The Development of a Through Circulation Solar Heated Air Drier for Cassava Chips

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ABSTRACT

A pilot scale through circulation drier using solar heated air has been developed for drying cassava chips. Described is design of the drier system, which includes a bottom ventilated drying bin, centrifugal fan and solar collector. In evaluation trials the variables studied were drier loading (37.5 to 150.0 kg/m^2), airflow (11 to 18 $m^3/min.\ m^2$) and varying air conditions in the range 24 to 28°C and 62 to 72% RH. Design parameters for drier scale-up are presented.

Introduction

The great potential in tropical Latin American countries for using dry cassava as a source of carbohydrate in animal feed concentrates (Pachico, 1980; Gómez, 1982) has led to the need for developing efficient methods of drying that are technically and economically suited to production and cost structures prevailing in the region. Natural drying on concrete floors is the method most commonly employed for drying cassava for animal feed. During the 1970s research by various workers aimed at improving natural drying techniques, both on concrete floors (Thanh, 1979) and in vertical and inclined trays (Roa, 1974; Best, 1978). These study results have led to greater understanding of the effect that factors such as chip geometry, loading density and ambient conditions have on the rate of drying.

Despite improvements in drying efficiency and advantages of natural drying over artificial drying in terms of relatively low capital and operating costs, the method remains totally dependent on the weather. Consequently, natural drying is not practical in areas with year round high relative humidity and in regions with marked wet seasons. The periods in which natural drying is possible are restricted. In these cases, the use of forced air, through circulation driers, operating with ambient or heated air, or a combination of both, provide an economically feasible alternative to fully artificial, continuous drying plants whose scale and costs of operation are such that their use in Latin America has seldom met with success (Crown, 1981; Freivalds, 1982).

This paper reports preliminary results of a joint project between the Centro Internacional de Agricultura Tropical, CIAT and the Universidad del Valle, Cali, Colombia, with a principal objective to develop and evaluate a forced air through circulation cassava drier for use by farmers' associations on the Atlantic Coast of Colombia (Ospina et al, manuscript in preparation). The complete evaluation will include a technical and economic comparison of ambient, solar heated and fuel fired air systems: results of trials of the solar heated air system only are presented here.

Drying system

The drying system constructed at CIAT is an adapted version of the system developed at the Centro Nacional de Treinamento em Armazenagem, CENTREINAR, Brazil (Sinicio and Roa, 1980) and consists of a solar collector, a centrifugal fan and a drying bin (Figure 1). The centrifugal fan draws air through the solar collector and passes it through a 305 mm diameter duct into the plenum chamber of the drying bin.

The solar collector, with an area of 10 m^2, is constructed on a concrete base and is made of a 200 mm layer of fine stones upon which are placed concrete blocks, arranged longitudinally along the collector. The concrete blocks, 200 mm square section and 400 mm long, are designed so their cavities may be oriented to maximize solar radiation absorption. The stones and blocks are painted mat black. Above the blocks, a polythene cover is supported by chicken wire and the lateral brick walls of the collector. CIAT's proximity to the equator has made it unnecessary to incline the collector.

The centrifugal fan has forward curved blades driven at 600 rpm by a 1.5 hp electric motor. Air flow can be varied between 0 and 38 m^3/min by adjusting a butterfly valve placed before the plenum chamber. Air flow is measured with a pitot tube connected to an inclined manometer.

The drying bin, with dimensions of 1.0x2.0x1.7 m high, is constructed of brick with a concrete floor. At a height of 60 mm above the floor and supported by wooden cross beams, a galvanized steel sheet with 3% opening (3 mm diameter holes) is placed. Onto this perforated floor, which has an area of 2 m^2, are loaded the cassava chips to be dried. The drying bin is protected from the rain by a corrugated sheet roof raised 800 mm above the walls.

Thermohydrographs are used to monitor ambient temperature and relative humidity and air conditions in the plenum chamber. Solar radiation is measured using an integrating pyranometer.

Procedure

The cassava variety used in the trials was HMC 1, harvested from 12 through to 15 months. The whole cassava roots were washed in a concrete tank before chipping in a Thai type chipping machine (Thanh, et al, 1979). The cassava chips were sampled for fresh moisture content and then loaded into the drier. The change in moisture content of the cassava chips during drying was determined by weighing three 200 mm diameter sampling cylinders placed in the drying bed. At the end of the drying period a further sample of dry cassava was taken for moisture determination. On both fresh and dry samples, moisture content measurements were carried out by drying to constant weight in an oven at 60°C. During drying the cassava was turned at 0800, 1200 and 1600 hours to prevent deterioration of the upper layers of chips, and the fan was operated continuously day and night.

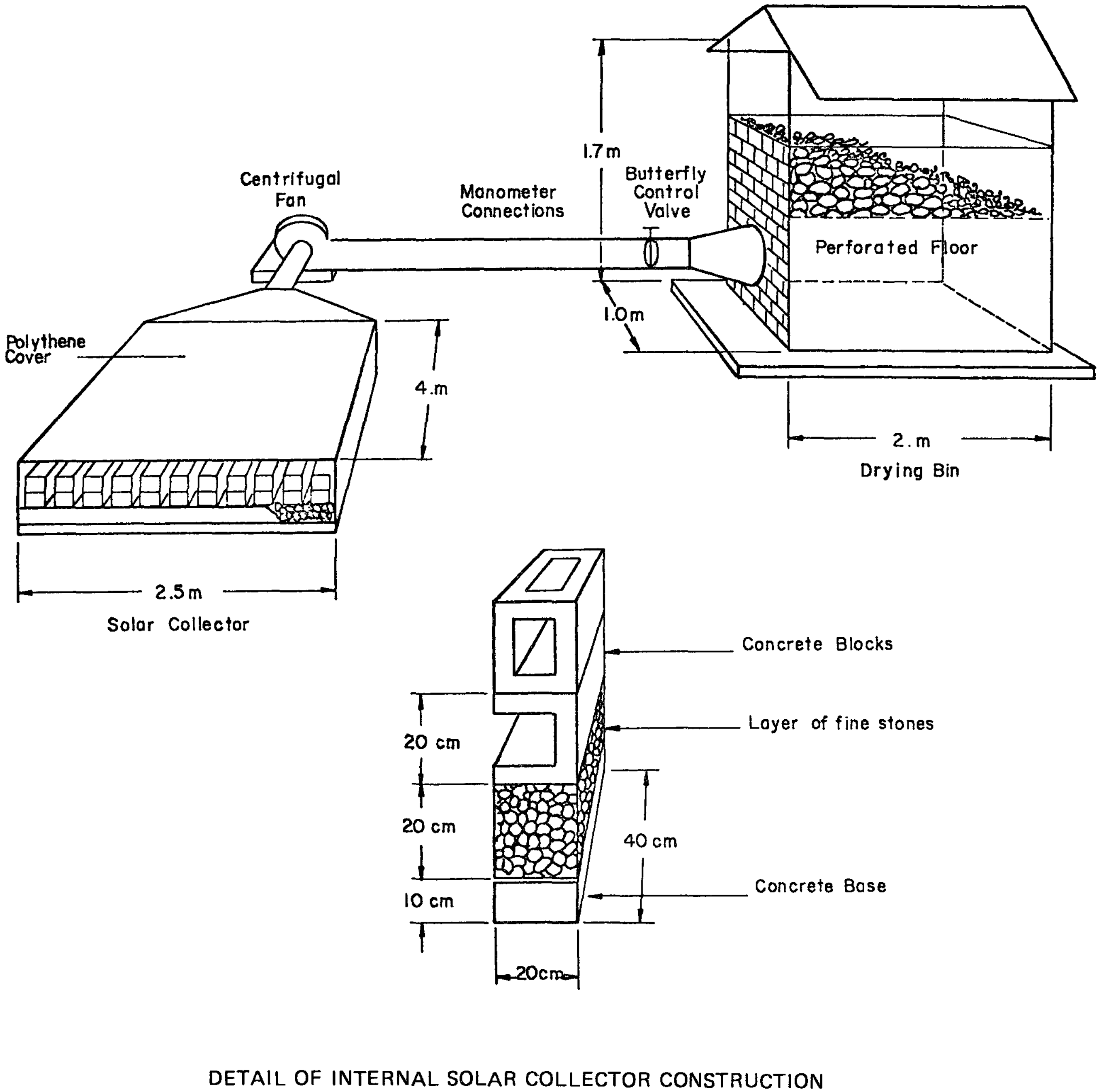

Figure 1. Through circulation cassava drying system with solar collector.

To date three sets of trials have been undertaken as part of the evaluation of the drying system. The objectives of each set of trials were as follows:

1st set: To determine optimum drier loading.
2nd set: To determine optimum airflow rate.
3rd set: To determine the optimum time of starting drying.

Results and Discussion

In analysis of results the parameter used to compare trials is the rate of loss of moisture, in kg of water per hour per square meter of drying floor. This parameter, which is a function of the initial moisture content of the chips, the airflow rate and the temperature and relative humidity of the drying air, gives an indication of drying efficiency.

The results of the first set of five trials, in which the loading rate was varied from 37.5 to 150.0 kg of fresh cassava chips per square meter of drying floor are in Table 1. The drying time increases with increasing loading, however, the rate of loss of moisture is highest at 2.04 kg/h m^2 for a loading of 150 kg/m^2, followed by 1.90 kg/h m^2 for a loading of 75 kg/m^2. At the 150 kg/m^2 loading, discoloration of the cassava chips occurred after 36 hours and a faint malodorousness was observed. It was therefore believed that this loading was too high to produce dry cassava of an acceptable quality. On the other hand, the 75.0 kg/m^2 loading gave a drying time of 25 hours which, taking into account practical plant operating conditions, is too long for a one-day-per-batch system. Under the circumstances it was decided to opt for the 125 kg/m^2 loading which, drying in 45 hours, would fit into a 2-day-per-batch operation.

In the second set of trials, the airflow rate was varied between 11 and 18 m^3 per minute per square meter of drying floor, at a constant drier loading of 125 kg/m^2, Table 2. The rate of loss of moisture for the two extreme conditions of airflow rate were the same at 1.82 kg/h.m^2. However, at the 18.3 m^3/min.m^2 airflow rate the relative humidity of the drying air was six points higher, which suggests that the higher airflow rate will be necessary to allow for the worst drying air conditions encountered.

Finally, a set of four trials was conducted in which drying was started at 0800, 1100, 1400 and 1700 hours, Table 3. The results clearly indicate that in terms of drying time and rate of loss of moisture it is advantageous to initiate drying in the later hours of the afternoon. Starting at 1,700 hours makes best use of the night hours, when relative humidity of the air is high, to remove moisture from the fresh cassava chips and then, on the second day of drying, the hottest hours are available to terminate the process.

An important parameter for selecting an appropriate fan for the drying system is the pressure drop through the drying bed; this never exceeded 0.33 inches water gauge. It was observed during the drying trials that the pressure drop decreased during drying as the resistance to airflow was reduced, presumably because the chips, on losing moisture, lost their tendency to adhere to one another. There was also a noticeable shrinking of the drying bed, for a drier loading of 125 kg/m^2, the thickness of the layer of cassava chips decreased from approximately 250 mm to 180 mm.

Table 1. Determination of optimum drier loading.

Drier loading kg/m²[a]	Initial moisture content % dry basis	Mean airflow rate m³/min.m²[b]	Conditions of drying air T°C	%RH	Drying time h[c]	Rate of loss of moisture kg/h m²[d]
37.5	184	13.4	25	67	22	1.10
75.0	173	12.0	28	59	25	1.90
100.0	178	10.6	28	63	43	1.49
125.0	178	11.2	27	66	45	1.78
150.0	212	11.0	28	63	50	2.04

[a]Drier loading in kg of fresh chips per square meter of drying floor.

[b]Mean airflow rate over the drying period in cubic meters per minute per square meter of drying floor.

[c]Drying time in continuous hours from the time of starting at 1400 hours.

[d]Rate of loss of moisture in kg per hour per square meter of drying floor.

Table 2. Determination of optimum airflow rate. (Drier loading 125.0 kg/m²)[a]

Mean airflow rate m³/min.m²[b]	Initial moisture content % dry basis	Conditions of drying air T°C	%RH	Drying time h[c]	Rate of loss of moisture kg/h m²[d]
18.3	230	24	71	48	1.82
15.7	190	25	71	49	1.67
12.5	228	27	62	71[e]	1.22
11.3	249	26	65	49	1.82

[a]Drier loading in kg of fresh chips per square meter of drying floor.

[b]Mean airflow rate over the drying period in cubic meters per minute per square meter of drying floor.

[c]Drying time in continuous hours from the time of starting at 1400 hours.

[d]Rate of loss of moisture in kg per hour per square meter of drying floor.

[e]In this trial drying was interrupted for 18 hours because of rain.

Table 3. Determination of the optimum time of starting drying. (Drier loading 125.0 kg/m^{2a} and mean airflow rate 16.5 m^3/min.m^{2b}.

Time of starting drying h	Initial moisture content % dry basis	Conditions of drying air T°C	%RH	Drying time h[c]	Rate of loss of moisture kg/h m^{2d}
0800	203	25	72	54	1.55
1100	209	26	69	49	1.73
1400	227	26	67	47	1.85
1700	214	26	67	46	1.85

[a]Drier loading in kg of fresh chips per square meter of drying floor.

[b]Mean airflow rate over the drying period in cubic meters per minute per square meter of drying floor.

[c]Drying time in continuous hours from the time of starting at 1400 hours.

[d]Rate of loss of moisture in kg per hour per square meter of drying floor.

The detailed evaluation of the solar collector has not been concluded. However, during the period of these trials the collector gave average increases in air temperature of between 1° and 3°C, corresponding to reductions of between 4.4% and 9.6% in relative humidity. Yet to be determine is whether the additional cost of the solar collector is justified in terms of increased drier loading, as compared with drying using ambient air alone.

Future work and conclusions

These preliminary results indicate that basically two areas require further investigation. First, a comparison of one-and 2-day drying needs to be made, as the former may be more convenient in terms of root supply to the processing plant and will definitely produce dry cassava of a higher visual quality. It was hoped to evaluate quality of the dried product by measuring the condensed tannin content, production of which during drying could account for the brown discoloration observed. Unfortunately the high tannin content of the periderm (bark) interfered with the results. Secondly, to make better use of the drying capacity of the air, which after a certain drying period leaves the drying bed unsaturated, a double bed bin or a two bin reversible airflow system will be tested.

Although it is evident that further development work is needed, results from these trials show that at a drier loading of 125 kg/m^2 and an airflow rate of 18 m^3/min.m^2, it is possible to dry cassava chips in 2 days, using solar heated air at average temperatures ranging between 24° and 28°C and relative humidities in the range 62% to 72%. This is equivalent to a requirement of 8 square meters of drying floor and 146 cubic meters per minute of airflow for each ton of cassava chips to be dried.

References

Akhtar, J. Drying of cassava with heated air. Asian Institute of Technology. AIT Thesis No. AE-78-5. 1978. 47 p.

Best, R. Cassava processing for animal feed. In Cassava harvesting and processing: Proceedings of a Workshop held at CIAT, Cali, Colombia, 24-28 April 1978. Ottawa, IDRC-114e, 1978. 12-20.

Chirife, J. and Cachero, R.A. Through-circulation drying of tapioca root. Journal of Food Science. 35, 1970. 364-368.

Crown, F. White elephant tales: Venezuela's cassava processing plants. Agribusiness Worldwide. Dec. 1980/Jan. 1981. 24-29.

Freivalds, J. Farm fiction: the feasibility studies for cassava production and processing in Espiritu Santo, Brasil. Agribusiness Worldwide 3(6), 1982.

Gómez, G. Utilización de Raíces y Productos de Yuca en Alimentación Animal. En: Yuca: Investigación, Producción y Utilización. Referencia de los Cursos de Capacitación sobre Yuca dictados por el Centro Internacional de Agricultura Tropical. Compilado por Carlos E. Domínguez. PNVA/CIAT. 1982.

Ospina, B., Best, R., and Gómez, G. Natural drying of cassava for animal feed - the establishment of small scale agroindustries on the Atlantic Coast of Colombia. Paper to be presented at the 6th Symposium of the International Society of Tropical Root Crops. Lima, Peru. February 21-26, 1983.

Ospina, V.E. Quantifiçao de deteriraçao de mandioca durante a secagem em barcaça por conveçcao forçada de ar aquecido com coletor solar. Tesis de Maestría, Universidad Estadual de Campinas, Faculdade de Engenharia de Alimentos e Agrícola. 1980. 100 p.

Pachico, D. Prospects for the feeds concentrates industry in Latin America: Market potential for Colombia. Centro Internacional de Agricultura Tropical, CIAT, Cali, Colombia. Internal Document. March 1980. 24 p.

Roa, G. Natural drying of cassava. Ph. D. Thesis. Department of Agricultural Engineering. Michigan State University. 1974. 234 p.

Rossi, S.J. y Roa, G. Secagem e armazenamento de productos agropecuários com uso de energía solar e ar natural. Secretaria da Industria, Comercio, Ciencia e Tecnología. Academia de Ciencias do Estado de Sao Paulo. Publicación ACIESP No. 22. 1980. 295 p.

Sinicio, R. and Roa, G. Secador Rural de Café, Cacau, Mandioca e outros productos agropecuários com uso de energía solar. Centro Nacional De Treinamento em Armazenagem, CENTREINAR, Viçosa-Brasil. Serie Centreinar No. 1. 1980. 22 p.

Thahn, N.C., Muttamara, S., Lohani, B.N., Rao, B.V.P.C., and Burintratikul. Optimization of drying and pelleting techniques for tapioca roots. International Development Research Centre - Asian Institute of Technology. Final Report No. III. Bangkok, Thailand. 1979. 119 p.

Webb, B.H. and Gill, K.S. Artificial heat drying of tapioca chips. Malaysia Agric. Res. 3: 1974. 67-76.