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Cassava Harvesting and Processing

PROCEEDINGS OF A WORKSHOP HELD AT
CIAT, CALI, COLOMBIA
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EDITORS: EDWARD J. WEBER
JAMES H. COCK
AMY CHOUINARD

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Cassava Harvesting and Processing

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Small-Scale Production of Sweet and Sour Starch in Colombia

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Abstract. Small-scale starch extraction in Colombian rural areas is discussed from the technical and economic points of view. A description of the processes used for producing sweet and sour starches is given together with data on possible mechanisms for fermentation in sour-starch production. It is shown that the fermentation step produces surface modifications on the starch granules and molecular breakdown that seem to be essential for use in bread baking. Sweet starch could be upgraded to meet user specifications on ash and moisture content by modifying the washing-peeling and drying steps. The proposed modifications would not affect the profitability of the process and would open new markets for small-scale sweet starch. Some recommendations are given.

Small-scale cassava starch extraction in rural Colombian areas probably has much in common with that in other countries. It comprises two processes — sour and sweet — that supply two noncompetitive markets. Sour starch, obtained by fermentation following extraction, is used exclusively in the food industry, and sweet starch competes with cornstarch in the textile, paper, and adhesive industries. Sour cassava starch is used in the preparation of *pan de yuca,* a traditional bread that is made of starch; hard, salted unfermented cheeses; eggs; and water.

The functional properties of the two starches differ. When viewed under the microscope using polarized light, the granules of starch are similar in size and shape, although the sour starch granules show a partial loss of birefringence and a marked tendency to aggregate. Under the scanning electron microscope (SEM), the two starches show significant differences. All the granules are round or oval in shape, some with truncated concave edges, but the sweet starch granules appear smooth and homogeneous and those of sour, or laboratory acid-treated starches[1] resemble dented balls (Fig. 1).

Other properties of the three types of starches (sweet, sour, and acid-treated, Table 1) indicate that fermentation involves more than a surface attack on the granules.[2] Although the sour and acid-treated starches look similar, there are substantial differences in the average molecular weight and alkali number (30 000 and 8.2 and 136 000 and 3.5 respectively). Acid treatment produces a viscosity similar to that of the sour starch (Fig. 2) but does not reduce molecular weight sufficiently to be suitable for use in *pan de yuca* baking (Table 2). It would appear that the starch molecules break down internally through enzymatic action, probably of microbial origin, produced during fermentation.

Quality specifications of starch as currently used by several industrial groups in Colombia are shown in Table 3. They are generally applied to cornstarch, which accounts for a high proportion of the total market, but are also commonly extrapolated to other starches. They include some notable inconsistencies that suggest a lack of knowledge on the part of starch users — for example:

- Regulations for some products insist on the removal of crude fat or fibre, although it is commercially impossible, and in the case of sausages, makes no sense;
- The specifications given for bakery products probably correspond to sour starch, whereas the

[1]The mechanisms involved in the modification of the starch were studied by acid treatment of sweet starch.

[2]Surface differences between sweet and sour starch can be observed under the SEM, but acid-treated and sour starch appear similar.

Table 1. Some characteristics of sweet, sour, and acid-treated cassava starch.

	pH (20 °C 10% water suspension)	Starch (%)	Alkali no.[a] (ml/g)	Specific vol	Mol. wt[b] (g/mol)	Viscosity[c] (BU) 90 °C	63 °C	50 °C
Sweet starch	6.0–6.5	97	1.2	2.0	215.000	1.300	500	800
Sour starch	3.5–4.0	96–99	8.2	4.2	30.000	560	360	140
Acid-treated[d]	3.5	97	4.8	2.2	136.000	680	200	280
Acid-treated[e]	3.6	97	5.1	2.3	–	550	200	300

[a]Reducing end groups determination by the alkali number according to Schoch (1967).
[b]Potenciometric method, according to Ceh (1976).
[c]5.5% water suspension.
[d]20 days at 37 °C with a mixture of acetic, butyric, lactic 2:1:1 acids (pH 3.6).
[e]10 days at 37 °C with acetic acid (pH 3.5).

Table 2. Functional properties of sweet, sour, and acid-treated starch in *pan de yuca* making.[a]

Starch	Specific vol.	Crumb structure	Other properties
Sour starch	4.2	Loose structure, large alveola	Thin and crispy crust
Acid-treated[b]	2.2	Dense structure, small alveola	Thick crust, characteristic flavour diminished
Acid-treated[c]	2.3	Dense structure, small alveola	Thick crust, characteristic flavour diminished
Sweet starch	<2.0	Very poor	Very light cheese flavour

[a]Baked product (200 °C) made from sour cassava starch, hard, salted unfermented cheese (1:1), 1 egg per pound of starch, and water; no leavening agent is added. Final weight is 22 g.
[b]20 days at 37 °C with a mixture of acetic, butyric, and lactic acids.
[c]10 days at 37 °C with acetic acid (pH 3.5).

Table 3. Quality specifications for starch in Colombia.

Characteristic	Cardboard	Paper	Bakery	Sausages
Moisture (% range)	7.0–14.0	11.0–12.0	14.0	11.0–13.0
Fat (% maximum)	0.04	absent	0.7	absent
Crude fibre (% maximum)	–	absent	–	0.1
Crude protein, Nx6.25 (% maximum)	0.35	0.5	0.6	0.4
Ash (% maximum)	0.10	0.40	0.2	0.2
Colour	White	White	Light yellow	Light yellow
pH (aqueous suspension)	5.0	7.0	4.2–5.5	6.0
Scott viscosity (cold)	80–100	–	–	–
Scott viscosity (hot)	–	75	–	90–100
Gelatinization temp (°C)	74	70–75	–	80–82

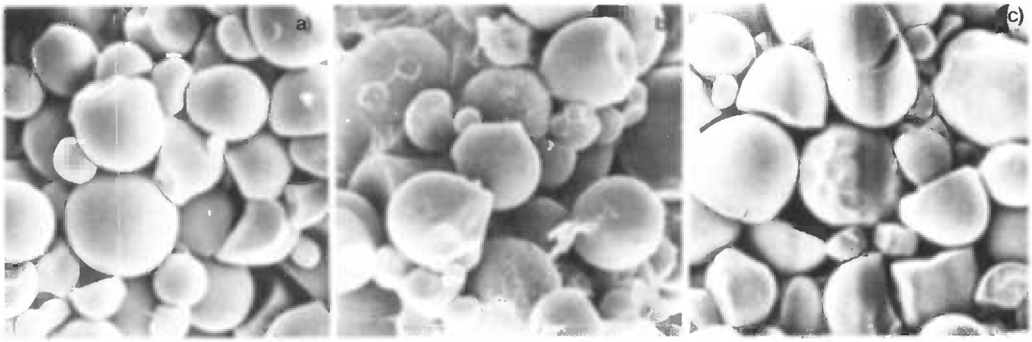

Fig. 1. Photomicrographs of starch granules: sweet starch, a); sour starch, b); and starch that has been treated with lactic acid, 10 days, and has a pH 3.6, c).

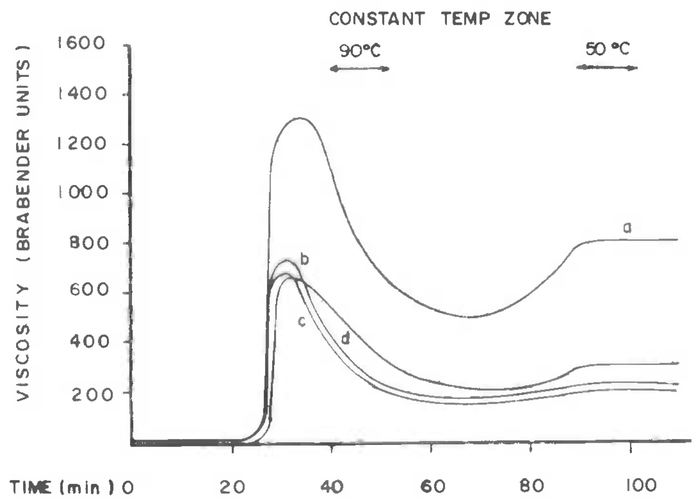

Fig. 2. Amylographs of sweet, a); sour, c); and acid-treated — acetic-butyric-lactic, 2:1:1 20 days, pH 3.6, b); acetic, 10 days, 37 °C, pH 3.5, d) — cassava starches at 5% suspension.

other specifications refer exclusively to sweet starch;

- Gelatinization temperatures for sausage use are abnormally high;
- Some important characteristics, such as speck count and cleanliness, are lacking.

No matter how irrational the specifications may seem, the starch producers must attempt to comply. At present, cassava starch obtained by small-scale rural processes seldom fulfills user specifications. A typical product may contain 17% moisture, 0.3% crude protein (N × 6.25), 0.4% crude fibre, 0.2% ash, and 0.06% crude fat, its pH ranging between 3.1 and 4.0.

A detailed look at the steps in starch production brings to light some instances where improvements might be introduced. The initial steps (washing, peeling, grating, screening, and settling) are exactly the same for sweet and sour starch.

Washing and Grating

The roots are received in the factory within 24 hours after harvesting. They have been packed in jute sacks together with some leaves that are said to protect them against mechanical damage during transportation. The raw material is stored for a maximum of 3 days before processing (Fig. 3).

During peeling, the workers reject dark roots or cuts of roots as well as any softened or otherwise damaged material. In the large-capacity factories, washing-peeling is mechanized, but generally it is carried out by hand with the help of ordinary knives. Sometimes, it is necessary to follow mechanical washing-peeling by a hand operation.

After peeling, the roots are washed, although in many instances they do not become completely clean. The soil strongly adheres to the inner skin and to the pulp and is doubtless the cause of the high ash content in the finished product. A marked improvement would be possible if the roots were washed before and after peeling. In fact, experiments have shown that washing-peeling-washing can cut ash content in half.

The peeled roots are fed to a motor-powered grating machine that has a rotating cylinder with sharp protrusions. The roots are pressed against the moving cylinder and reduced to pulp, releasing most of the starch granules. At times, especially using homemade equipment, large portions of roots can go through the machines without being crushed, thus reducing final yield. The grating or rasping machines are, in general, only operated at selected intervals because they have a higher capacity than the equipment for screening.

Screening, Settling, and Refining

The pulp is fed into a revolving metal cylinder (1 m diameter × 0.80 m height) where it is mixed with water. The inner part of the cylinder is equipped with buckets that aid in the mixing action and in later discharging the waste pulp. The lateral surface of the cylinder, which has 1-cm openings and a filter of cotton cloth inside, acts as a sieve. As the starch granules are set free and suspended in water, they flow through the sieve, leaving the pulp behind. Water is continuously added to the revolving cylinder until a completely clear liquid comes out. Screening is performed only once, and the screen openings, which approximate 100-mesh size, are so large that they do not satisfactorily reduce the fibre content.

In some less-mechanized processes, a piece of wool cloth is stretched over a container, and when the pulp is fed onto the cloth, an operator mixes it with water by hand.

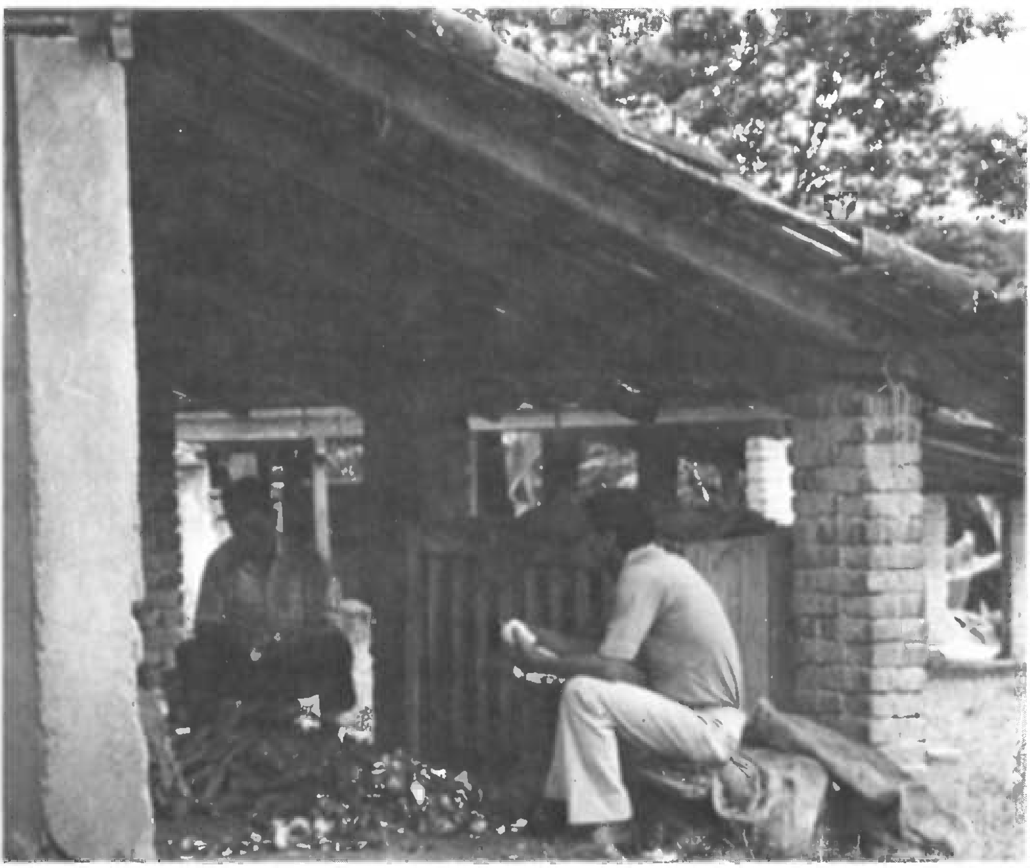

Fig. 3. *In this small-scale starch factory, the roots are peeled by hand but not washed beforehand. The ash content, therefore, is likely to be high.*

The starch milk goes to rectangular brick tanks that are covered by glazed tile. The dimensions and number of the tanks vary according to the size of the factory. The starch is allowed to settle in tanks for 3–7 days; then the supernatant water is drawn off to the level of the upper layer of settled material. This layer is called *mancha* (literally "stain") and is composed of starch and protein. It is scraped from the surface of the white starch and discarded. This operation is generally the only refining step conducted, and it is not repeated. Thus, the resulting starch still contains significant quantities of proteinaceous materials.

After the *mancha* has been removed, the product is sweet starch and can be dried directly or allowed to ferment and become sour starch. In the latter process, the starch is transferred to tanks to ferment. In this step, the starch is resuspended in water and left to stand 8–20 days. The settled starch is covered by a thin layer of water, and sometimes a small layer of waste pulp is added.

Fermentation

Fermentation is produced by several microorganisms that comprise lactic acid bacteria together with lesser amounts of gram-positive rods (probably butyric acid bacteria), yeast, and fungi. The fermentation lasts for close to 20 days under ambient conditions in the tropical areas (25 °C and 80% relative humidity). Within a few days, the pH drops from 6.5 to 3.5 or even lower and remains stable. Samples taken from three sour starch factories indicated that, after fermentation, lactic acid predominates in the supernatant with acetic — and sometimes butyric — acid also present.

After fermentation, the excess water is removed and the product dried.

Drying

Drying is the same for both sweet and sour starch. The starch is broken into small lumps (1–3 cm) and spread out in thin layers (less than 3 cm) on large open areas for sun drying. It is normally deposited on concrete yards, wooden trays placed on wood supports 1 m high, or on the roof of the factory (some roofs are equipped with sliding lids that can be pulled over the starch in foul weather). Drying generally takes between 24 and 120 hours, during which time dirt contamination is a real problem. The operators move the starch frequently to speed up the process, but sometimes during the rainy season, drying is so slow that the starch is spoiled by extended microbial attack.

The workers usually judge the dryness of the starch by feeling it. Thus, the moisture content fluctuates and is often too high to meet user specifications. The dry starch is packed in kraft paper bags or in cotton sacks without additional grinding or sieving.

Improvement of the quality of the starch is obtained with mechanized drying (50 °C, 6 hours), which lowers ash content from 0.20 to 0.14%. Artificial drying is rare, possibly because many people believe that the sour starch cannot be dried at temperatures above ambient. Our studies indicate, however, that drying at 50 °C does not adversely affect the quality of standard *pan de yuca*.

Economics of Starch Production

The processing, structure, and uses of sweet and sour starch differ, so it would follow that the economics are also different, as a look at the required investment, production costs, and profitability proves.

In calculations presented here, a hypothetical capacity of 500 kg/hour, based on fresh cassava roots, has been assumed, because this capacity corresponds to a large rural starch plant. A typical yield of 20%, 300 days/year, 10 hours/day has also been assumed. The cost/t of sweet starch is approximately U.S. $335.20 and U.S. $340.00 for sour starch.

Capital investment is higher for the production of sour starch (U.S. $30 500) than for the production of sweet starch (U.S. $20 500). Extra equipment (fermentation tanks) and in-process material account for the difference. Machinery constitutes 24.6% of fixed capital in sweet-starch and 45.5% in sour-starch production. Product inventories and credit to customers account for 80–90% of the working capital and for 24–30% of total investment (Fig. 4 and 5).

Raw materials constitute 84–85% of the total production costs (U.S. $100 600 for sweet starch and U.S. $102 100 for sour starch), whereas capital charges account for only 1.7–3.2% (Fig. 4a and 5a). The introduction of mechanized drying would increase the fixed capital by 38% and would bring the total capital investment to 24.5%. However, it would increase the total cost of production of sour starch only 3.9%, because the capital charges represent only 3.2% of the total cost. The figures are similar for the sweet-starch operation.

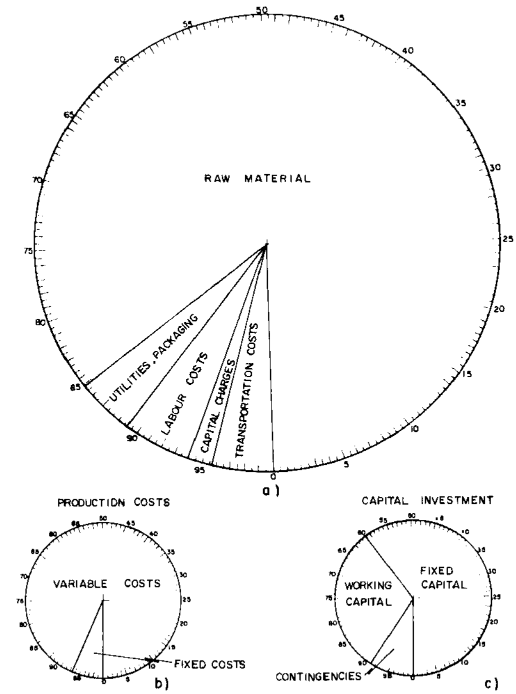

Fig. 4. Production of sweet cassava starch (percentage distribution of production costs and capital investment).

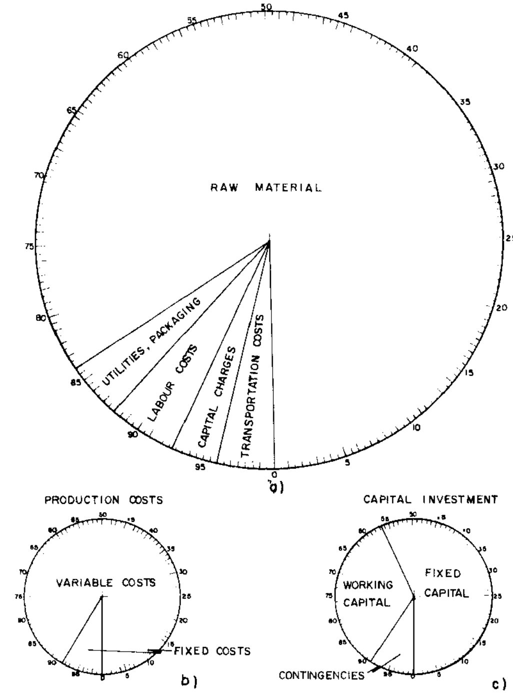

Fig. 5. Production of sour cassava starch (percentage distribution of production costs and capital investment).

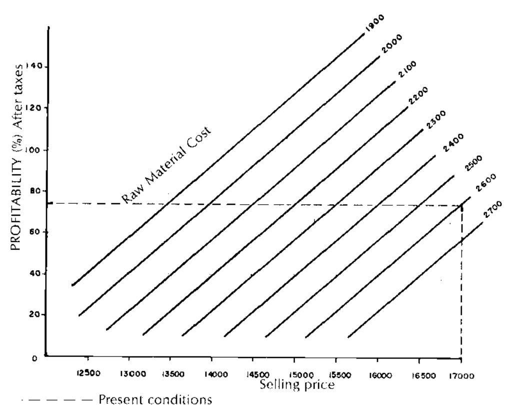

Fig. 6. Production of sweet cassava starch (return on investment, Col. $/t).

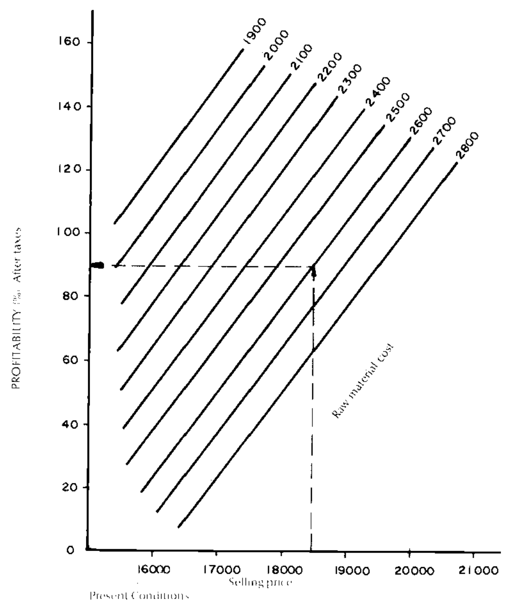

Fig. 7. Production of sour cassava starch (return on investment, Col. $/t).

Selling Price and Profitability

Profitability is based on return on investment (Fig. 6 and 7). Operating at full capacity, the manufacturers' return on fixed capital is 59.8% for sweet starch and 133.8% for sour starch.

The interrelationships between starch price, fresh cassava roots' cost, and profitability are very important. For example, a selling price of Col. $14 000/t of sweet starch based on Col. $2200/t for fresh roots nets a profit of 40%, whereas at Col. $1900/t for fresh roots, the profit is increased to 95%. A sour starch price of Col. $1700/t and the same cost of raw material means a profit of 107%, going up to 147% for the lower cassava price.

The present raw-material costs and selling prices correspond to acceptable levels of profitability.

Conclusions and Recommendations

The raw materials in starch production represent 84–85% of total costs, i.e., the economy of the process is dependent on a constant supply of cassava roots. Thus, efforts to improve agricultural yields are necessary if sweet cassava starch is ever to compete with cornstarch for industrial markets. It will also be important to rationalize the industrial specifications for different cassava starch applications, and it would be convenient to study the possibility of creating agroindustrial complexes in which the agricultural production, the starch processing, and the marketing of the product could be integrated without excluding existing small factories.

Studies also need to be oriented toward improving the efficiency of the different operations within cassava starch production, focusing on technology appropriate to the rural processor.

The rural cassava starch industry is important enough in tropical areas of Colombia to warrant both technical assistance and financial support. The former should include research into appropriate designs for solar or conventional starch driers, and the latter should take the form of credit for working capital and for the purchase of additional equipment.