments we have used this as a type of comparison. If we say that we get only 20 tons of yuca produced per hectare as compared to 5 tons of corn which, as you know, is above the average per year production when we get two crops produced, yuca requires about eight to ten to eleven months to produce depending upon the season. If we compare corn at 5 tons per hectare and yuca at 20 tons per hectare, which is much less than we are capable of producing, we find that our yuca diets are in the neighbourhood of 20 to 25% more economical, even considering the larger quantities of protein, than corn or sorghum diets. I think this is a fair comparison since we compared the actual cost or the actual price of corn which in Colombia we consider to be about 1200 to 1500 pesos which in dollars will be about $80 to $85 per ton. We used this figure and we come out with 270 pesos per ton as a cost for our yuca used in our experiments. So it's more economical and I think if we use the actual production figures in realizing that varieties are available, we have seen there the varieties that produce up to 45 or 50 tons of yuca per hectare and I think there is ample leeway in considering these in animal feeds.

Mr. Williams :

Dr. Jeffers, what is the genetic status of the rats you used in this trial? Were they inbred strains?

Dr Jeffers :

I am sorry you asked that question because these experiments were conducted under such very limiting conditions that if I were to tell you what all these limiting conditions were my entire data might be thrown out entirely. We have absolutely no information on these rats. This work is extremely preliminary. Four rats per treatment. I think we would be very presumptious indeed to present any statistical information on this since the coefficients of variability were very high.

Dr. Montaldo :

I want to ask Dr. Maner how important is yuca in Colombia? I am asking this question because we have just two Colombians in Venezuela and they always refuse to give information on yuca. Yuca is used in large quantities in the feeding of livestock because I have seen much work in Labolina, San Paulo and lately a paper in Santo Domingo using it on chickens but it looks like all experiments have been going after that. We prepare in Venezuela, Maracai, dry leaves of yuca and we got a very high content of protein 20% on the dry leaves compared with 16% on alfalfa. If you are interested you can tell us about that.

Dr. Maner :

Well to try to answer your question. Yuca ranks 7th in Colombia as far as economic importance is concerned. Figures published by the Ministry of Agriculture ranks yuca as 7th in economic value. Secondly, I should say that yuca, or cassava, is not commonly used in animal feeds. We started this work approximately 2½ to 3 years ago with the idea of trying to reduce the competition for human consumption not only in Colombia but in other areas of the world. As you well know Brazil produces some 12 million short tons of yuca per year which offers tremendous potential. I am happy to say that the swine producers where we are actually working and pushing yuca as a swine feed, have just discovered yuca as a swine feed and they are planting it or seeding it in large acreages. I have said on the farm, feeding of yuca should be done by rotational seeding possibly on a monthly basis because we can seed it almost any month in Colombia and many other parts of the world. If this method is practised you can tremendously reduce the cost of swine feed.

To answer your other question, we have done one trial comparing dried yuca leaves to alfalfa and found them to be equal. In our studies we find that yuca leaves on an air dried basis which contains 7 to 8% moisture, containing approximately 17% protein does offer some potential. We also know that if you harvest leaves from yuca with a high hydrocyanic acid content you must dry them and let them stand for a number of days to help to eliminate some of the HCN toxicity.

Dr. Montaldo :

Have you compared yuca with alfalfa and is there a difference of the dry yuca leaves and alfalfa, because after being dried they lost all the acidity?

Dr. Maner :

Yes, we have compared them on feeding trials with swine and found them to be equal.