# Food Quality and Chemical Composition

Dry Matter Content, Total Protein and Consumer Acceptability of Potatoes (Solanum spp.) Produced Under Hot Tropical Conditions

Authors: N. Espinola, D.J. Midmore, and S. Poats, Biologist, crop physiologist, and anthropologist, respectively, International Potato Center, Lima, Peru.

ABSTRACT

The influence of a range of tropical growing conditions, the dry matter and protein contents and consumer acceptability of potatoes was studied in Peru. Dry matter decreased at hotter sites. Agronomic treatments to reduce soil temperature marginally improved percentage of tuber dry matter. Protein, expressed as a percentage of dry matter, increased at the hotter sites but on fresh weight basis, protein remained similar at each site. Although there was no direct relationship between taste and dry matter for samples within a site, dry matter was related to texture. Qualitative assessments of tuber taste from Peruvian testers are included. Implications of these results for breeding potatoes for hot climates are discussed.

Dry matter content is the most commonly used criteria to determine culinary quality in potatoes. In Peru, native potatoes are traditionally grown in highland production zones (> 3,000 m.a.s.l.) and are prized for high dry matter content. These native and other highland-grown potatoes are preferred by most Peruvian consumers over potatoes with a lower dry matter content produced in the irrigated valleys of the coastal desert. Potatoes from both production zones are consumed by people in Lima, the capital city.

Potatoes with optimum qualities of taste and texture are referred to as arenosa or harinosa (sandy or floury) (Brush et al., 1980; Poats, 1982), and usually have dry matter content above 24%. In Peruvian markets, arenosa potatoes normally are higher priced than those judged to be low in dry matter content. Due to these consumer preferences, dry matter and protein contents and consumer acceptability were also examined of potatoes grown experimentally in Peru's eastern lowland and mid-elevation humid tropical forest zones.

## Background

Relatively little work has been reported regarding the effects of agronomic manipulations and novel production environments on dry matter content, nutritional quality and acceptability of potatoes. Studies of Wurr and Allen (1974) and Ifenkwe, Allen and Wurr (1974) showed that percent dry matter is directly related to tuber size. Dry matter at a given tuber size can also be increased by planting either at closer spacings or delaying harvest (Bleasedale and Thompson, 1968). Maris (1969) and Simmonds (1974) suggested that a high level of dry matter is associated with late maturity. Reports from India suggest that dry matter content

varies with variety and location (Verma et al, 1975). Similar results have been obtained in the USA (Hoff et al, 1978; Haynes, 1981). Studies in Peru indicate that potatoes respond qualitatively and quantitatively to local environmental and climatological conditions, yet the extent of the response appears to be governed by the tuber's genetic constitution (Moreno, 1973; Poats, 1982).

Since physiological responses of potatoes to climatic features also imply biochemical changes which could affect tuber quality, it is important to measure quality not only by means of dry matter and protein contents but also in terms of consumer acceptability. To date, there appear to be no published studies in which potatoes produced in novel environments, such as under high temperature regimes, have been evaluated on all three criteria of productivity, nutritional composition and quality, and consumer acceptability.

In 1982 a coordinated approach to examine quality of potatoes produced under hot, humid conditions was initiated at the International Potato Center (CIP)[1]. The original objective of the research on potatoes grown under hot conditions was to identify practices and progenies that would provide high yields. Investigation of qualitative aspects began as a by-product. However, the results have encouraged further study and also indicate the route these studies should follow.

## Materials and Methods

Tubers used in these experiments were produced in four distinct ecological zones representing a wide range of growing conditions. At three locations potatoes were produced under warm to hot conditions. Tubers for sampling were from bare soil plots and from plots with agronomic treatments designed to reduce soil temperatures. In Lima and San Ramon, lime and straw mulch, respectively, were used as soil reflectants, and in Yurimaguas partial shading of plants was achieved with adjacent maize plants.

Six heat-tolerant clones: DTO-33, DTO-2, 69-47-2, 374080.5, LT-1, LT-2, and LT-4 were used in the experiments together with the broadly adapted varieties Mariva and Desiree.

Each clone or variety was analyzed for dry matter and total protein as a percentage of total dry matter, and submitted for consumer taste tests. For laboratory analyses (at CIP and at the Department of Nutrition at the Peruvian National Agricultural University, UNA, in La Molina), potatoes of each clone or variety were divided into two groups: one remained raw while the other was boiled for approximately 30 minutes with skins intact. Tubers of both groups were then cut longitudinally into thin slices and freezedried. Samples were weighed before and after dehydration to determine dry matter content. Once dehydrated, the samples were finely ground (60 mesh) and analyzed for total protein by the microkjeldahl method (AOAC, 1970).

---

[1]This did not actually begin in an organized, interdisciplinary manner. The antropologist started consumer testing potatoes produced under lowland, hot humid conditions, in early 1980 on-an ad-hoc basis, in response to tentative evidence that potatoes produced in lowland humid zones of Peru were unacceptable to local consumers (Poats, 1982). Meanwhile, the agronomist began experiments to modify the environmental stresses of potatoes produced under hot, humid conditions (Midmore, 1980). In 1981 the biologist began laboratory analysis of Midmore's experimentally-produced potatoes and some consumer tests with volunteers from the International Potato Center.

Consumer acceptability of the potato samples, was evaluated by taste tests at two locations under slightly different procedures. In CIP and UNA laboratories, volunteers rated potato samples in comparison to locally available controls. In these evaluations, potatoes were rated for flavor on a scale of 1 to 5: 1 = bad, 2 = regular, 3 = good, 4 = very good, and 5 = excellent; texture was rated on a scale of 1 to 3: 1 = hard, 2 = watery and 3 = adequate. Another set of samples was rated by a panel of women from a low-income district (Pamplona Alta) of Lima. The panel compared qualitatively the tastes between each sample, and between samples and locally purchased potatoes. Although residents of Lima, all of the women originally came from areas outside Lima and represented a fairly broad sample of the national population.

## Results and Discussion

### Dry Matter

Dry matter in crude samples of Desiree (Table 1) and Mariva (Table 2) decreased with increase in temperature. Yurimaguas, the highest temperature site, dry matter content of Desiree was 12.5% and Mariva 16.6%. In contrast, at medium and cool temperatures dry matter content ranged from 16% to 19% for Desiree and 20% to 28% for Mariva.

Table 1. Dry matter content and total protein on a dry and fresh weight basis in raw and cooked potato samples of var. Desiree from four production sites.

| Site/ Treatment | Raw | | | Cooked | | |
|---|---|---|---|---|---|---|
| | | Total Protein | | | Total Protein | |
| | Dry matter % | Dry weight basis % | Fresh weight basis % | Dry matter % | Dry weight basis % | Fresh weight basis % |
| Huancayo | | | | | | |
| Control | 19.4 | 11.94 | 2.31 | 22.3 | 12.18 | 2.71 |
| La Molina (1981) | | | | | | |
| Control | 15.5 | 11.0 | 1.70 | 19.8 | 14.0 | 2.8 |
| Mulch | 16.7 | 10.2 | 1.70 | 17.7 | 13.6 | 2.4 |
| San Ramon (rain 1981) | | | | | | |
| Control | 15.0 | 16.0 | 2.4 | 15.9 | 16.3 | 2.6 |
| Mulch | 15.3 | 15.7 | 2.4 | 15.5 | 16.1 | 2.5 |
| (dry 1982) | | | | | | |
| Control | 15.0 | 18.0 | 2.7 | 16.2 | 18.5 | 3.0 |
| Mulch | 16.0 | 17.5 | 2.8 | 16.4 | 17.1 | 2.8 |
| Yurimaguas | | | | | | |
| Control pH6 | 14.3 | 19.6 | 2.8 | 14.9 | 18.8 | 2.8 |
| Control pH4 | 12.5 | 18.4 | 2.3 | 13.4 | 16.4 | 2.2 |
| pH4 + Maize | 12.6 | 19.8 | 2.5 | 13.3 | 15.8 | 2.1 |

Besides the direct effect of temperature on tuber dry matter, indirectly the reduction of crop duration at hotter sites led to smaller tuber size, a possible immature harvest, and consequently less total dry matter, in accord with data of Verma et al, (1965).

Table 2. Results of taste tests (women panel) on tubers of var. Mariva from three production sites.

| Production Site | Organoleptic characteristics |
|---|---|
| Huancayo | Sandy (mealy) or floury, good taste, good for making puree or soups. Not good for frying. |
| La Molina | Good taste, slightly sandy (mealy), good for making papa a la huancaina (a cold potato dish), stuffed potatoes or frying. |
| San Ramon | Sweet taste, good only for frying, papa a la huancaina or stuffed potatoes. |

Nevertheless, it should be noted that when Desiree was planted in a less acid (pH 6) soil than normal (pH 4) at Yurimaguas, the dry matter content increased 2%, confirming results reported by Grison (1973) that soil type can affect tuber dry matter content.

There would appear to be little chance for agronomically improving tuber dry matter content either by planting in alternative seasons at hot sites or by implementing agronomic techniques that reduce soil temperature and conserve moisture (Table 1). However, both techniques have successfully improved absolute tuber yields per unit land area (Midmore, 1980). There were some clonal differences in dry matter content within a site indicating a potential to select for higher dry matter content.

Differences in dry matter content were observed between raw and cooked samples of the same potato variety or clone. Dry matter tended to increase per unit weight upon cooking due to the loss of water and water-soluble contents through the skin. Cooked samples (the usual form for consumption) should therefore be used in evaluating nutritional quality.

Total Protein

Protein values for Desiree are expressed either as percent of total dry matter or percentage of fresh weight for both raw and cooked samples. Comparing raw samples on a fresh weight basis, those produced in La Molina had lowest values (Table 1). When cooked samples were compared, Yurimaguas had the lowest protein values.

Conducting the same comparisons with protein expressed on a dry weight basis, or as a percentage of total dry matter (the most common way of expressing protein), we may erroneously affirm that tubers from hotter areas have higher protein

content than those of cooler areas. Yurimaguas potatoes, in fact, showed 19.8% protein expressed as a percentage of dry matter. In reality, what is being measured here is not the variation in protein quantity, but the variation in carbohydrate; less total dry matter causes relatively the same amount of protein to occupy a larger proportion of the dry matter. For this reason, it is more accurate to compare protein content of potatoes produced under different ecological conditions on a fresh weight rather than a dry weight basis. In addition, as noted above, the protein values for tubers grown in Yurimaguas (Table 1) show that the protein decreased after cooking indicating the loss of soluble nitrogenous constituents, not observed in the samples from the cooler sites. This phenomenon deserves further study.

For Mariva, the percentage of protein expressed on a dry weight basis demonstrated the same tendencies as those of Desiree in moving from one environmental zone to another. The Mariva samples were analyzed in a fresh state which would account for somewhat lower values. Variability between clones for protein content on a fresh weight basis of cooked samples exists and may be further improved upon by conscious selection. Variations of protein content reported here between sites are probably due, as indicated by Moreno (1977), to the effects of climate on the metabolism of the potato plant.

## Consumer Acceptability Tests

All varieties were evaluated for flavor and texture to determine influence of the production environments. With the variety Mariva (Table 2) the taste changed according to production zone with the most desirable taste in the Huancayo (higher elevation) sample and the least in the San Ramon (mid-elevation) sample where a sweet taste was detected.

For Desiree (Table 3), produced on the coast (La Molina) and in both the mid-elevation (San Ramon) and lowland (Yurimaguas) humid tropical zones, several undesirable flavors, such as a metalic taste and bitterness, were detected, depending in some locations on the agronomic treatments and time of planting. These flavors became more marked with increases in the temperatures of the production zone. Many potatoes grown in San Ramon were judged by tasters to be suitable only for frying. Table 4 presents consumer acceptability of other varieties, many of which demonstrated similar taste characteristics.

The relationship between flavor or texture and dry matter content in one variety, Desiree, were measured using numerical codes. Although flavor was only loosely correlated to dry matter, texture was found to have a higher correlation with dry matter content.

In hot regions of the world where the potato is not traditionally consumed, emphasis should be placed on maintenance of acceptable dry matter content so that the potato can compete with locally-adapted carbohydrate sources.

## Conclusions

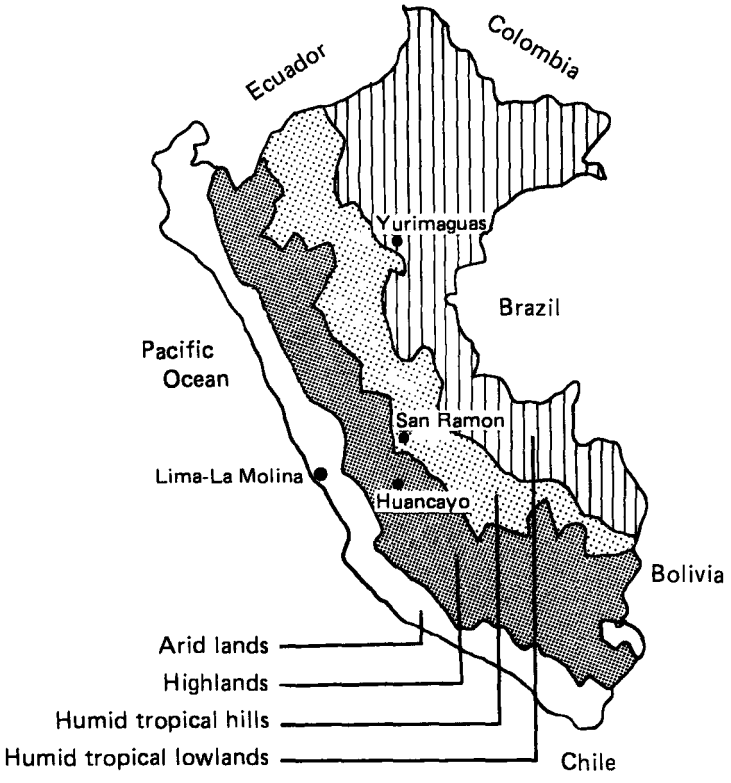
Dry matter, protein, taste, and texture vary in accordance with variations in production environment. There was a tendency for dry matter to decrease with increase in temperature and for flavor and texture quality to diminish. This tendency reached an extreme in the lowland humid tropical zone (Yurimaguas) where the dry matter content of some varieties and clones dropped to 12% and the taste, according to consumer panels, was unacceptable.

Table 3. Results of taste tests at CIP with the variety Desiree, produced at three sites.

| Site/ Treatment | Taste | Texture | Comments |
|---|---|---|---|
| La Molina | | | |
| Control | 2.5 | 2.9 | "Off taste" |
| Soil reflectant | 2.5 | 2.8 | Slightly strange taste |
| San Ramon (rainy season) | | | |
| Control | 2.5 | 2.2 | Metalic taste |
| Mulch | 2.2 | 2.6 | Metalic taste |
| (dry season) | | | |
| Control | 2.3 | 2.6 | Slightly bitter, biting |
| Mulch | 2.1 | 2.7 | Slightly bitter, sticky |
| Yurimaguas | | | |
| pH6 (alkaline soil treatment) | 1.7 | 2.0 | Watery, acid |
| pH4 | - | - | Watery, bitter "Green" taste, biting Suitable for pig feed |
| pH4 + Maize | - | - | Suitable for pig feed |

Table 4. Results of taste tests at CIP with various clones from three production sites.

| Site/ Clone | Taste | Texture | Comments |
|---|---|---|---|
| La Molina | | | |
| Mariva | 3.8 | 3.0 | - |
| DTO-2 | 3.0 | 2.5 | Slightly strange taste |
| DTO-33 | 2.9 | 2.5 | Slightly strange taste |
| San Ramon | | | |
| DTO-2 | 3.0 | 2.9 | Slightly bitter |
| DTO-33 | 2.2 | 2.3 | Slightly bitter |
| 69-47-2 | 2.6 | 2.1 | Slightly bitter |
| 374080.5 | 2.6 | 2.5 | Bitter taste |
| Yurimaguas | | | |
| LT-1 | 2.4 | 2.3 | Biting, slightly hard |
| LT-2 | 2.4 | 2.6 | Slightly acid, sticky |
| LT-4 | - | - | No taste, strange smell, good perhaps for frying |




| | Arid lands | Highlands | Humid Tropical Hills | | Humid Tropical Lowlands |
|---|---|---|---|---|---|
| | <1000m | > 1000m | 500-1000m | | <500m |
| Experimental Station | Lima | Huancayo | San Ramon | | Yurimaguas |
| Growing Season | Jan-Mar | Oct-Mar | Dec-Mar | May-Aug | May-Aug |
| Approximate Season Length (days) | 110 | 150 | 95 | 95 | 70 - 90 |
| Mean Max t°C | 27.9 | 20.6 | 29.0 | 29.7 | 31.4 |
| Mean Min t°C | 19.1 | 6.6 | 18.7 | 17.3 | 19.9 |
| Mean Monthly Rainfall | – | 100 | 235 | 72 | 126 |

Figure 1. Location of CIP experimental stations, and data pertaining to growing seasons.

Agronomic practices to decrease temperature improved dry matter content in some experiments, but differences were not detected by consumers. It is possible that an increase of 1% to 2% in dry matter is not detectable when the total dry matter content remains below 18%.

It is essential to evaluate protein on a fresh weight basis when comparing potatoes produced in different ecological zones because dry matter content varies significantly.

Consumer acceptability is an important part of food production. Consumer acceptance declines with increases in temperature of the production zones. The recommendation is that consumer acceptability tests be made on a selective, rigorous basis at all stages for materials produced in novel production environments such as the hot humid tropics.

References


Bleasdale, J.K.A. and Thompson, R. Some effects of plant spacing on potato quality. Eur. Potato J., 12, 1969. 173-187.

Brush, S.B., Carney, H.J., and Huaman, Z. Dynamics of Andean potato agriculture. Econ. Bot. 35, 1981. 70-88.

Grison, C. La Matiere séche. Influence des conditions de productions. (Institut technique de la pomme de terre). Fiche d'information No. 53, 1973.

Haynes, G.K. The stability of high specific gravity genotypes of potatoes under high temperatures. M.S. thesis, North Carolina University, Raleigh, 1981.

Hoff, J.E., Shuelock, L., and Erickson, H.T. Breeding for high protein and dry matter in the potato at Purdue University. Purdue University Experiment Station, West Lafayette, Indiana, Res. Bull. 953, 1978.

Horwits, W. (Ed.) Official methods of analysis of the association official agricultural chemists. Washington, D.C. AOAC, 1979 p. 858.

Ifenkwe, O.P., Allen, E. J., and Wurr, D.C.E. Factors affecting the relationship between tuber size and dry matter content. Am. Potato J. 51, 1974. 233-242.

Maris, B. Studies on maturity, yield under water weight and some other characters of potato progenies. Emphtlica 18, 1969. 297-319.

Midmore, D. Physiological aspects of potato adaptation to hot humid tropics. In potato production in the humid tropics. Bandung, Indosenia, Oct. 1980. In press.

Moreno, U. Respuesta de la planta de papa a los factores edáficos y climáticos de la Costa y de los Andes del Perú. Anales Científicos XII, 1974. 1-11.

Poats, S.V. Potato preferences. A preliminary examination. Social Science Department. Working paper 1982-3. International Potato Center.

Poats S.V. and Woolfe, J.A. Feeding people with potatoes: The importance of nutritional considerations in potato research and acceptability. Unpublished manuscript, International Potato Center, November 19, 1982.

Simmonds, N.W. Dry matter content of potatoes in relation to country of origin. Potato Res. 17, 1974. 178-186.

Steward, F.C., Moreno, J., and Roca, W.M. Growth, form and composition of potato plants as affected by environment. Annals of Bot. Supplement N° 2. 1981, Academic Press. London, New York.

Verma, S.C., Joshi, K.C. Sharma, T.C., and Malhotra, V.P. Dry matter content of the potato varieties grown at different locations. India Potato Ass. 2, 1975. 15-17.

Verma, S.C., Sharda, R.T., Joshi, K.C., and Sharma T.R. Production and distribution of dry matter in some varieties of potato. Indian J. Pl. Physiol. 12, 1969. 166-172.

Wurr, E.C.D. and Allen, J.E. Some effects of planting density and variety on the relationship between tuber size and tuber dry-matter percentage in potatoes. J. Agri. Sci. Camb. 82, 1974. 277-282.

Wurr, E.C.D., Bean, J.N., and Allen, J.E. Effects of variety and date of harvest on the tuber dry-matter percentage of potatoes. J. Agric. Sci. Camb. 90, 1978. 597-604.