

**SESSION 5:**  
**TECHNOLOGY DEVELOPMENT**

# IMPROVING CASSAVA SOUR STARCH QUALITY IN COLOMBIA<sup>1</sup>

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## Introduction

Fermented or “sour” starch extracted from cassava is used in Colombia to prepare traditional, gluten-free, cheese breads such as *pandeyuca* and *pandebono*. Starch extraction consists of peeling, washing, and grating fresh cassava roots. The pulp is then screened under running water to obtain starch milk or *lechada*. The starch is then sedimented out and placed into wooden or tiled tanks (about 1 m<sup>3</sup>), where it ferments naturally over 20 to 30 days under anaerobic conditions and at an average temperature of 21 °C. The resulting sour starch is then sun-dried to obtain a stable product with 10%-15% moisture, and is marketed (Brabet and Dufour, 1996; Jory, 1989).

Bread-making potential (BMP) is the main criterion of quality for sour starch and is defined as the ability of the starch to swell during baking (Laurent, 1992).

Although quality and rapidity are two major issues in cassava starch production, sour starch is still produced according to traditional methods. Hence, sour starch is highly variable in product quality, limiting its use in food industries.

Fermentation and sun-drying critically influence the BMP of sour starch (Brabet and Dufour, 1996; Larssonneur, 1993). Developing adequate control of and suitable practices for these two processing steps would help stabilize and improve sour starch's economic value and strengthen the status of this agroindustry.

Cassava processors sometimes improve sour starch quality by inoculating batches with surface water from fermentation tanks in which good quality products have been produced. But this practice still results in irregular quality of sour starch.

We therefore studied the natural fermentation of cassava starch in detail, in an attempt to relate the nature of microflora and their effect

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1. No abstract was provided by the authors.

on final product quality. We then carried out a cassava starch inoculation trial, using amylolytic lactic acid bacteria (ALAB), isolated and selected from previous fermentation kinetic studies. Our purpose was to standardize product quality and reduce fermentation time.

We also carried out studies to confirm the role of sun-drying in the acquisition of BMP, and to determine the key factors responsible. The trials involved sun-drying kinetic studies, oven-drying at 40 °C and at 55 °C, drying under cover, oven-drying at 40 °C under ultraviolet (UV) light, and drying with water added.

## Cassava Starch Fermentation

### Natural fermentation

Natural fermentation of cassava starch is characterized by the presence of a predominantly lactic acid flora ( $10^8$ - $10^9$  cfu/g dry matter of starch), confirmed by the rapid and drastic decrease of pH (7 to 3.5 in 5 days), while total acidity increases because of a mainly lactic acid production (Brabet and Dufour, 1996). Lactic acid flora has an active catabolism but its level is constant during fermentation.

At the start of fermentation, starch is the main source of fermentable sugar. Gómez (1993) isolated 75 lactic acid bacterial strains, exhibiting good amylolytic activity, from natural cassava starch fermentation. This ALAB strain bank is currently being molecularly and biochemically characterized.

Previous works have shown modifications of cassava starch physicochemical and rheological characteristics during fermentation (Brabet and Dufour, 1996; Brabet and Mestres, 1991; Camargo et al.,

1988; Cárdenas and de Buckle, 1980; Larssonneur, 1993; Nakamura and Park, 1975).

### Effect of a starter culture on cassava starch fermentation and quality

A fermentation with starch inoculation was carried out at the "SDT Agroindustrial," a starch-processing plant in La Agustina, Cauca Department, Colombia, using cassava lactic acid bacterial strain, ALAB 20, used for the starch inoculation trial, was isolated from a previous natural cassava starch fermentation and identified as *Lactobacillus crispatus*, using the Gómez (1993) API 50CH system. Flores (1993) studied the physiological parameters of this ALAB 20 strain during a lactic acid fermentation on an MRS-starch medium in a bioreactor. (The glucose in the medium was replaced by soluble starch.)

The fermentation tank was partitioned into two: one part for natural fermentation and the other for inoculated-starch fermentation. Inoculated and noninoculated *lechadas* (aqueous starch suspensions) were first sampled. Then, samples of inoculated and noninoculated starch were taken at 1, 2, 3, 4, 5, 7, 10, 14, and 20 days of fermentation.

**Changes in amylolytic and total lactic acid flora.** Total lactic acid flora on MRS medium showed no significant difference between inoculated and noninoculated starch (Figures 1 and 2). This flora reached  $10^8$ - $10^9$  cfu/g of dry matter of starch on the second day and remained constant until the end of fermentation. In contrast, as a proportion of total flora, amylolytic flora on MRS-starch medium (MRS

medium where glucose was replaced by 20 g/L of soluble starch) were in a higher proportion in inoculated starch than in noninoculated (Figures 1, 2, and 3). Furthermore, flora were heterogenous during the natural fermentation, whereas the inoculated fermentation resulted in a predominance of the ALAB 20 strain.

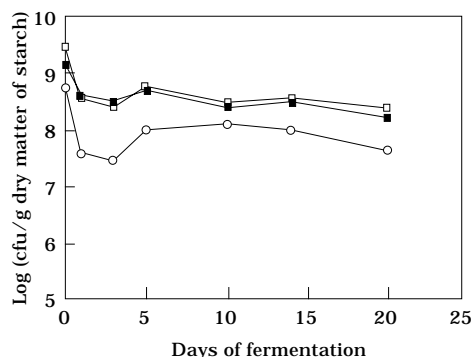


Figure 1. Changes in anaerobic microflora on MRS and MRS-starch media in natural fermentation. (□ = total lactic acid flora on MRS agar; ■ = total flora on MRS-starch agar; ○ = amylolytic flora on MRS-starch agar.)

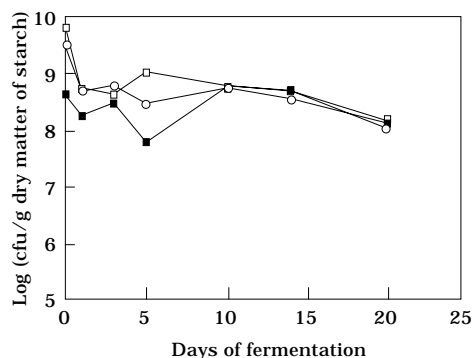


Figure 2. Changes in anaerobic microflora on MRS and MRS-starch media in inoculated-starch fermentation. (□ = total lactic acid flora on MRS agar; ○ = total flora on MRS-starch agar; ■ = amylolytic flora on MRS-starch agar.)

**pH and lactic acid production.**

In the inoculated-starch fermentation, acidification was more notable during the first 5 days of fermentation, but pH value finally stabilized at 3.5 (pK<sub>a</sub> of lactic acid) in both fermentations (Figure 4). The inoculated fermentation produced slightly more lactic acid (Figure 5) during the first days of fermentation.

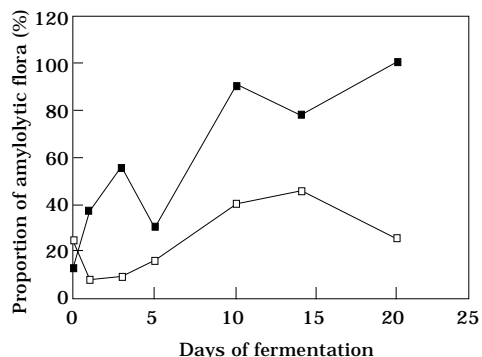


Figure 3. Evolution of amylolytic flora as proportion of total flora on MRS-starch medium during cassava starch fermentation. (□ = natural fermentation; ■ = inoculated-starch fermentation.)

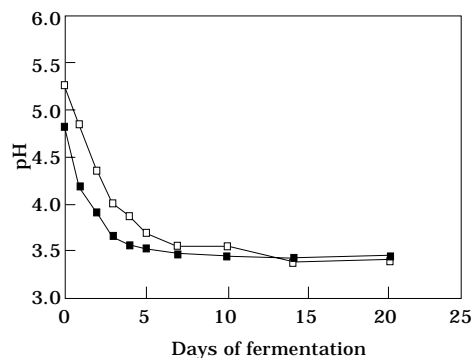


Figure 4. Evolution of pH during cassava starch fermentation. (□ = natural fermentation; ■ = inoculated-starch fermentation.)

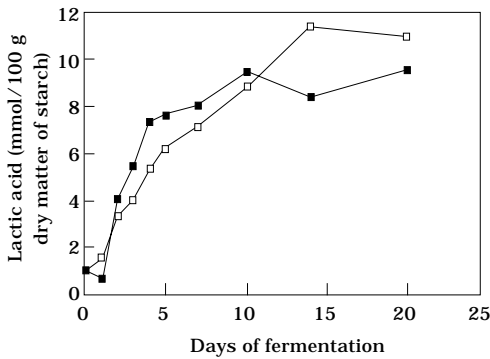


Figure 5. Evolution of lactic acid content during cassava starch fermentation. (□ = natural fermentation; ■ = inoculated-starch fermentation.)

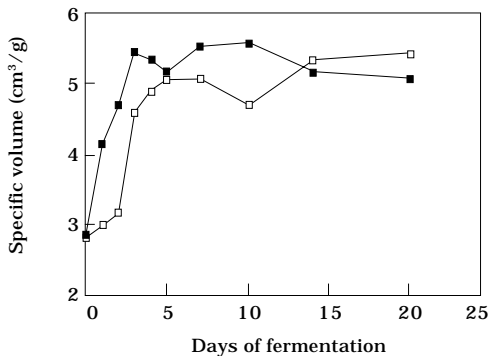


Figure 6. Evolution of cassava starch bread-making capacity during fermentation. (□ = natural fermentation; ■ = inoculated-starch fermentation.)

**Bread-making potential of starch.** Inoculation of cassava starch with ALAB 20 allowed the final BMP to be reached 10 days earlier, compared with natural fermentation. But the final BMP of the starch was not improved (Figure 6).

## Sun-Drying Cassava Sour Starch

### Importance of ultraviolet radiation

Kinetic studies of drying cassava sour starch in the sun (8 h) were realized.

Sour starch specific BMP increased from 2 cm<sup>3</sup>/g (wet starch) to at least 5 cm<sup>3</sup>/g in 4 h of sun-drying (Larsonneur, 1993). The same starch sample, when oven-dried at 40 °C (slow drying) or 55 °C (rapid drying), or dried under cover for 8 h, did not expand (specific BMP of 2-2.5 cm<sup>3</sup>/g).

These results demonstrate the need for sun-drying if sour starch is to acquire BMP, and the importance of solar radiation. The results also explain why Brazilian plants producing cassava sour starch do not artificially dry starch during the rainy season but ferment it instead for various months until the dry season arrives.

Oven-drying trials of sour cassava starch at 40 °C and under a UV lamp (Cole-Palmer, G-09817-20, 4 W, 254 nm and 366 nm) were conducted for 8 and 16 days. Under UV radiation, the sour starch's capacity for bread making increased to a value close to that of the sun-dried starch control, whereas oven-dried samples expanded little:

Treatment	Bread-making potential (cm <sup>3</sup> /g) at:		
	8 h	8 days	16 days
Sun-drying	6.82	6.82	
Oven-drying at 40 °C		2.46	3.18
Oven-drying at 40 °C and under UV:			
254 nm		3.94	4.95
366 nm		3.78	4.75

These results show that UV radiation is one of the different types of sun radiation able to develop the BMP of cassava sour starch. Compared with 8 h of sun-drying, the lengthy period (8 and 16 days) needed to increase the bread-making capacity

of sour starch may be explained by the low power (4 W) of the UV lamp used.

### **The role of water in sun-drying sour starch**

Water content of cassava sour starch during sun-drying plays an important role in improving the starch's bread-making capacity. For example, cassava sour starch oven-dried at 40 °C for 8 h, then rehumidified to 50% and sun-dried for another 8 h, had a higher bread-making capacity (5.10 cm<sup>3</sup>/g) than the same starch sample dried under the same conditions but without the additional water (3.75 cm<sup>3</sup>/g).

Better results are obtained (7.4 cm<sup>3</sup>/g) if sour starch is sun-dried at 40 °C for 8 h, then sun-dried for another 8 h, but with water added every hour for 3 h. In contrast, the expansion of the starch in the sun-dried control (8 h) was 5.03 cm<sup>3</sup>/g.

## **Conclusions**

To improve the quality of cassava sour starch, the following recommendations should be made to the *rallanderos* (cassava sour starch producers):

- (1) *To ferment.* Starch should be fermented for at least 20 days. The pH should be controlled at 3.5. The fermentation tank should be covered with about 5 cm of water to ensure anaerobic conditions and lactic acid fermentation.
- (2) *To dry.* Sour starch should be dried under sunny conditions. Starch samples should be turned over to ensure exposure of all starch granules.

The preliminary results of starch inoculation trial demonstrated that the use of ALAB 20 as a starter culture helped reduce fermentation time. Replicated starch inoculation trials, using the same strain, will be undertaken to confirm these results. Other lactic inocula will also be investigated for reducing fermentation time and improving cassava sour starch quality.

From the results cited above, the concept of an artificial drying apparatus, using UV radiation and controlling starch moisture, can be visualized. This would make standardizing sour starch drying and quality possible, which would no longer be at the mercy of the weather.

Studies are being conducted to evaluate the influence of cassava variety and root storage on sour starch quality. Climatic conditions and the water used during production may also have effects.

## **Acknowledgments**

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## **References**

- Brabet, C. and Dufour, D. 1996. El almidón agrío de yuca: producción y estudios de los propiedades fisicoquímicas. In: Proceedings of the Simposio en Carbohidratos, del 4 al 6 octubre 1993, Quito, Ecuador. p. 197-203.

- \_\_\_\_\_ and Mestres, C. 1991. Evaluación de las modificaciones estructurales del almidón de yuca durante la fermentación: medida de la viscosidad intrínseca y técnica de cromatografía de permeación en gel. In: Proceedings of the taller "Avances sobre Almidón y Yuca"; abstracts, 17-20 June, Cali, Colombia. CIAT, Cali, Colombia. p. 1-6.
- Camargo, C.; Colonna, P.; Buleon, A.; and Richard-Molard, D. 1988. Functional properties of sour cassava (*Manihot utilissima*) starch/polvilho azedo. *J. Sci. Food Agric.* 45:273-289.
- Cárdenas, O. S. and de Buckle, T. S. 1980. Sour cassava starch production: a preliminary study. *J. Food Sci.* 45:1509-1512, 1528.
- Flores, C. 1993. Estudio preliminar del comportamiento fisiológico y enzimático en bioreactor de cuatro bacterias amilolíticas aisladas del almidón agrio de yuca (*Manihot esculenta* Crantz) en Colombia. Informe de trabajo. CIAT, Cali, Colombia. 22 p.
- Gómez, Y. 1993. Bacterias lácticas amilolíticas presentes en la fermentación del almidón agrio de yuca. Thesis. Facultad de Ciencias, Departamento de Biología, Universidad del Valle, Cali, Colombia. 69 p.
- Jory, M. 1989. Contribution à l'étude de deux processus de transformation du manioc comportant une phase de fermentation: le gari au Togo, l'amidon aigre en Colombie. Mémoire de Mastère en technologie alimentaire régions chaudes. Ecole nationale supérieure des industries agricoles et alimentaires (ENSIA) and CIRAD, Montpellier, France. 45 p.
- Larsonneur, S. 1993. Influence du séchage solaire sur la qualité de l'amidon aigre de manioc. Projet de fin d'études. Génie biologique, produits biologique et alimentaires, Université de technologie de Compiègne, France. 87 p.
- Laurent, L. 1992. Qualité de l'amidon aigre de manioc: validation d'une méthode d'évaluation du pouvoir de panification et mise en place d'une épreuve descriptive d'analyse sensorielle. Projet de fin d'études. Génie biologique, produits biologiques et alimentaires, Université de technologie de Compiègne, France. 68 p.
- Nakamura, I. M. and Park, Y. K. 1975. Some physico-chemical properties of fermented cassava starch ("polvilho azedo"). *Starch/Stärke* 27(9):295-297.

# INVESTIGATING SOUR STARCH PRODUCTION IN BRAZIL

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## Abstract

In sour starch producing countries such as Brazil and Colombia, most production is from small and medium-sized plants. If the sector is to develop, it must adapt to changing circumstances, environmental factors, and market demand for improved product quality. Data on current processing operations are essential for identifying and prioritizing development and modernization needs.

This paper presents the results of a detailed, in-depth investigation of sour starch production in southern Brazil. We first describe the major processing operations: root preparation, disintegration, screening for fiber removal, sedimentation, and drying. Then we discuss the inputs and outputs for each operation, the composition of products and intermediates within the process, and, in particular, the volume and composition of waste waters—a factor of increasing environmental concern.

The data are then related to starch production technology used in other

countries. Areas identified for future development and improvement include quality definition and standardization, marketing and promotion, and pollution abatement measures.

## Introduction

### *Production of sour starch*

In Brazil, sour starch (*polvilho azedo*) is manufactured principally in the State of Minas Gerais (MG), with additional production in São Paulo and Paraná States. Plants are typically small to medium-sized, processing about 10-20 t/day of roots, although larger plants can process as many as 50 t/day.

An estimated 80 plants operate in the municipalities of Cachoeira da Minas and Conceição dos Ouros, in the region of Pouso Alegre, southern MG. Typical plants produce about 3 t/day of starch, although some larger plants produce 10-15 t/day. The Empresa de Assistência Técnica e Extensão Rural (EMATER) (personal communication, 1993) suggests that the region produced about 18,000 t in 1986, and is now producing 12-13 thousand tons per year.

Sour starch production is also concentrated around Divinópolis

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where about 10 small plants operate, each employing three to four people and producing more than 100 t of starch per year (EMATER, personal communication, 1993). These exist alongside more than 100 very small starch production units, based on family farms, which sell to the local market, supermarkets, bakeries, and households. The total 1985 production in the Divinópolis region was estimated to be about 10,000 t. Current production is probably below this figure if trends mirror those of the Pouso Alegre region. No apparent change has occurred in the number of the region's plants during the last 3 years.

Sour starch is used in certain snacks, mainly *pão de queijo* and *biscoitos*, on sale in public eating places such as cafés and bus stations. The market for these products is stagnating, because of increasing competition from other snack products and the effects of the current economic climate on consumer spending. However, *pão de queijo* has recently begun to be marketed through a fast-food chain which specializes in the product, and supermarkets have begun stocking it as a frozen product.

Although this expanded market has resulted in a more buoyant demand for sour starch, it has not had the kind of effect on the industry that might have been expected. In Paraná State, especially, producers of *pão de queijo* are increasingly replacing sour starch with industrially produced, unfermented, sweet starch (*fecula*), or sun-dried sweet starch (*polvilho doce*).

If the local sour starch industry is to survive, it must adapt to changing circumstances—e.g., increased demand for an improved quality product, increasing costs of inputs, and concern for environmental conservation—by improving its

processing methods. Before changes can be made, accurate and detailed data are needed on current processing operations. Cereda and Takahashi (Ch. 25, this volume) have gathered information on processing operations in *farinha* and native starch industries in Brazil. But comprehensive data are unavailable on operations and problems experienced in small and medium-sized sour starch plants. We, therefore, conducted a detailed analysis of plant operations in two plants in Minas Gerais.

### Production Technology

The small- to medium-scale production of sour starch in Brazil is schematically similar to that of sour starch in Colombia as described by Salazar de Buckle et al. (1971) (Figure 1).

Lorry loads of fresh roots are delivered to the plant and fed into a rotary washer fitted with overhead water sprays for part of its length. As well as washing off dirt and debris, the tumbling action of the roots as they pass along the washer also removes most of the bark. Washed roots are transferred to the hopper-fed, root disintegrator, via an inspection conveyor, at which an operator cuts up excessively large roots, and removes remaining bark and stems.

All plants employ similarly constructed disintegrators known as the "Jahn rasper" (Grace, 1977; Radley 1976). This machine consists of a hollow, cylindrical drum, with tooth-edged steel blades sandwiched between local hardwood slats fixed longitudinally to its surface. The drum is mounted between two circular steel endplates on a central shaft and housed inside a steel casing, the base of which includes a screening plate.

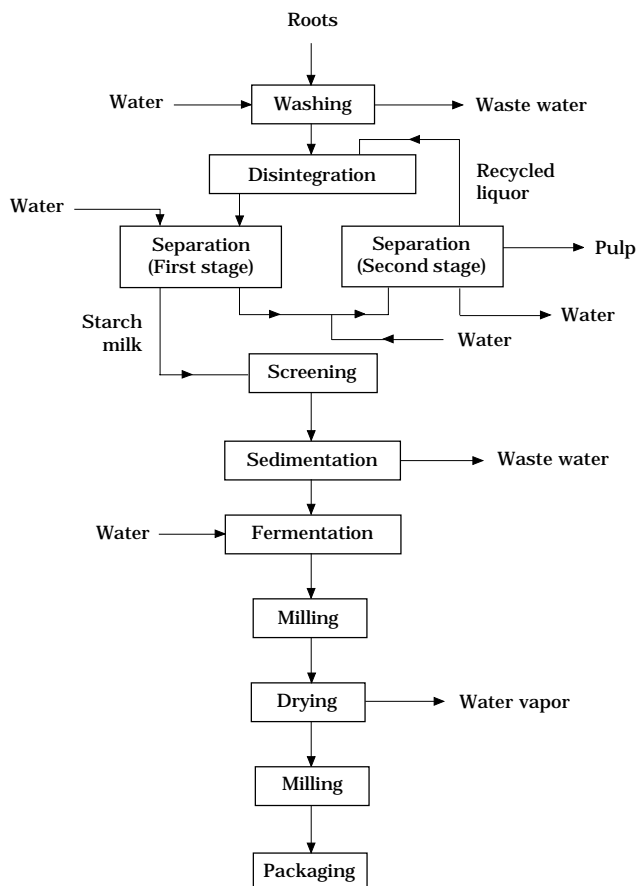


Figure 1. Sour starch manufacture in a typical plant in Minas Gerais State, Brazil.

Recycled liquor from the starch separators is continuously fed into the disintegrator. The resultant slurry of crushed roots passes through the screening plate into a sump tank from which it is pumped to the separators.

All plants employ a two-stage separation process to remove the liberated starch from the fibrous pulp (*massa*). The majority of plants employ two centrifugal separators, which have replaced the traditional, rotating brush-and-screen washers.

The centrifugal separator consists of a rotating conical screen, housed inside a shaped, mild-steel casing,

tapering from front to back. The conical screen is a metal frame covered with a nylon mesh. The narrow end of the cone is closed with a fixed metal plate connected to the drive shaft. Slurry is pumped into the center of the separator (toward the fixed plate) and forced through the screen to an outlet at the bottom of the casing into a sump tank. Water is sprayed into the slurry from jets positioned around the screen.

In the sump tank, the slurry receives extra water to facilitate pumping it over a flatbed reciprocating screen to remove any remaining fiber (larger plants employ an additional

centrifugal separator). The slurry then enters a second separator for further starch extraction. Liquor discharged from the second separator is returned to the disintegrator, and the suspension of pulp, or "starch milk," is discharged to storage tanks.

The milk then flows into sedimentation channels or "tables" (Bruinsma et al., 1981). Dimensions for the channels vary considerably from plant to plant: in length, from 150 to 200 m; in width, from 0.6 to 1.0 m; and in depth, from 0.4 to 0.6 m. The channels are usually lined with ceramic tiles because both starch and starch milk attack concrete. The channels are roofed to protect the starch from rain or sunlight.

The milk is directed into one end of the channels and the supernatant liquor flows over a weir at the other end to be discharged as waste water into nearby watercourses, seepage pits, or infiltration channels.

After overnight settling, supernatant remaining in the sedimentation channels is discharged by removing the weir. The surface of the settled starch is sometimes washed to remove those uppermost layers containing high concentrations of dirt, protein, and fiber impurities. Over several days, the channels are allowed to fill with successive layers of starch until space is available in the fermentation tanks. The starch is then dug out of the channel, transferred to the tanks, covered with water, and left to ferment for a minimum of 30 days. The tanks are also lined with ceramic tiles and are usually constructed in series adjacent to the sedimentation channels. They, too, are roofed to prevent exposure to sunlight and rain.

After fermentation, the starch is removed from the tanks, broken up with a spike mill, and dried on hessian

sacks laid on raised, drying tables, usually made of bamboo. The drying starch is agitated manually at regular intervals. When dry, the starch is collected, milled to a powder, and packaged into 50-kg bags or, in some plants, into packs for direct sale to retailers.

## **Monitoring Plant Operations**

### ***Measuring process parameters and sampling procedures***

With the agreement and cooperation of plant management and staff, processing operations at two plants were monitored for 3 weeks.

Monitoring activities were:

- (1) Measuring water flows within processing operations to determine water consumption at each stage;
- (2) Periodic sampling of fresh roots, disintegrator slurry, starch milk, waste fibrous pulp, fermented and dried starch;
- (3) Sampling of water supplies and generated effluents throughout the process to characterize pollution loads.

During monitoring, no attempt was made to influence plant management and staff in their work.

### ***Sample analysis***

Moisture content of root, starch cake, and pulp samples were determined by oven drying at about 45 °C to constant weight. Dried samples were stored and later analyzed for starch content, using enzyme hydrolysis (AOAC, 1965) and crude fiber (Harris, 1970).

Immediately after collection, the pH of all water and effluent samples was measured with a hand-held meter (CIBA Corning Diagnostics Ltd., Halsted, UK). The samples were then

taken to a local laboratory and analyzed for chemical oxygen demand (COD), and suspended and dissolved solids.

## Results and Discussion

### Root washing

Table 1 shows the proportions of dirt, bark, peel, and parenchyma in the roots received at the two plants and Table 2 shows the composition of the washed roots.

The root washers employed in the two plants had a similar design: a semicircular, slatted trough, 7 m long with a 0.95-m diameter. It had fixed, 4-bladed paddles, mounted 0.3 m apart on an overhead, central rotating

shaft, which was driven at 150 rpm by a 2.2-kW (3 HP) motor. In plant A, the trough was fitted with an overhead water spray for the latter two-thirds of its length, whereas in plant B, the spray covered only the last third.

The flow of roots through the washers was, in effect, the same for both plants at 0.55 kg/s of fresh roots. But plant A used a much larger volume of water for washing: about 1.95 L/s (or 3.55 m<sup>3</sup>/t of roots), compared with 0.70 L/s (or 1.27 m<sup>3</sup>/t) for plant B (Table 3). The washer's performance at plant A, as measured by the percentage removal of bark, was considerably more effective (about 95%), compared with that of plant B (78% to 80%). At plant B higher levels of dirt and bark fragments were visibly observable in the sedimented starch.

Large sweet-starch plants in Brazil and India employ similar washers. In smaller Brazilian and Colombian plants, root washing is performed in batches, using rotating, slatted drums with a continuous supply of water. But in medium-sized plants in India, roots are passed through a flatbed conveyor washer, removing only the dirt and leaving the bark (Trim et al., 1993). For sago production, both the bark and peel are removed manually.

Table 1. Composition (%) of residues from washing fresh cassava roots at two plants producing sour starch, Minas Gerais, Brazil.

Component	Plant A	Plant B
Dirt	0.50	0.49
Bark	2.35	1.84
Peel	15.01	17.47
Parenchyma	82.14	80.20

Table 2. Composition of roots, starch, and pulp at two plants producing sour starch, Minas Gerais, Brazil.

Sample	Component (% DM) <sup>a</sup>					
	Total solids (%)	Starch	Crude fiber	Fat	Protein	Ash
Plant A:						
Washed roots	34.45	89.35	1.92	0.44	2.55	1.32
Dried starch	88.10	96.59	0.35	-	-	-
Pulp	7.70	85.59	8.45	0.16	1.36	0.96
Plant B:						
Washed roots	36.85	90.11	2.16	0.19	2.68	1.10
Dried starch	88.73	96.43	0.41	-	-	-
Pulp	7.23	82.21	12.14	0.24	1.79	1.26

a. (% DM) = percentage of dry matter.

Table 3. Total water consumption at two plants producing sour cassava starch, Minas Gerais, Brazil.

Operation	Water consumption	
	m <sup>3</sup> /t of roots	m <sup>3</sup> /t of product
Plant A:		
Root washing	3.55	15.24
Starch extraction	3.78	16.22
Total	7.33	31.46
Plant B:		
Root washing	1.27	4.70
Starch extraction	4.50	16.67
Total	5.77	21.37

### Root disintegration

The drums in the disintegrators at the two plants were of similar construction, 0.32 m in diameter and 0.28 m in width. The blades were longitudinally spaced, at about 12 mm, around the circumference of the drum. Each drum had 80 to 85 blades. The disintegrators were both directly driven by an electric motor and rotated at 2,500 rpm. However, plant A employed a smaller motor (11.2 kW or 15 HP) than did plant B (18.6 kW or 25 HP). Both plants employed 1.5-kW (2 HP) centrifugal pumps to transfer the slurry from the disintegrator sump to the separators.

The total solids content of the disintegrated root slurry at plant A was 8.2% and at plant B, 7.6%. Although these values are similar, the disintegrator at plant B produced a much finer slurry, indicating a higher degree of root maceration. This was reflected in the starch extraction efficiency (i.e., the fraction of starch released in disintegration) at plant A (81%), compared with plant B (84%). These figures are considerably higher than those quoted by Bruinsma et al. (1981) of 61% to 68% for small- to medium-scale production, but close

to that reported by Trim et al. (1993) of 83% for an Indian sago plant. However, in the Indian plant, two perforated drum disintegrators were used in series to improve starch extraction.

The operation of the disintegrator at plant B was much smoother, with less notable strain on the motor, because of variation in feeding the roots. Furthermore, the plant operator thought that the throughput of roots in the disintegrator could be increased, thus increasing maximum output.

### Starch separation

Plant A employed two identical centrifugal separators, both belt-driven from a common 3.7-kW (5 HP) motor and rotating at 650 rpm. The rotating conical screen in each was 0.70 m in length, 0.25 m in diameter at the narrow end, and 0.76 m at the wider end. It was covered with nylon mesh (PA-120-125/ASTM<sup>1</sup>). The steel casing was 1 m squared in front, tapering to 0.5 m squared at the back.

Water was fed to the first separator at 0.90 L/s and to the second at 0.72 L/s. Fresh water was also added to the sump tank between the separators at a rate of 0.44 L/s. The total water added was therefore 2.06 L/s (3.78 m<sup>3</sup>/t of roots). Starch milk was discharged from the first separator directly into the sedimentation channel at a rate of 1.99 L/s with a concentration of solids at 7.1%.

Plant B used a single centrifugal separator, identical to those at plant A, for the primary stage, and a rotating brush-and-screen washer for

1. ASTM = American Society for Testing and Materials.

the second stage. The operating speed of the centrifugal separator at 760 rpm was higher than at plant A, although using a similarly powered motor.

The brush-and-screen washer consisted of a semicircular, screened trough (5.65 m long and 0.42 m in diameter), above which a shaft, rotating at 530 rpm, was centrally mounted. Plastic brushes were spaced at 90 mm intervals along the shaft, which was rotated by a 2.2-kW (2 HP) centrifugal pump.

Water was sprayed into the separator at a rate of 0.74 L/s and into the washer at 0.55 L/s; 1.20 L/s of water was fed into the sump tank between the two. Total water consumption was therefore 2.48 L/s (4.51 m<sup>3</sup>/t of roots). Starch milk was discharged from the washer at a rate of 2.52 L/s with a concentration of solids at 6.80%.

The solids content of the waste pulp was 7.70% in plant A and 7.23% in plant B (Table 2). The starch content of the pulp at plant A was 85.59% and at plant B, 82.21%. The higher concentration from plant A again indicates less efficient disintegration of the roots. Trim et al. (1993) measured a starch concentration of 72% in the pulp discharged from a system of reciprocating screens.

The concentration of free starch in the waste pulp was very low at both plants (0.32% at plant A and 0.18% at plant B), indicating a high efficiency of extraction of free starch from the pulp.

### **Sedimentation and fermentation**

Plant A used six channels, constructed side by side and connected in series to minimize space and ease unloading. Each channel was 32 m long, 0.74 m wide, and

0.4 m deep. Plant B had four similarly constructed channels, each 45 m long, 0.82 m wide, and 0.5 m deep. Both sets of channels had a weir, 0.15 m high, at one end. The residence time for starch milk flowing into empty channels was 3.0 h for plant A and 2.4 h for plant B. The solids content of batches of sedimented starch removed from the channels averaged 59.9% for plant A and 59.1% for plant B.

In India, tanks are used instead of channels for sedimentation, largely because of historical reasons (Trim et al., 1993). After overnight settling and removal of the supernatant liquor, the starch cake had a concentration of solids at 50%, but after washing, the concentration was 55%.

Starch and crude fiber concentrations of the settled cake in the two plants were similar, averaging 96.7% for starch and 0.3% for crude fiber (dry matter basis).

The changes occurring in the starch as a result of fermentation are the subject of much recent research (e.g., Brabet et al., Ch. 27, this volume) but were not studied in this investigation. Although a minimum fermentation time of 30 days is necessary, starch often remained in the tanks at the two plants for longer periods because of the lack of available drying space. Such prolonged fermentation had no detrimental effect on starch quality. The temperature of the fermenting starch at the two plants ranged between 12 and 13 °C.

### **Drying**

Both plants employed traditional drying tables, raised about 1 m from the ground. They were essentially bamboo mats (*esteiras*), 4.0 m long and 1.2 m wide, tied to bamboo beams mounted on wooden stakes. Plant A

had 600 *esteiras*, with a total drying area of 2,800 m<sup>2</sup>, and plant B had 760 *esteiras* (3,650 m<sup>2</sup>). The fermented starch was spread on cotton sacks stretched across the tables with a wet starch loading of about 1.8 to 2.0 kg/m<sup>2</sup>.

In summer, drying may take 6 to 7 h, but in winter it may take 2 working days or 13 h. Starch that is still damp by the end of the day is gathered up in cotton sacks and placed in storage sheds overnight.

Figure 2 shows the drying curves for batches of starch dried at the two plants (moisture contents are given on a wet basis). As calculated from Table 2, the moisture content (dry basis) of the dried starch produced at plant A was 11.9% and that at plant B, 11.3%. The dried starch contents were 96.6% at plant A and 96.4% at plant B (dry matter basis) (Table 2).

Many plants in the area are investing in drying tables made of wire mesh within wooden frames. The mesh provides improved ventilation around the starch and so reduces drying time.

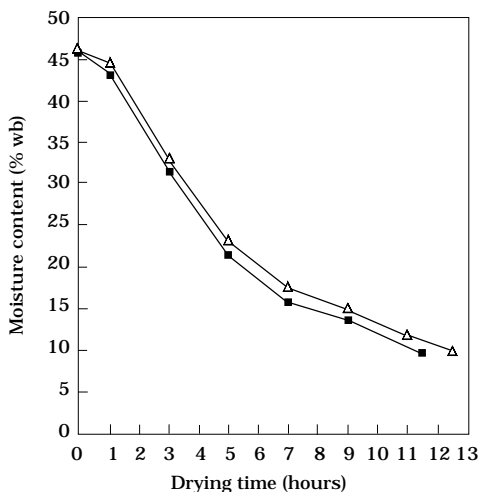


Figure 2. Sour starch drying curves at two plants in Minas Gerais, Brazil. (■ = plant A; △ = plant B.)

### Material balance

The material balance for the processing operations at the two plants was calculated from the measured data of process flows and from results of laboratory analyses (Figures 3 and 4). Figure 3 shows that the total mass flow of dried starch in plant A was 23% and Figure 4, 27% in plant B. A more accurate comparison is that of starch recovery efficiency—the fraction of starch in the roots recovered in the product. The overall starch recovery was about 67% for plant A and 72% for plant B.

### Product quality

Table 2 gives the composition of the starch products. The results indicate no significant difference in starch purity in products from the two plants, especially in root washing, despite their different processing procedures.

Processors commonly define quality in terms of the degree of whiteness and the acid taste of the sour starch, but no data exist to confirm that these criteria are linked to commercial value. Producers believe quality improves the more the processing environment is clean, the more water used, and the purer the processing water. Spring water is usually preferred to well or river water. The lower temperature of spring water is also believed to improve fermentation. Intense sunlight and agitated air movement around the starch on a second or third day's drying may deteriorate quality by encouraging growth of mold.

### Water consumption and characteristics of waste water

Plant A used more water for root washing (3.55 m<sup>3</sup>/t of roots) than did plant B (1.27 m<sup>3</sup>/t) (Table 3). However, plant A used appreciably

less water for root disintegration and starch separation (3.78 m<sup>3</sup>/t) than did plant B (4.50 m<sup>3</sup>/t). Total water consumption was 7.33 m<sup>3</sup>/t for plant A, and 5.77 m<sup>3</sup>/t for plant B. The flow of water recycled from the separators to the disintegrator was marginally different in the two plants: plant A recycled 3.50 m<sup>3</sup>/t and plant B, 4.22 m<sup>3</sup>/t. In sago production in India (Trim et al., 1993), water consumption was 6.40 m<sup>3</sup>/t, of which 4.10 m<sup>3</sup>/t was used for disintegration and separation.

Table 4 shows the results of analyses of the two principal

effluents from the plants. These data confirm the highly polluting nature of these waste waters. The COD of the waste waters from plant A was 4,800 mg/L and from plant B, 3,500 mg/L. The CODs of the supernatant liquor discharged from the sedimentation channels were 11,500 mg/L for plant A and 14,800 mg/L for plant B, that is, much higher than the 6,700 mg/L noted in liquor discharged from sedimentation tanks in India (Trim et al., 1993).

Analyses also indicated that the supernatant liquors contained significant levels of cyanide

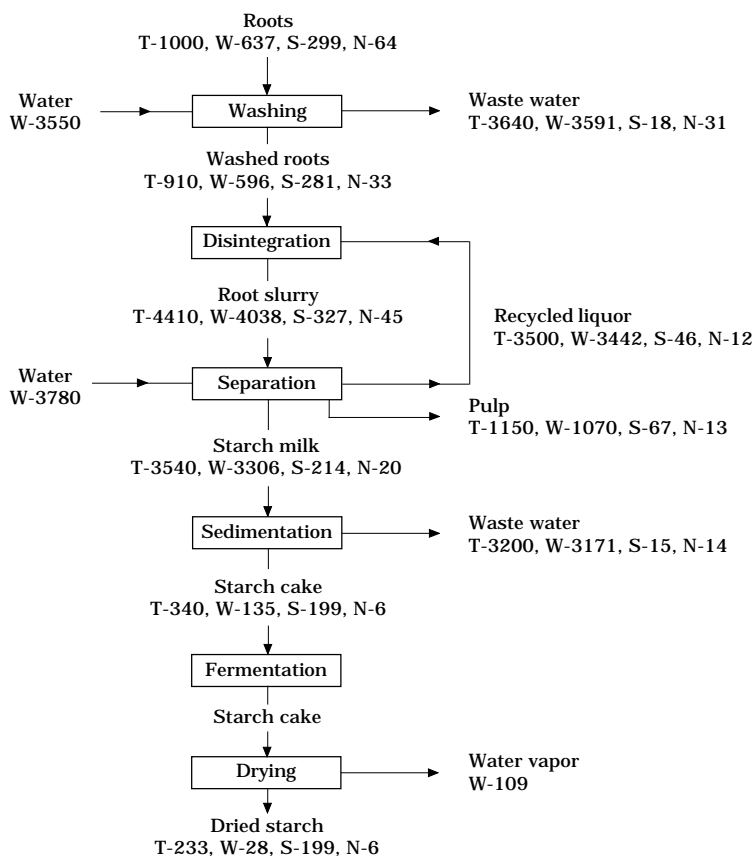


Figure 3. Material balance, based on 1,000 kg of roots, for plant A in Minas Gerais, Brazil. (T = total mass flow; W = water flow; S = starch flow; N = flow of nonstarch components.)

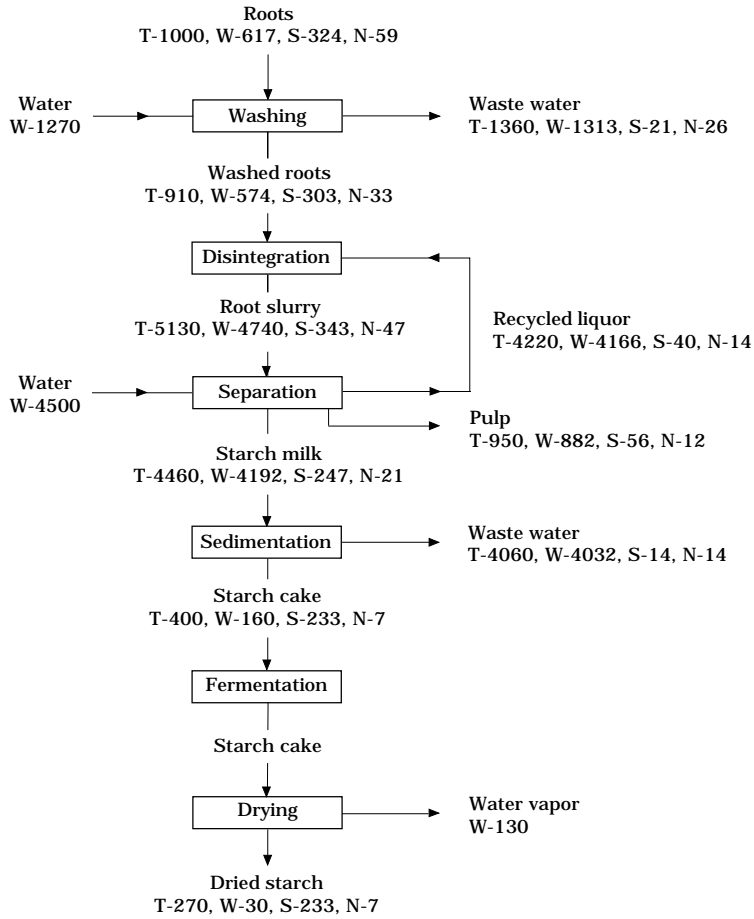


Figure 4. Material balance, based on 1,000 kg of roots for plant B in Minas Gerais, Brazil. (T = total mass flow; W = water flow; S = starch flow; N = flow of nonstarch components.)

Table 4. Characteristics of waste waters at two plants processing cassava sour starch in Minas Gerais, Brazil.

Sample	Characteristic <sup>a</sup>				
	COD (mg/L)	DS (mg/L)	SS (mg/L)	pH	HCN (mg/kg)
Plant A:					
Waste waters	4,778	401	1,297	5.93	
Supernatant liquor	11,538	1,516	7,351	5.11	43
Plant B:					
Waste waters	3,475	618	1,797	6.21	
Supernatant liquor	14,778	3,370	4,979	5.38	62

a. COD = chemical oxygen demand; DS = dissolved solids; SS = suspended solids.

compounds, measured at 43-62 mg/kg. These values are much higher than those measured in India (20-35 mg/kg). The roots used in India for sago production are peeled before disintegration, thus carrying away larger quantities of cyanogens.

### ***Effluent treatment***

The effluent problem is a major environmental issue in both Pouso Alegre and Divinópolis. Many plants discharge their effluent directly into small streams feeding the local river. Fish and animals have been killed by polluted watercourses, and the State Water Authority is concerned about the dangers of polluting drinking water supplies.

Federal legislation requires that plants install effluent treatment systems capable of removing at least 85% of the pollution load. Some local authorities have threatened legal action against plants that do not install treatment systems, despite the fact that no effective treatment systems are available that are also economically feasible. In reality, however, plant closures are unlikely because of local socioeconomic factors, and pollution will continue until cost-effective solutions are found.

The most commonly used disposal systems include seepage pits (usually three pits used in series) or infiltration channels, which allow water to seep through the soil. The solid material is removed periodically and used as fertilizer. Some plants use the effluent for irrigating their cassava crop. The long-term effects of these methods are unknown.

## **Conclusions**

The two plants studied, and most of the others visited, were efficiently

organized and the equipment usually well maintained. Some significant changes in processing have been adopted over recent years, most notably the introduction of centrifugal separators for the recovery of starch from the macerated roots. An effective means of technology transfer exists through the localized nature of the industry, the local equipment supply and maintenance workshops, and plant workers setting up their own processing plants.

Plant operators see the most important issues as being:

- Availability and price of cassava roots;
- Access to "soft" loans to finance working capital;
- Labor costs;
- Packaging costs;
- Marketing and promotion;
- Perception of improved quality by consumers;
- Efficient and cost-effective effluent treatment systems.

Processors also consider fermentation and drying to be processing bottlenecks. The long fermentation periods tie up scarce working capital, and sun-drying is sometimes unreliable and requires considerable space. But, if improved technology for rapid fermentation and artificial drying become reality, then large-scale industrialists in other areas may be able to undercut small-scale producers in product price by having access to cheaper root supplies and reaching economies of scale. Such undercutting would mean the collapse of a large proportion of the industry in Minas Gerais.

The market for sour starch products is growing slowly, but competition in supply is intensifying and quality is becoming more important. Producers in Minas

Gerais may well encounter future problems as a result of increasing competition from new producers (especially in São Paulo State), who have greater financial resources, access to higher levels of technology, and are located near cheap and abundant supplies of roots.

Future priorities for research should be concentrated in three areas:

- (1) *Product quality.* Quality factors need to be clearly defined and standards established. Relationships between process inputs, operations, and quality factors need to be identified and evaluated.
- (2) *Markets.* Promotional efforts are required to expand consumer awareness of sour starch and its specialized properties and uses.
- (3) *Water pollution.* Affordable technology for water conservation, waste reduction, and treatment operations needs to be developed to minimize pollution.

## References

- AOAC (Association of Official Analytical Chemists). 1965. Official methods of analysis. 10th ed. Arlington, VA, USA.
- Bruinsma, D. H.; Witsenburg, W. W.; and Wurdemann, W. 1981. Cassava. In: Selection of technology for food processing in developing countries. Centre for Agricultural Publishing and Documentation (PUDOC), Wageningen, the Netherlands. p. 113-158.
- Grace, M. R. 1977. Cassava processing. FAO plant production and protection series. Food and Agriculture Organization of the United Nations (FAO), Rome. 155 p.
- Harris, L. E. 1970. Determination of cell wall (neutral detergent fiber) and cell contents. In: Nutrition research techniques for domestic and wild animals, vol. 1. Utah State University, Logan, UT, USA. p. 2801-2802.
- Radley, J. A. 1976. Starch production technology. Applied Science Publications, London, UK. 587 p.
- Salazar de Buckle, T.; Zapata M., L. E.; Cárdenas, O. S.; and Cabra, E. 1971. Small-scale production of sweet and sour starch in Colombia. In: Weber, E. J.; Cock, J. H.; and Chouinard, A. (eds.). Cassava harvesting and processing; proceedings of a workshop held at CIAT, Cali, Colombia. International Development Research Centre (IDRC), Ottawa, Canada. p. 26-32.
- Trim, D. S.; Nanda, S. K.; Curran, A.; Anantharaman, M.; and Nair, J. 1993. Investigation of cassava starch and sago production in India. Paper presented at the International Symposium on Tropical Root Crops, 6-9 Nov., Thiruvananthapuram, India.

# IMPLEMENTING TECHNOLOGICAL INNOVATIONS IN CASSAVA FLOUR AND STARCH PROCESSING: A CASE STUDY IN ECUADOR<sup>1</sup>

Vicente Ruiz\*

## Background

Before 1985, the only cassava processing technology known in Ecuador was mechanical rasping and hand-sieving to extract starch from the roots. Since then, new technologies have been introduced, and existing ones improved, to increase processing efficiency and open new markets for both cassava starch and flour.

These new technologies include chipping, drying, and grinding cassava roots to produce meal and flour from peeled cassava roots, and sieving coarse-grained flours to produce fine ones. Improved equipment for starch processing include raspers with saws, continuous flow washer-peelers, vibrating screens, and sedimentation channels.

In Manabí, Ecuador, a participatory approach has been used to facilitate the adoption of improved technologies. The first step was to train the technical team of the Unión

de Asociaciones de Trabajadores Agrícolas, Productores y Procesadores de Yuca (UATAPPY). This team copied and adapted some prototype equipment and tools on-site in the Association's processing plants. The products—cassava starch and flour—were efficiently produced and entered national and international markets.

## Flour Processing

### ***Technology introduced from Colombia***

In late 1985, trials showed that cassava meal could be technically and economically produced, using a technology introduced from CIAT, Colombia. The technology consisted of chipping, drying, and grinding dried cassava. Chips, produced by a Thai-type, mechanical, disc chipper, are dried on outdoor concrete floors and then ground in hammer mills.

### ***Technology currently used by UATAPPY***

In addition to cassava meal, three other types of flour are produced: white industrial flour, table flour, and sieved whole-grain flour. The technology used to produce these flours differs from that for cassava meal (Table 1). To produce white

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1. No abstract was provided by the author.

Table 1. Comparison of steps in the processing of different cassava flours, once roots are received, using current technology, Manabi, Ecuador.

Process (technique)	Flour			
	Cassava meal <sup>a</sup>	White industrial flour	Table flour	Sieved whole-grain flour
Peeling (manual)		X	X	X
Washing (manual, mechanical)			X	X
Chipping (Thai-type disc chipper)	X	X	X	X
Drying (concrete floors)	X	X		
Drying (trays)			X	X
Milling (hammer mill)	X	X	X	X
Sieving (vibrating or centrifuge screen)			X	X
Packaging (polypropylene)	X	X	X	X

a. Original technology, introduced from Colombia. The other products are produced with more recent technology.

industrial flour, the roots are peeled by hand before being fed to the chipper. The rest of the process is the same as for cassava meal. To produce table flour, the roots are peeled and washed before chipping, and then dried naturally on trays, or artificially. Once the dried chips are ground, the resulting flour is sieved through a vibrating or centrifuge screen. Sieved whole-grain flour is produced by passing the meal through a vibrating screen as for table flour.

## Starch Processing

### **Traditional technology used in Ecuador**

Manual starch extraction in Ecuador dates back about 50 years. Traditionally, to extract cassava starch, roots are peeled and washed by hand, grated by hand or

mechanically with an engine-driven wooden drum covered with a perforated zinc plate, then sieved by hand. Sedimentation is carried out in wooden or concrete tanks, and the starch dried on concrete floors or on paper (Figure 1).

### **Technology currently used by UATAPPY**

The UATAPPY is currently extracting cassava starch with mechanized technology developed with the technical assistance of CIAT and the Fundación Adelanto Comunitario (FACE), and with the financial support of the Fundación para el Desarrollo Agropecuario (FUNDAGRO). Cassava roots undergo the following procedures: washing and peeling, in either batch or continuous flow, with Brazilian-type washers; mechanical rasping with Brazilian-type saw blades; sieving, both by hand and vibrating screens;

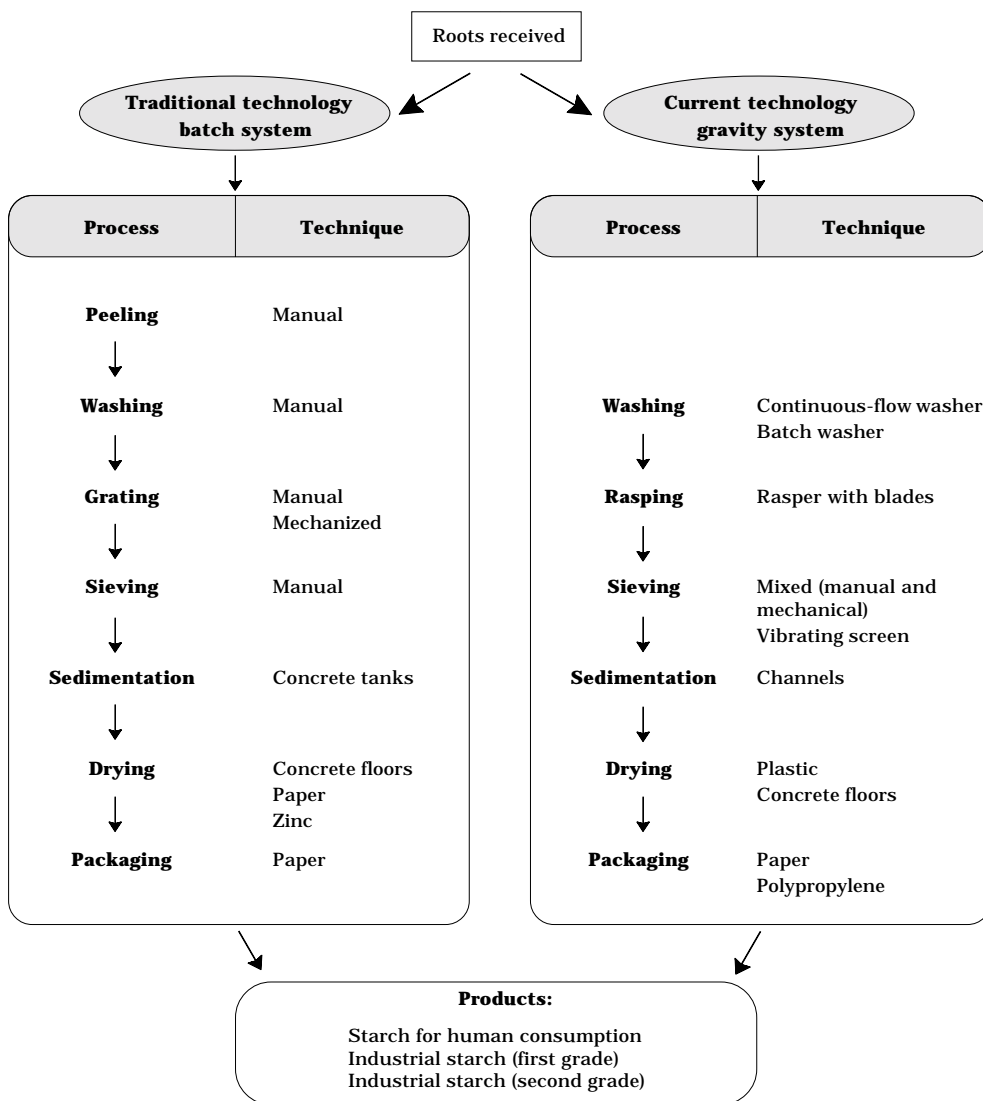


Figure 1. Differences in traditional and current technologies for cassava starch extraction, Manabí, Ecuador. Current technologies include innovations introduced from Colombia and Brazil.

and sedimentation in concrete channels lined with ceramic tiles. Drying is carried out naturally on plastic sheets placed on bamboo platforms. When a finer quality product is required, milling is done in hammer mills (Figure 1).

## Experiments

Sour starch production trials were first carried out in December 1992 and renewed in November 1993 at two starch factories, both UATAPPY members. Artificial drying trials with

a flash dryer will be conducted, together with mechanized sieving, using vibrating or centrifuge screens.

### **Training and Institutional Support**

To introduce and adapt new cassava processing technologies, especially for starch, UATAPPY received technical and financial support from FUNDAGRO and CIAT. Its technical team has received training nationally and in Colombia and Brazil on

elements of processing and technology.

### **Results**

- (1) Product quality (flours and starch) has improved, allowing new markets to be opened at national and international levels.
- (2) Higher yields have been obtained and efficiency has improved.
- (3) Production capacity, especially of starch, has increased.

# THE INFLUENCE OF VARIETY AND PROCESSING ON THE PHYSICOCHEMICAL AND FUNCTIONAL PROPERTIES OF CASSAVA STARCH AND FLOUR

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and *C. C. Wheatley* †

## Abstract

The influence of certain processing conditions on the quality, functional properties, and product potential of flour made from three cassava cultivars are being evaluated as part of a project (DGXII) funded by the European Union (EU). The collaborators in this project are the Universidad del Valle (UNIVALLE), Colombia; CIRAD-SAR, France; the Natural Resources Institute (NRI), UK; and CIAT, Colombia.

The influence of drying temperature (40, 60, and 80 °C), milling procedure (hammer, roller, pin, and paddle), and particle size (< 250 μm and < 160 μm) on the quality, functional properties, and product potential of flour from three cassava cultivars are being evaluated. The influence of genetic variability on starch quality is also being evaluated, using starches made from cultivars chosen from the cassava core collection established at CIAT.

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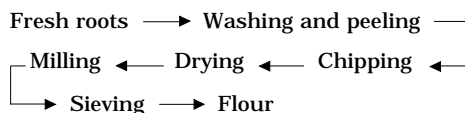
† Centro Internacional de la Papa (CIP), stationed at Bogor, Indonesia.

This chapter outlines the results so far.

## Materials and Methods

The cassava cultivars used in this research were selected after the cassava core collection, held at CIAT, Cali, Colombia, was evaluated (Wheatley et al., 1993). Cultivars were selected to represent a broad variability in root contents of cyanogens, dry matter, and amylose.

Experiments were designed to determine how flour preparation influences the resultant quality of the end product. In October 1992, 1,500 kg of fresh roots of the cassava cultivar CM 3306-4 were harvested at CIAT. The roots were processed into flour as outlined:



In August and September 1993, two more cultivars of cassava (CM 3306-4, M Ven 25) were harvested 10 months after planting and similarly processed.

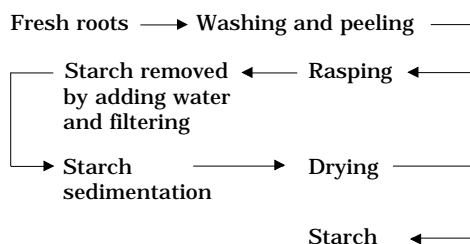
Before drying, the chips from each cultivars were divided into three lots of

475 kg. They were then dried in a layer, about 15 cm thick, on the floor (3 m<sup>2</sup> area) of an airflow bin dryer. Drying temperatures used were 40, 60, and 80 °C.

Four different types of mill were used to grind the resultant dry chips: (1) hammer mill (set at 5,800 rpm and with a 1/8-inch screen), (2) roller mill (first pass with rollers set at 300 µm apart and second pass with rollers set at 30 µm), (3) pin mill, and (4) a paddle auger in a cylindrical sifter with a 5-mm and 250-µm screen. The flours produced were divided into two sieve fractions to give two particle sizes: smaller than 250 µm, and smaller than 106 µm.

The flours produced by the different treatments were analyzed with a Brabender amylograph (BA). Gelatinization profiles were determined from 6%-starch solutions, using a heating and cooling rate of 1.5 °C/min. The temperature was increased to 95 °C, held for 20 min, and cooled at a rate of 1.5 °C/min to 50 °C. The viscographs obtained were used to calculate the following parameters: the initial temperature of gelatinization, peak viscosity, ease of cooking, gel instability, and gelatinization index.

In October 1992, 29 cassava cultivars were harvested at CIAT 10 to 12 months after planting. Starch samples were extracted as outlined:



Starch samples were also prepared from another 33 cassava cultivars,

including the same 29 cultivars, harvested at CIAT in July 1993 9 months after planting.

The starch samples extracted from the cassava cultivars in 1992 were analyzed with a BA. Gelatinization profiles were determined from 6%-starch solutions as described above. The amylose contents were determined, using an iodo-colometric test and a calibration curve prepared from potato amylose and amylopectin. The crystallinity of the starch granules was determined with an X-ray diffraction system. The diffraction data were collected over an angular range from 4° to 32° 2θ.

Starch samples from both harvests will be examined for granular size distribution, amylose-to-amylopectin ratio, chain length, degree of polymerization, X-ray diffraction patterns and absolute crystallinity, differential scanning calorimetry (DSC) analysis, pasting and rheological characteristics, swelling power and solubility, and water-binding capacity.

## Results

### Flour

The various processing procedures used in these experiments all influenced the gelatinization profiles of the resultant flours (Figures 1 to 4; Table 1). Whether the differences obtained in gelatinization properties are enough to significantly influence the potential uses of the flours is yet to be determined. At the time of writing, the flours prepared from the cultivars harvested and processed in August and September 1993 were not yet analyzed.

### Starch

Figure 5 shows a sample of the X-ray diffractograms obtained from starches

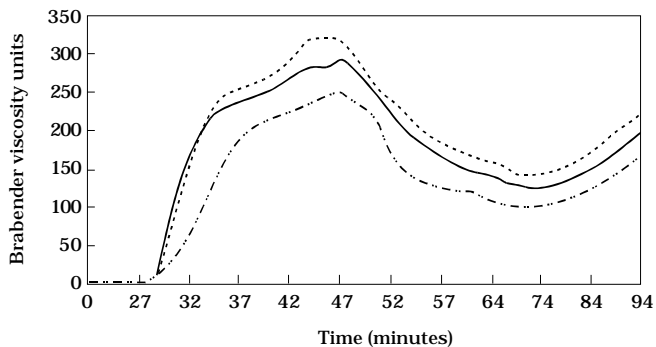


Figure 1. Viscoamylograph of cassava flour in relation to drying temperatures (· · · · = 40 °C; - - - - = 60 °C; — = 80 °C). Brabender curves were obtained from flour suspension at 6% of dry matter. The flour had a particle size smaller than 250  $\mu\text{m}$ , after milling with rollers.

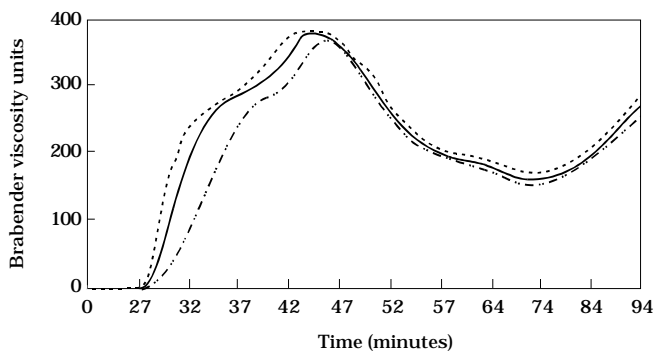


Figure 2. Viscoamylograph of cassava flour in relation to drying temperatures (· · · · = 40 °C; — = 60 °C; - - - - = 80 °C). Brabender curves were obtained from flour suspension at 6% of dry matter. The flour had a particle size smaller than 250  $\mu\text{m}$ , after milling with a hammer mill.

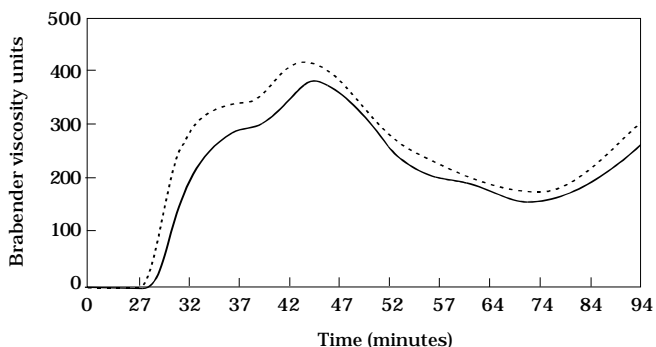


Figure 3. Viscoamylograph of cassava flour in relation to particle size (— = 250  $\mu\text{m}$ ; - - - - = 106  $\mu\text{m}$ ). Brabender curves were obtained from flour suspension at 6% of dry matter. Chips were dried at 60 °C and milled in a hammer mill.

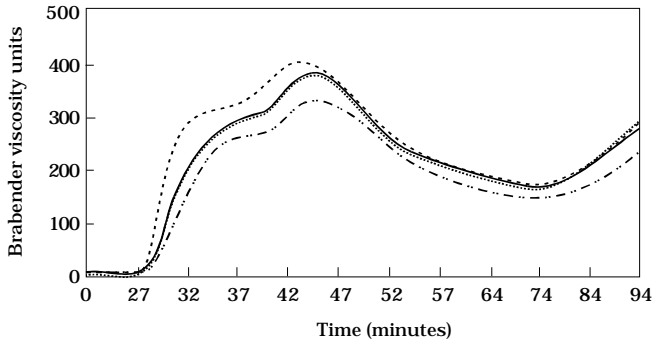


Figure 4. Viscoamylograph of cassava flour in relation to milling method (— = hammer mill; ..... = pin mill; ---- = roller mill; - · - · - = paddle mill). The flour was made from chips dried at 60 °C, and flour particle size was smaller than 250 μm. Brabender curves were obtained from flour suspension at 6% of dry matter.

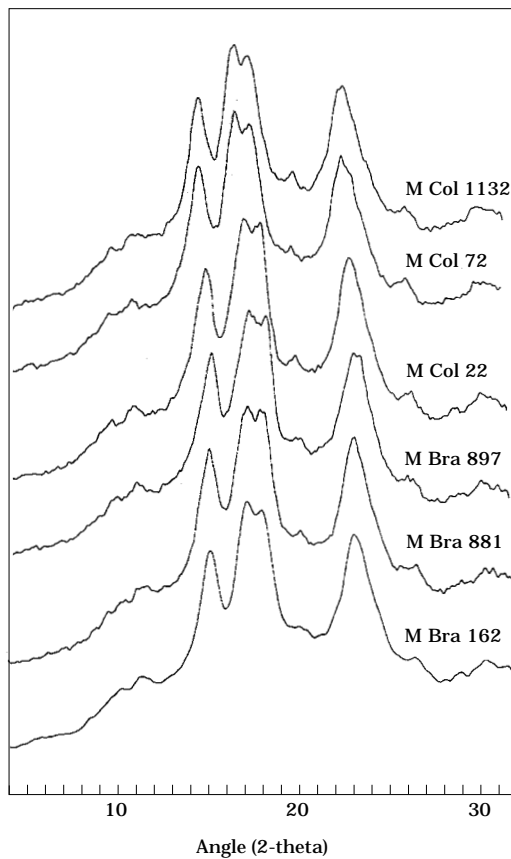


Figure 5. A sample of wide-angle, X-ray diffractograms of native starches from cassava cultivars harvested at CIAT, October 1992.

Table 1. Cassava flour functionality characteristics in relation to its particle size, the drying air temperature, and the milling procedure of the chips.

Flour characteristic	Milling equipment and drying temperatures (°C)											
	Hammer			Roller			Pin			Paddle		
	40	60	80	40	60	80	40	60	80	40	60	80
<b>Flour composition:</b>												
<b>Flour A<sup>a</sup>:</b>												
Starch (% db)	83	82	79	85	83	81	84	82	81	88	86	82
Fiber (% db)	0.9	0.8	1.0	1.4	1.0	1.6	1.2	0.7	1.3	1.0	1.2	1.3
Ash (% db)	1.5	1.7	1.7	1.8	1.8	1.8	1.5	1.6	1.7	1.6	1.5	1.4
<b>Flour B<sup>b</sup>:</b>												
Starch (% db)	87	85	83	86	86	86	86	86	85	92	91	87
Fiber (% db)	0.6	0.8	0.4	0.4	0.5	0.6	1.1	0.8	1.1	0.6	0.8	1.1
Ash (% db)	1.4	1.5	1.5	1.7	1.3	1.6	1.5	1.5	1.7	1.5	1.3	1.5
<b>Gelatinization temperature (°C):</b>												
Flour A	65.5	65.5	65.5	65.5	65.5	65.5	64.0	65.5	65.5	65.5	65.5	65.5
Flour B	65.5	65.5	65.5	65.5	65.5	65.5	65.5	64.0	65.5	65.5	65.5	65.5
<b>Maximum viscosity:</b>												
Flour A	371	380	380	255	323	295	380	380	340	408	410	410
Flour B	385	420	380	285	350	327	387	405	360	400	430	425
<b>Viscosity at 95 °C:</b>												
Flour A	365	365	366	251	321	289	377	363	340	390	380	385
Flour B	375	387	367	284	338	320	377	380	358	380	390	385
<b>Viscosity after 20 min at 95 °C:</b>												
Flour A	172	175	185	102	152	131	202	183	239	168	180	190
Flour B	177	190	185	119	160	152	177	190	228	170	185	200
<b>Viscosity at 50 °C after cooling:</b>												
Flour A	285	300	322	180	252	210	292	313	319	295	318	350
Flour B	308	327	320	180	285	260	297	340	335	305	340	380
<b>Ease of cooking<sup>c</sup>:</b>												
Flour A	19	17	16	20	18	20	19	17	16	17	16	15
Flour B	18	16	16	20	17	16	18	17	15	17	16	14
<b>Gel instability<sup>d</sup>:</b>												
Flour A	199	205	185	153	171	164	178	197	101	240	230	220
Flour B	208	230	195	166	190	175	210	215	132	230	245	225
<b>Gelatinization index<sup>e</sup>:</b>												
Flour A	113	125	137	78	100	79	90	130	80	127	138	160
Flour B	131	137	135	61	125	108	120	150	107	135	155	180

a. Flour A = flour with particles smaller than 250 µm.

b. Flour B = flour with particles smaller than 106 µm.

c. Ease of cooking = time to maximum viscosity - time to gelatinization.

d. Gel instability = maximum viscosity - viscosity after 20 min at 95 °C.

e. Gelatinization index = viscosity at 50 °C after cooling - viscosity after 20 min at 95 °C.

made from the roots of the October 1992 harvest. All spectra of the 29 cultivars analyzed showed an A-type, X-ray diffraction pattern. Table 2 gives values calculated for starch

crystallinity and amylose content, together with the analysis reported by CIAT of root dry matter and cyanogen contents. Table 3 gives the gelatinization profiles of starch

Table 2. Dry matter of fresh roots, cyanogen content of fresh parenchyma, amylose content, and crystallinity of starch obtained from 29 cassava cultivars harvested at 10-12 months at CIAT, Palmira, Colombia, October 1992.

Cultivar	Dry matter (%)	Total cyanogens (as HCN, mg/kg, db)	Amylose (% in starch)	Crystallinity (%) <sup>a</sup>
M Bra 162	32	1,012	17	39
M Bra 881	31	832	20	41
M Bra 897	36	98	21	38
M Col 22	35	85	23	37
M Col 72	33	248	22	41
M Col 1132	21	69	26	39
M Col 1486	37	120	22	43
M Col 1684	37	752	23	38
M Col 2066	30	58	24	43
M Col 2215	43	243	25	44
M CR 35	45	17	24	41
M Mal 1	38	411	25	39
M Mal 2	27	413	24	40
M Mex 59	34	311	21	39
M Nga 2	22	632	23	47
M Per 196	33	393	21	42
M Tai 1	33	629	22	38
M Ven 25	27	1,628	22	43
M Ven 77	32	223	23	40
CG 1-37	35	182	22	44
CG 165-7	23	402	22	44
CG 402-11	18	169	20	45
CG 915-1	37	149	24	41
CG 1118-121	27	27	25	39
CG 1141-1	40	337	24	44
CM 489-1	23	86		41
CM 2766-5	32	82		43
CM 2772-3	27	114		42
CM 3306-4	39	82		43

a. Based on the separation and integration of the areas under the crystalline and amorphous X-ray diffraction peaks.

Table 3. Values of total cyanogen content in parenchyma, amylose content, starch crystallinity, and starch functionality characteristics for six cassava cultivars harvested in October 1992 at CIAT, Palmira, Colombia.

Characteristic	Cultivar					
	CM 3306	CG 1-37	M Ven 77	CG 165-7	M Tai 1	M Ven 25
Total cyanogen in parenchyma (as HCN, mg/kg, db)	82	182	223	402	629	1,628
Amylose (%)	26	22	23	22	22	22
Crystallinity (%)	43	44	40	44	43	43
Gelatinization temperature (°C)	64.0	64.0	65.5	62.5	62.5	62.5
Maximum viscosity	975	775	610	800	780	730
Viscosity at 95 °C	415	320	330	350	340	310
Viscosity after 20 min at 95 °C	260	225	195	220	230	190
Viscosity at 50 °C after cooling	520	460	380	435	410	330
Ease of cooking <sup>a</sup>	4	4	7	5	5	5
Gel instability <sup>b</sup>	715	550	415	580	550	540
Gelatinization index <sup>c</sup>	260	235	185	215	180	140

- a. Ease of cooking = time to maximum viscosity - time to gelatinization.  
 b. Gel instability = maximum viscosity - viscosity after 20 min at 95 °C.  
 c. Gelatinization index = viscosity at 50 °C after cooling - viscosity after 20 min at 95 °C.

samples analyzed. The results obtained show a similar trend to that reported by Wheatley et al. (1993). Differences in starch viscosity characteristics were observed between cultivars with high and low cyanogenic content.

Research is continuing with the 33 starch samples obtained from cultivars harvested in July-August 1993.

## Reference

- Wheatley, C. C.; Orrego, J. I.; Sánchez, T.; and Granados, E. 1993. Quality evaluation of the cassava core collection at CIAT. In: Roca, W. M. and Thro, A. M. (eds.). Proceedings of the First International Scientific Meeting of the Cassava Biotechnology Network, Cartagena de Indias, Colombia, 25-28 August 1992. Working document no. 123. CIAT, Cali, Colombia. p. 255-264.

## CHAPTER 31

# ESTABLISHING AND OPERATING A CASSAVA FLOUR PLANT ON THE ATLANTIC COAST OF COLOMBIA<sup>1</sup>

Francisco Figueroa\*

### Background

CIAT has developed a strategy to design and implement cassava projects, integrating aspects of the crop's production, processing, and commercialization in northern Colombia. Within this framework, three phases of development can be distinguished:

- (1) *Research*: developing technology for cassava processing, and studying in detail the technology's market opportunities, both on a national and regional basis.
- (2) *Pilot project or market test*: producing and marketing on a small scale under real market conditions.
- (3) *Commercialization or expansion*: consolidating the market for new products and replicating the processing units.

A project to develop, under this strategy, a rural cassava flour industry was begun, and its progress so far is reported here.

Results of phase I (research) indicated that, under the cost and

price structures of cassava and wheat in Colombia, producing cassava flour at a price competitive with that of wheat flour was economically feasible (Tables 1, 2, and 3). Hence, the next phase, that of the pilot-project, was initiated.

In the research phase, baked products had been considered as the main market, where cassava flour would substitute 15% of wheat flour. But, because bakers saw a high risk of decreased product quality when using cassava flour, phase II was focused on other food categories where cassava flour would not present high risks.

With phase II, the production, processing, and marketing components of the cassava flour system were integrated under the real conditions of a cassava-growing region in Colombia. These results can be used by both public and private enterprises to promote the replication of rural, cassava flour-producing plants and the product's use in the national food industry.

The institutions participating in the project are CIAT, Cali; Universidad del Valle, Cali; the Fondo de Desarrollo Rural Integrado (DRI) of the Colombian Ministry of Agriculture; and the Fundación para

\* Fundación para la Investigación y el Desarrollo de Tecnologías Apropriadas al Agro (FUNDIAGRO), Colombia.

1. No abstract was provided by the author.

Table 1. Variable costs (US\$) of cassava flour in January 1994, Chinú, Colombia.

Item	Unit/t	Unit cost	Cost/t
Raw material	3.5 t	43.00	150.50
Labor	60 man-hours	0.40	24.00
Package	25 units	0.30	7.50
Electricity	140 kW/h	0.10	14.00
Mineral coal	550 kg	0.04	22.00
Water	7 m <sup>3</sup>	0.40	2.80
Variable costs			220.80

Table 2. Fixed costs (US\$) of cassava flour, Chinú, Colombia, January 1994.

Item	Cost/month	Cost/t
Manager <sup>a</sup>	123.00	6.15
Production chief <sup>b</sup>	12.00	0.60
Watchman	121.00	6.05
Maintenance	125.00	6.25
Other expenses	15.00	0.75
Fixed costs	396.00	19.80

- a. The cost is shared by the chip and flour plants.  
 b. Bonus for production.

Table 3. Production costs (US\$) of flour in Chinú, Colombia, January 1994.

Item	Cost/t
Variable costs	220.80
Fixed costs	19.80
Total production costs	240.60

la Investigación y el Desarrollo de Tecnologías Apropriadas al Agro (FUNDIAGRO). The donor agency is the International Development Research Centre (IDRC), Canada.

### Methodology Used in the Integrated Cassava Project

The integrated cassava project is a rural development strategy. It is

carried out by small-scale, rural producers and inhabitants. It is implemented in three phases, and promotes cassava's transformation in agroindustry by integrating functions of production, processing, and commercialization. It is supported by governmental and nongovernmental organizations.

### Phase I of the Flour Project: Research (1985-1987)

Colombia's economic situation, the prospects for cassava, and the national potential for cassava-based products were studied to select the most promising product and choose an appropriate site. The Atlantic coastal region (northern Colombia) was also studied as having the greatest potential for developing the project. Aspects such as cassava production, farmer organizations, and markets were taken into account to choose the best site for the pilot plant.

#### Aim

The objective of this phase was to determine the economic and technical conditions required for the project.

#### Activities

Studies were made of the cassava production and marketing systems on Colombia's Atlantic coast. On-farm

trials were conducted with improved cassava production technology. Economic studies were made of the wheat milling and baking industries. The experimental cassava flour plant was designed and developed. Trials were made of equipment and processing. Laboratory trials were made on flour quality and consumer acceptance.

### Results

The results demonstrated the technical and economic feasibility of producing cassava flour to

compete with wheat flour in Colombia.

### Phase II: Pilot Project (1988-1992)

A pilot plant was set up in Chinú, Department of Córdoba (Figure 1), with technical conditions for semicommercial operation under real market conditions.

### Aims

The major objective was to validate the technology under real field

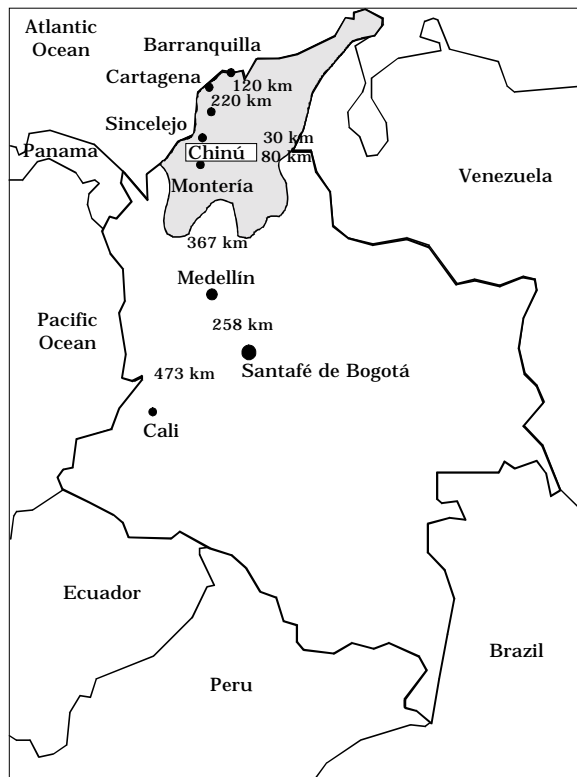


Figure 1. Site for the cassava-flour production pilot plant in northern Colombia. The pilot plant is part of phase II of a project to develop new, market-oriented, cassava-based products and their markets.

conditions, integrating production, processing, and marketing. Other objectives were to (1) gather reliable data on production costs and on the investment needed to establish this type of plant; (2) produce enough cassava flour to promote its use among consumers; and (3) use the plant as a display model to expand this technology to other regions of Colombia.

### **Activities**

The main activity was to establish the pilot plant. Criteria for site selection included aspects of cassava production, land availability, potential for increasing cassava yields, processing, raw material availability (production, seasonality, access to fresh market), service infrastructure (water, electricity, roads), proximity to terminal markets, institutional presence and support, potential project impact, and socioeconomic importance of cassava.

Alternative sites were surveyed, four potential zones selected, then a site, with farmer organizations close by, was chosen. The pilot plant was redesigned, in which combined natural and artificial drying was eliminated. A designer and builder were contracted and the redesigned plant built.

### **Results**

The pilot plant began operating with adjustments in production, processing, and marketing. A viable and functional model was obtained.

## **Phase III: Commercial Expansion (1993 Onward)**

A market study for the new product was designed and developed, clients

were contacted, and test trials conducted with them.

Commercializing cassava flour in the meat processing and adhesive industries began.

At the time of writing, project expansion to other areas of Colombia had not yet started, market expansion was still to come, together with a further consolidation of the new rural agroindustry.

### **Aim**

The objective was to market cassava flour and consolidate a rural agroindustry that would benefit farmers, not only in northern Colombia, but also in other regions.

### **Activities**

A marketing plan was designed and executed, and market segments selected. A bibliographical review was made of cassava flour uses. Commercial contacts were established and sales volume and conditions determined.

### **Results**

Commercialization of cassava flour has begun. The model has been evaluated and adjusted and new sites selected. The project is expanding to other zones.

## **A Cooperative Carries Out the Project**

The Cooperativa de Productores de los Algarrobos (COOPROALGA), based in Chinú, is a first-order organization with 43 members, all small-scale farmers dedicated to growing cassava intercropped with maize or yam. Most members pay rent for land and the remaining 20% own it.

COOPROALGA manages two plants, one producing cassava chips for animal feed, and the other the pilot cassava flour plant (Figure 2).

### Characteristics of the Plant, Process, and Product

#### The flour plant

The cassava flour plant is a warehouse with an office, bathrooms, a tool room, a coal storage room, and areas where cassava roots are received, washed, chipped, and dried. The ground area of the plant is 2,058 m<sup>2</sup>.

The plant has two water storage tanks, one underground with a capacity of 39 m<sup>3</sup> and the other elevated, holding 6 m<sup>3</sup>. All the plant's residual waters flow in two independent lines. The plant's walls are of concrete blocks, and the roof has a metal framework and is tiled with asbestos.

Construction of the plant had cost US\$29,484.00 in March 1990. The

Universidad del Valle and CIAT designed the main processing equipment, which was built in Cali.

#### Processing

A batch process was implemented and includes the following operations: harvest, transport, reception, weighing, selecting, preparing, washing, chipping, drying, premilling, and milling. The resulting cassava flour is then packaged and stored (Table 4 and Figure 3).

Each batch is processed in 2 days. On the first day, the roots are harvested, transported, selected, and prepared. On the second day, they are washed, chipped, dried, and milled, and the resulting flour stored.

#### The product

Before harvesting, the farmer prunes the cassava plant, removing aerial parts, and on the next day he harvests and packs the roots, and takes them to the plant.

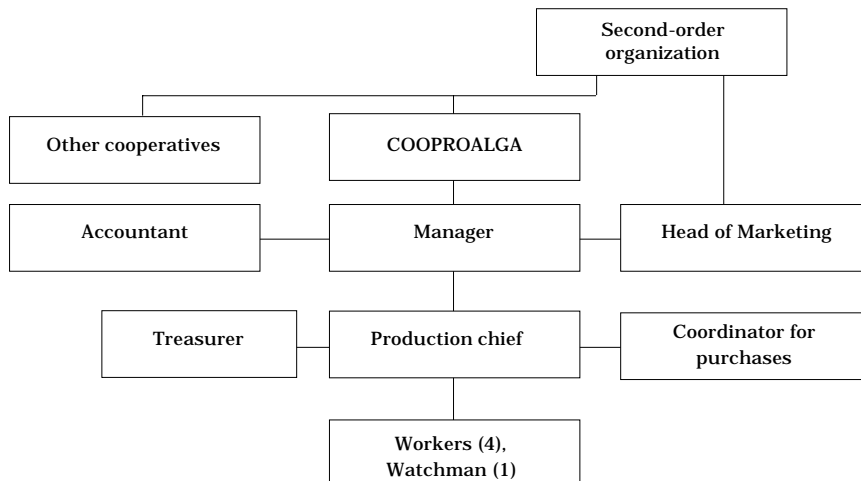


Figure 2. The organization of the pilot cassava flour plant set up in Chinú, northern Colombia.

Table 4. Processing 1 t of cassava flour in a pilot plant, Chinú, northern Colombia.

Day	Hours	Activity	Man-hours (no.)	Workers (no.)
1	5:00 - 11:00	Harvest (3.5 t)	-	-
	9:00 - 14:00	Root transportation	-	-
	9:00 - 14:00	Reception and weighing	2	1
	14:00 - 18:00	Selection and preparation	20	5
2	7:00 - 11:00	Washing and chipping	8	2
	7:00 - 11:00	Loading the drying chamber	4	1
	6:00 - 7:00	Cleaning the burners	1	1
	7:00 - 8:00	Drying starts	1	1
	8:00 - 20:00	Drying (chip turning)	20	3
3	6:00 - 7:00	Cleaning and maintenance	2	2
	6:00 - 7:00	Unloading the dryer	1	2
	7:00 - 8:00	Milling and packaging	1	2
Total			60	6

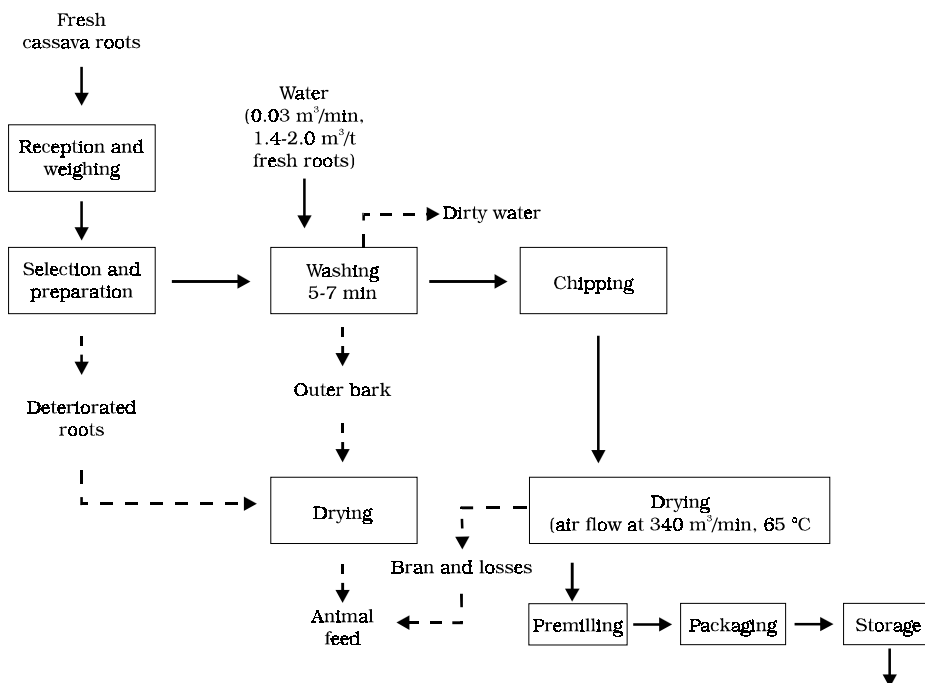


Figure 3. Procedures in cassava flour processing at the pilot plant, Chinú, northern Colombia. (Dotted lines refer to secondary processes.)

Cassava roots are received in 50 to 60 kg sacks, and should have been harvested on the day of receipt. They should also be free of diseases, deterioration, or severe mechanical damage, and should be from varieties containing high dry matter content.

After washing, chipping, drying, milling, and sieving through 150 microscreens, cassava flour is finally obtained.

## CHAPTER 32

# IMPROVING PROCESSING TECHNOLOGIES FOR HIGH-QUALITY CASSAVA FLOUR

D. M. Jones\*, D. S. Trim\*, and  
C. C. Wheatley\*\*

### Abstract

The potential of cassava flour to diversify markets for cassava producers is investigated. The effects of different root processing regimes on cyanogen contents and microbiological counts—major factors governing quality in cassava flour—were investigated at CIAT. Chipping, rasping, and different drying technologies were evaluated in terms of product quality. Three types of chippers, five rasps, and drying by sun, oven, or bin were used. Rasping and drying reduced the cyanogenic glucoside contents of the roots by 90% to 100%, but microbiological counts were high for all drying technologies. The chipping trials indicate that sun drying on trays produced chips of similar microbiological quality to artificial drying.

### Introduction

Cassava is grown in many parts of the developing world, mainly by small-scale farmers, for both food and income. Often such farmers have

limited scope for other crops, because of harsh climate, poor soils, or both. Markets for fresh roots for direct consumption are stagnant or diminishing in many places because of increasing urbanization and changes in eating habits. Demand for roots for starch and chips for animal feed, although existing where such industries operate, is limited. Cassava flour is a product that could help diversify and strengthen cassava markets for these small producers.

The main industrial market opportunities for cassava flour are in the substitution of other raw materials, primarily wheat flour or starches, for further processing into final products. In some areas, smaller regional markets exist for local, cassava-based food specialties. To penetrate these markets, cassava flour must be of at least comparable quality to the product it is potentially replacing. Possible clients are unlikely to risk changing feed stocks if it is at all possible that the quality of their end product will be adversely affected.

### Factors of Flour Quality

#### *Microbiological quality*

Wheat flour tends to be of high microbiological quality, because the economic product (the grain) develops

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above the ground; is cultivated with modern, large-scale, farming practices; and is harvested at relatively low moisture content. In contrast, cassava roots are usually cultivated with basic farming practices, picking up a microbial load from the soil, and have a much higher moisture content than grains. Hence, cassava flour is likely to have higher levels of microbiological growth.

Table 1 gives selected flour standards. The Colombian standard permits the same maximum bacterial loads for both wheat and cassava flours. Cassava flour has a lower maximum permitted moisture than wheat flour, because of its perceived greater susceptibility to contamination.

**Cyanogens**

Cassava flour also contains residual levels of cyanogenic compounds (cyanogens), mostly cyanogenic

glucosides (CG), cyanohydrins, and hydrogen cyanide (HCN). The glucosides initially present in the fresh roots are broken down, during processing, to the other cyanogens given above (Bokanga, 1992). Cyanogen concentrations are expressed as mg HCN equivalent per kg of dry matter, unless otherwise stated. Nonglucosidic cyanogen (NGC) concentration describes the combined concentrations of cyanohydrins and HCN. The cyanogen levels remaining vary with the raw material concentration and the processing technologies employed (Fish and Trim, 1993). These levels are not a major concern for nonfood use.

Hydrogen cyanide is toxic, but is usually present only in small quantities because of its volatility. Evidence suggests that cyanide poisoning and intoxication resulting from consumption of cassava flour may be caused by high residual

Table 1. Quality standards for selected flours.

Quality criterion	Cassava flour		Wheat flour	
	Colombian <sup>a</sup>	African <sup>b</sup>	Colombian <sup>c</sup>	Tanzanian <sup>d</sup>
Chemical composition (maximum permitted levels):				
Moisture (%)	12	13	14	
Starch (% minimum)	62			
Ash (%)	2	3	0.7	
Crude fiber (%)	2.5	2	2	
Sand (%)	3	10		
Crude cellulose (%)	5			
Total HCN (mg/kg)	50			
Microbial content (cfu/g):				
Aflatoxins	0			
Aerobic plate count at 35 °C	2 x 10 <sup>5</sup>		2 x 10 <sup>5</sup>	1 x 10 <sup>5</sup>
Coliform bacteria	1 x 10 <sup>2</sup>		1 x 10 <sup>2</sup>	
<i>Escherichia coli</i>	0		0	0
Salmonella	0		0	0
Molds and yeasts	1 x 10 <sup>3</sup>		1 x 10 <sup>3</sup>	1 x 10 <sup>3</sup>

a. ICONTEC, 1990.  
 b. FAO and WHO, 1992.  
 c. ICONTEC, 1967.  
 d. Tanzania Bureau of Standards, 1989.

cyanohydrin levels, which then decompose after ingestion (Banea, 1993; Mlingi et al., 1992). The effect of consuming CG on health is less clear and has not yet been thoroughly investigated.

Few official standards exist specifically for cassava chips and flour for human consumption. The Colombian standard for dried cassava sets a maximum total cyanogen content of 50 mg/kg (fresh basis), measured as HCN (ICONTEC, 1990). The regional standard being developed for Africa (FAO and WHO, 1992) sets a maximum total cyanogen content of 10 mg/kg (fresh basis). The standards are expected to evolve with the product, and further guidance may be found in the proceedings of the Cassava Safety Workshop held in 1994.

### **Research on Processing Technologies**

The quality of the cassava flour produced at the CIAT pilot plant was rigorously evaluated in terms of residual cyanogens and microbiological quality (results not shown). Research was then carried out at CIAT, with the following objectives:

- (1) To investigate the modification of chip size as a means of increasing the elimination of total cyanogenic potential (CNP) during flour production. The degree of cyanogen elimination achieved by the pilot plant effectively sets the maximum initial cyanogen concentration in the feed roots acceptable by a plant of this type. Increasing the elimination of cyanogens without fundamentally changing the process would ensure that the cassava flour produced meets

the standard, and would increase the range of varieties that the plant's processing operations can satisfactorily detoxify. Manually peeling the roots was not investigated at this stage.

- (2) To investigate means of processing high cyanide varieties of cassava into flour with safe residual cyanogen levels.

High cyanogen varieties are more suited to some agroecological zones, and are preferred to low cyanogen varieties in some regions. The operations of chipping and drying do not eliminate enough cyanogens to process high cyanogen varieties satisfactorily.

### **Effect of Chip Size on Residual Cyanogens in Bin-dried Chips**

#### **Methods**

Trials were carried out with three different chipping disks: the standard disk (CIAT-designed); a modified version with reduced chip aperture to give thinner chips; and a grating disk designed by the Ecole nationale supérieure des industries agricoles et alimentaires (ENSIA), France (Monroy-Rivera, 1990). Roots 11 months old were harvested the day before the trial and stored outdoors overnight (normal factory plant practice). The roots were washed in a drum washer, which also effectively dehulks the roots, and chipped. The wet chips were bin-dried at 60 °C, at loading densities of 75 and 85 kg/m<sup>2</sup> (Figure 1). Six samples were taken from both fresh and dried chips, and analyzed with the modified Cooke method (O'Brien et al., 1991).

#### **Results**

Table 2 gives the cyanogen contents measured during these trials.

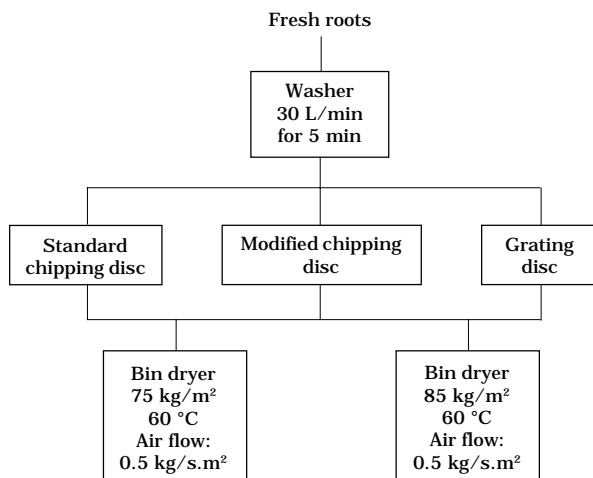


Figure 1. Procedures used in cassava-chipping trials.

**Standard disk.** The total CNP in the fresh chips were reduced by about 34% by chipping with the standard disk, followed by drying within 5 hours. This figure is consistent with the results obtained by using the same disk at the pilot plant, where proportionally greater reductions in CNP were achieved with longer drying times. This was despite processing a different variety under different climatic conditions.

**Modified disk.** The modified disk achieved a similar level of reduction in CG, but with a lower overall CNP reduction of 28%.

The modified chips had an average thickness of 4.3 mm, compared with 6.1 mm for the normal chips, providing a greater cut-surface area. A greater initial elimination of the CG was therefore expected in the modified fresh chips because of the higher percentage of damaged root tissue. Under suitable conditions, a faster drying rate was also expected, leading to surface drying of the chips in a

shorter period, and earlier termination of cyanogenic reactions.

The low degree of elimination obtained with the modified chips indicates that the effect of fast drying is masking any effect of chipping, which would be more obvious at the slower drying rates obtained at higher loading densities.

**Grating disk.** The grating disk showed a higher reduction (56%) than the standard chipper (34%) of CNP, with chipping and drying. This is consistent with the greater extent of tissue damage achieved. Reduction of CG with chipping and drying was consistent at 59%-61%. The reduction in CG is dictated by the quantity of glucosides brought into contact with linamarase enzyme, which, in turn, depends on the extent of tissue damage. Cyanogenic glucosides in undamaged tissue remain intact. The chips produced by the grating disk were more fragile than the pilot plant ones and less suitable for bin drying.

Table 2. Cyanogen concentrations<sup>a</sup> measured during cassava chipping trials<sup>b</sup>.

Cyanogenic contents	Standard disk at loading density (kg/m <sup>2</sup> ):						Modified disk at loading density of 85 kg/m <sup>2</sup>			Grating disk at loading density (kg/m <sup>2</sup> ):					
	85			75						85			75		
	CNP	NGC	CG	CNP	NGC	CG	CNP	NGC	CG	CNP	NGC	CG	CNP	NGC	CG
Fresh chips (mg HCN equiv./kg dry matter)	1,269	253	1,016	1,096	172	924	832	152	680	858	320	539	1,118	198	920
Dried chips (mg HCN equiv./kg dry matter)	812	35	776	746	38	709	598	7	591	396	40	356	480	41	439
Reduction with chipping (%)			20			16			18			37			18
Reduction with chipping and drying (%)	36		39	32		35	28		29	54		59	57		61

a. CNP = total cyanogen potential; NGC = nonglucosidic cyanogen content; CG = cyanogenic glucoside content.

b. Each value is an average of six samples; percentage of reduction in both CNP and CG is based on fresh chips CNP; all trials used roots of M Ven 25, a high cyanogen variety.

## Summary

Elimination of CNP from chips made by the standard disk increased with drying time, regardless of cassava variety or location.

The grating disk eliminated 22% more CNP than the pilot plant disk at the same loading density. Grated chips, however, are more fragile than standard chips and less suitable for bin drying.

## Effect of Different Raspsers on Residual CNP in Tray-Dried Pulps

The effect of different raspsers on the degree of cyanogen elimination achieved with rasping and drying was investigated. Rasping almost completely destroys the root tissue structure, much more so than chipping. The trials used roots of M Ven 25, a very high cyanogen variety, to establish the upper limits of cyanogen elimination.

## Methods

Five different raspsers were used:

- (1) A conventional, wooden Jahn rasper, in which serrated blades are mounted laterally on a wooden drum.
- (2) A punched-drum rasper, consisting of a metal sheet with outward facing jagged holes (punched through with a nail), fixed around a wooden drum frame.
- (3) A pin rasper (experimental), a metal drum scored diagonally in both directions across its length with metal pins protruding about 5 mm from the drum's surface.
- (4) An abrasion rasper (experimental), with a layer of carborundum, about 10 mm deep, fixed around a drum.

- (5) A plastic, Jahn rasper (experimental), in which metal serrated blades are mounted laterally on a plastic drum.

Four of the rasper drums tested were interchangeable within the same rasper frame, designed to investigate their relative starch extraction efficiency. The drums were 400 mm in length and 270 mm in diameter. The plastic Jahn rasper drum was a smaller, self-contained unit, 275 mm in length and 200 mm in diameter. An ordinary 5-HP motor was used for all the raspsers. The wooden Jahn rasper and the punched-drum rasper are in common use in the cassava starch industry.

Roots were harvested at 9 months and stored as for the chipping trials. The roots were washed in clean but untreated water and dehusked manually. Fifteen kilograms of the washed roots were rasped without adding water. The resulting pulp was mixed and dried at 8 kg/m<sup>2</sup> on two trays in a despatch tray dryer at 60 °C (Figure 2). Four samples each of the fresh and dried pulps were taken for evaluation of cyanogen concentrations. This procedure was followed for each rasper.

## Results

Table 3 gives the cyanogen concentrations measured during this trial.

**Cyanogen contents of rasped pulps.** The reduction in CG with rasping only was variable, with both the Jahn raspsers reducing the CG by 65%, and the punched drum by 43%. When the pulps were both rasped and dried, the CNPs were reduced by 94%-96% for all raspsers, regardless of the degree of reduction effected by rasping alone. The residual CNPs in the pulps ranged

Table 3. Cyanogen concentrations<sup>a</sup> during cassava-rasping trials, measured in mg CN equiv./kg dry matter<sup>b</sup>.

Rasper drum		Fresh roots			Fresh pulp			Dried pulp			Reduction of CG with rasping (%)	Reduction with rasping and drying (%)	
Type	Feed (kg/min)	CNP	NGC	CG	CNP	NGC	CG	CNP	NGC	CG		CNP	CG
Wooden Jahn	28.6	2,318	271	2,047	2,195	1,409	786	104	29	74	66	96	97
Punched drum	32.6	2,417	243	2,175	2,267	968	1,299	152	88	64	46	94	97
Abrasion	2.1	2,024	235	1,789	1,932	1,372	559	132	29	103	72	94	95
Metal pin	15.0	2,608	315	2,293	2,236	881	1,355	163	27	137	48	94	95
Plastic Jahn	N/A	2,234	293	1,941	2,045	1,358	687	111	25	87	69	95	96

a. CNP = total cyanogenic potential; NGC = nonglucosidic cyanogen content; CG = cyanogenic glucoside content.

b. Each value is an average of six samples of fresh roots and four samples of pulp; percentage of reduction in both CNP and CG is based on fresh root CNP; all trials used roots of M Ven 25, a high cyanogen variety.

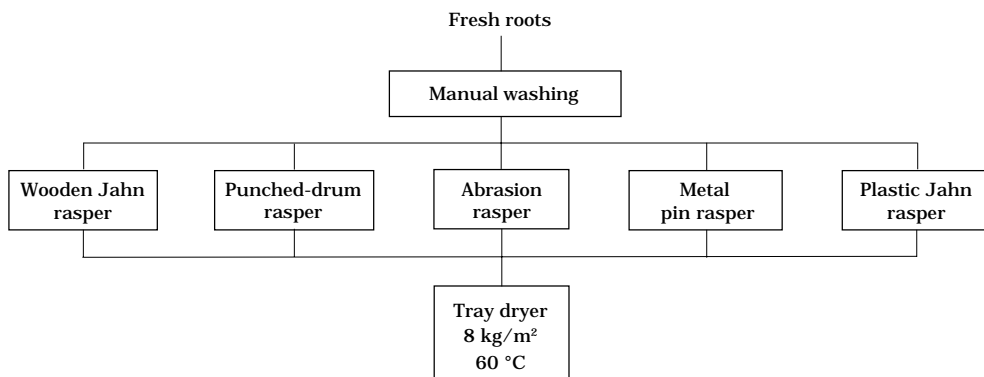


Figure 2. Procedures used in cassava-rasping trials.

from 104 to 163 mg/kg. In previous milling trials, the residual CNP concentration in first-grade flour was about 36% of the level in freshly dried chips. Assuming this to hold true for pulps, the flours would have CNPs between 38 and 58 mg/kg, thus mostly meeting the Colombian standard of 50 mg/kg.

This level of total cyanogen elimination probably approaches the maximum possible in practice, given that variations occur because of fluctuating conditions. No significant differences in the overall elimination of CNPs was found between the rasplers.

**Root throughput.** The abrasion raspler's root feed was 10% below that of the Jahn or punched-drum rasplers, thus making it unsuitable for commercial flour production. The shredding action employed by both the Jahn and punched-drum rasplers removes a deeper layer of root tissue with each contact than does the erosive action of the abrasion raspler, resulting in a larger root feed.

The pulp produced by the abrasion raspler was finer and more homogenous than the other pulps, indicating a greater degree of tissue comminution. However, the final

reduction in CNP achieved with the abrasion raspler was not significantly different to that achieved with the other rasplers. The pulp was also more liquid and difficult to handle than the others.

### Summary

Except for the abrasion raspler, the rasplers evaluated were suitable for processing roots with high cyanogen contents to flour with low cyanogen content. The wooden Jahn and the punched-drum rasplers are commercially available.

### Effect of Different Drying Techniques on Residual Cyanogens and the Microbiological Quality of Dried Pulps and Chips

The effects of different drying techniques (sun and artificial) on the microbiological quality and on the cyanogen concentrations of chips and rasped pulps were evaluated.

Rasped pulp is not suitable for bin drying, and the effect of rasping on the microbiological quality of the dried product is unknown. Because smaller operations may not be able to justify

the investment and cost of artificial drying, the effect of sun drying on the microbiological quality of products was also evaluated.

### Methods

Three trials were carried out on 10-month-old roots of cassava variety M Ven 25. The first two trials used the wooden Jahn and punched-drum rasps for root comminution. The roots were washed and dry-rasped as in the rasping trials described above. The pulps were dried at loading densities of 5 and 10 kg/m<sup>2</sup> on raised trays and on a concrete floor in the

sun, and in an oven at 60 °C. The final trial was carried out with the modified chipper, with the chips dried at 5 kg/m<sup>2</sup> in the same way (Figure 3). Chips were also bin-dried at 70 kg/m<sup>2</sup> and 60 °C (Figure 4). The chips and pulps were mixed manually every 2 h during drying. Three composite samples of each dried product were taken for microbiological analysis. The samples were analyzed for aerobic plate counts (APC) (35 °C), spore counts (35 °C), and yeasts and molds the following day (ICMSF, 1978). Four samples each of the fresh and dried pulps were also taken for cyanogen evaluation.

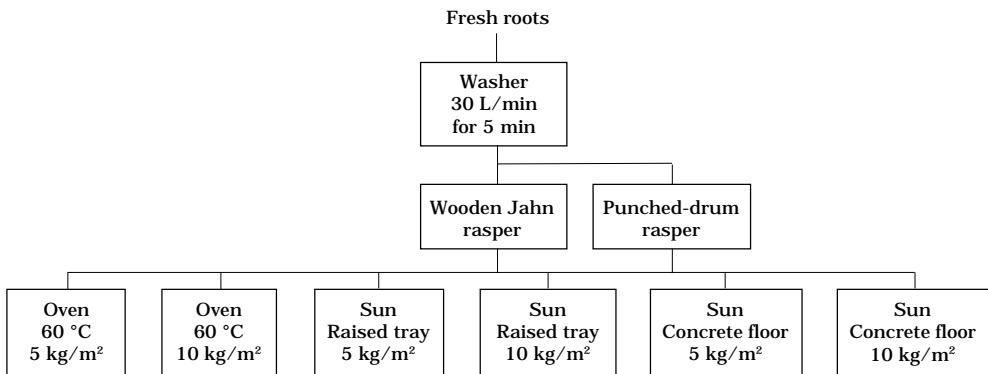


Figure 3. Procedures used in cassava rasping and drying trials.

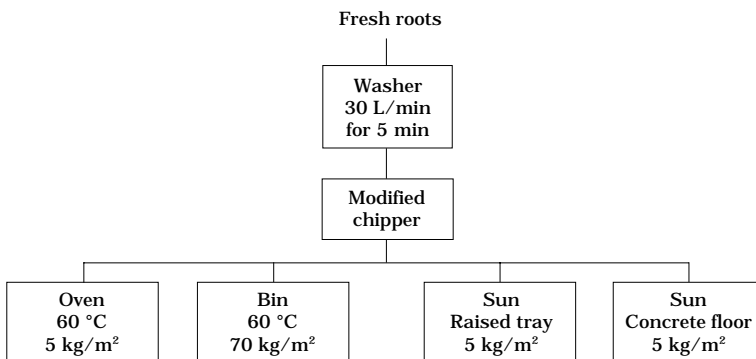


Figure 4. Procedures used in cassava chipping and drying trials.

**Results**

Table 4 gives the cyanogen concentrations measured during the trials and Table 5, the microbiological counts.

**Cyanogenic contents of dried chips and pulps.** Compared with the rasping-only trials, the punched drum reduced CG (88%) more than the wooden Jahn rasper (53%). Rasping and drying reduced the CG by 90%-100%. Sun-dried pulps tended to have higher residual NGC than did oven-dried pulps, possibly because of the higher rate of removal of HCN during forced-circulation oven drying, which would increase the rate of breakdown of cyanohydrin to HCN. Residual cyanohydrin levels tend to

drop with storage and may also be reduced by the heat generated by milling to flour.

**Microbiological quality of dry pulps and chips.** All of the dried, rasped, pulp samples had high APCs ( $10^8$  cfu/g), as did the chips which were sun dried on a concrete floor. The oven-dried, and raised-tray, sun-dried chips were of acceptable quality ( $10^5$  cfu/g), and the bin-dried chips had only slightly higher counts. The rasped pulps provide a better substrate for microbial growth than the chips, as the cell contents (e.g., sugars and proteins) have all been released by rasping.

However, the APCs of fresh chips have been measured at around

Table 4. Cyanogen concentrations<sup>a</sup> during drying trials (rasped pulp only), measured in mg CN equiv./kg dry matter<sup>b</sup>.

Cyanide concentration	Pulp sample from:									
	Wooden Jahn rasper					Punched-drum rasper				
	CNP	NGC	CG	Reduction with rasping and drying (%)		CNP	NGC	CG	Reduction with rasping and drying (%)	
				CNP	CG				CNP	CG
Fresh pulp	1,302	696	606		54	1,562	1,383	179		87
Dried pulp:										
Oven, 5 kg/m <sup>2</sup> , 60 °C	154	30	124	88	91	37	17	20	98	99
Oven, 10 kg/m <sup>2</sup> , 60 °C	105	31	74	92	94	33	28	5	98	>99
Sun, 5 kg/m <sup>2</sup> , raised tray	99	47	52	92	96	53	45	7	97	>99
Sun, 10 kg/m <sup>2</sup> , raised tray	67	51	15	95	99	60	50	9	96	99
Sun, 5 kg/m <sup>2</sup> , concrete floor	84	77	8	94	99	68	61	7	96	>99
Sun, 10 kg/m <sup>2</sup> , concrete floor	85	82	3	95	>99	81	73	8	95	99

a. CNP = total cyanogenic potential; NGC = nonglucosidic cyanogen content; CG = cyanogenic glucoside content.  
 b. Each value is an average of six samples of fresh roots and four samples of pulp; percentage of reduction in both CNP and CG is based on fresh pulp CNP; all trials used roots of M Ven 25, a high cyanogen variety.

Table 5. Microbiological quality of dried pulp and chips generated in cassava-drying trials.

Rasping and drying method	Loading density (kg/m <sup>2</sup> )	Microbiological count <sup>a</sup>		
		Aerobic plate count at 35 °C	Spore count at 35 °C	Yeast and mold count
<b>Wooden Jahn rasper:</b>				
Oven, 60 °C	5	3.43 x 10 <sup>8</sup>	3.18 x 10 <sup>5</sup>	4.99 x 10 <sup>4</sup>
Oven, 60 °C	10	3.58 x 10 <sup>8</sup>	2.61 x 10 <sup>5</sup>	5.40 x 10 <sup>4</sup>
Sun, raised tray	5	4.57 x 10 <sup>8</sup>	6.63 x 10 <sup>4</sup>	8.18 x 10 <sup>4</sup>
Sun, raised tray	10	2.95 x 10 <sup>8</sup>	3.10 x 10 <sup>4</sup>	5.64 x 10 <sup>4</sup>
Sun, floor	5	5.64 x 10 <sup>8</sup>	9.20 x 10 <sup>4</sup>	1.03 x 10 <sup>5</sup>
Sun, floor	10	3.51 x 10 <sup>8</sup>	3.28 x 10 <sup>4</sup>	3.08 x 10 <sup>4</sup>
<b>Punched-drum rasper:</b>				
Oven, 60 °C	5	1.01 x 10 <sup>8</sup>	8.02 x 10 <sup>4</sup>	6.33 x 10 <sup>3</sup>
Oven, 60 °C	10	2.12 x 10 <sup>8</sup>	3.74 x 10 <sup>4</sup>	2.65 x 10 <sup>4</sup>
Sun, raised tray	5	2.08 x 10 <sup>8</sup>	2.84 x 10 <sup>4</sup>	5.48 x 10 <sup>4</sup>
Sun, raised tray	10	5.24 x 10 <sup>8</sup>	1.92 x 10 <sup>4</sup>	1.97 x 10 <sup>5</sup>
Sun, floor	5	1.13 x 10 <sup>8</sup>	1.38 x 10 <sup>4</sup>	1.15 x 10 <sup>5</sup>
Sun, floor	10	5.93 x 10 <sup>8</sup>	1.87 x 10 <sup>4</sup>	7.13 x 10 <sup>4</sup>
<b>Modified chipper:</b>				
Oven, 60 °C	5	5.45 x 10 <sup>5</sup>	4.50 x 10 <sup>2</sup>	2.67 x 10 <sup>2</sup>
Bin, 60 °C	70	2.04 x 10 <sup>6</sup>	8.67 x 10 <sup>2</sup>	7.33 x 10 <sup>2</sup>
Sun, raised tray	5	2.18 x 10 <sup>5</sup>	3.33 x 10 <sup>2</sup>	1.33 x 10 <sup>2</sup>
Sun, floor	5	4.01 x 10 <sup>8</sup>	1.71 x 10 <sup>5</sup>	2.15 x 10 <sup>5</sup>

a. Counts expressed as colony forming units per gram (cfu/g), wet weight basis; average of three composite samples.

10<sup>5</sup> cfu/g (Table 6). Previous pilot-plant experience has shown that, with long drying times (22 h), the APCs of the chips are at 10<sup>8</sup> cfu/g, but reducing the drying time to 10 h reduces the APCs to 10<sup>5</sup> cfu/g. Faster drying of the pulp may therefore offer a means of reducing the counts. The shortest pulp drying time of 6 h was insufficient to affect the counts.

Raised-tray sun drying of chips gave a product of good microbiological quality with APCs similar to those of oven-dried chips. Thus, this method may have potential for reducing costs under suitable climatic conditions (site specific).

## Summary

Rasping and drying of cassava roots is an effective means of reducing the CNP present in high cyanogen cassava varieties. However, the greater degree of root disintegration leads to increased microbiological growth.

## Conclusions

Processing with the grating disk reduced CNP by 22% more than the standard disk. However, drying grated chips at high loading densities may be difficult.

Fast drying stopped the elimination of cyanogens early in the

Table 6. Microbiological quality of processed samples from pilot plant and CIAT trials, November 1991.

Sample	Microbiological counts <sup>a</sup>			
	Aerobic plate count at 35 °C	Spore count at 35 °C	Coliforms (MPN <sup>b</sup> )	Fecal coli-forms (MPN <sup>b</sup> )
CIAT:				
Soil	7.7 x 10 <sup>7</sup>	8.1 x 10 <sup>5</sup>	>1.1 x 10 <sup>3</sup>	15
Root peel <sup>c</sup>	3.0 x 10 <sup>7</sup>	6.2 x 10 <sup>4</sup>	>1.1 x 10 <sup>3</sup>	<3
Parenchyma	1.2 x 10 <sup>3</sup>	1.5 x 10 <sup>2</sup>	<3	<3
Pilot plant:				
Soil	6.8 x 10 <sup>7</sup>	5.7 x 10 <sup>7</sup>	>1.1 x 10 <sup>3</sup>	40
Root peel <sup>c</sup>	1.4 x 10 <sup>7</sup>	3.0 x 10 <sup>5</sup>	>1.1 x 10 <sup>3</sup>	7
Well water	4.6 x 10 <sup>3</sup>	8.3 x 10 <sup>1</sup>	<3	<3
Tank water <sup>d</sup>	4.7 x 10 <sup>3</sup>	2.6 x 10 <sup>2</sup>	<3	<3
Fresh chips	4.9 x 10 <sup>5</sup>	2.8 x 10 <sup>3</sup>	1.1 x 10 <sup>3</sup>	500

a. Counts expressed as cfu/g (wet weight basis) for processed samples and as cfu/ml for water samples.

b. MPN = most probable number.

c. Root peel includes bark and peel.

d. Tank water treated with 10-20 mg/L free chlorine.

SOURCE: D. S. Trim and P. Wareing, 1991, personal communication.

drying period of the modified-disk chips, masking any effect chip size might have had. Greater reduction in CNP is likely at higher loading densities.

Rasping and drying is an effective means of processing even very high cyanogen roots to a flour that meets the Colombian standard. Further work is needed to improve the product's microbiological quality.

In suitable climatic conditions, raised-tray sun drying of chips gives a product of good microbiological quality.

## References

- Banea, M. 1993. Cassava processing, dietary cyanide exposure and konzo in Zaire. Thesis for Master of Medical Sciences degree. International Child Health Unit (ICH), Uppsala, Sweden. 65 p.
- Bokanga, M. 1992. Mechanisms of the elimination of cyanogens from cassava during traditional processing. In: Westby, A. and Reilly, P. J. A. (eds.). Proceedings of a Regional Workshop on Traditional African Foods - Quality and Nutrition, 25-29 Nov. 1991, Dar es Salaam. International Foundation for Science (IFS), Uppsala, Sweden. p. 157-162.
- FAO and WHO (Food and Agriculture Organization of the United Nations and World Health Organization), Codex Alimentarius Commission. 1992. Codex standard for edible cassava flour—African regional standard—CODEX STAN 176-1991. Eighth session of the Codex Committee on Cereals, Pulses and Legumes, CX/CPL 92/9, June, 1992. FAO/WHO Food Standards Program, Rome, Italy. 17 p.
- Fish, D. M. and Trim, D. S. 1993. A review of research into the drying of cassava chips. *Trop. Sci.* 33:191-208.
- ICMSF (International Commission on Microbiological Specifications for Foods). 1978. Microorganisms in foods, 1: their significance and methods of enumeration. 2nd ed. Academic Press, London, UK.

- ICONTEC (Instituto Colombiano de Normas Técnicas). 1967. Harina de trigo para panificación. In: Industrias alimentarias, 2nd rev., vol. 10. NTC 267. Bogotá, Colombia. p. 55-67.
- \_\_\_\_\_. 1990. Yuca seca para consumo humano. In: Frutas, legumbres y hortalizas. NTC 2716. Bogotá, Colombia.
- Mlingi, N. L. V.; Assey, V. D.; Poulter, N. H.; and Rosling, H. 1992. Cyanohydrins from insufficiently processed cassava induces 'KONZO', a newly identified paralytic disease in man. In: Westby, A. and Reilly, P. J. A. (eds.). Proceedings of a Regional Workshop on Traditional African Foods - Quality and Nutrition, 25-29 Nov. 1991, Dar es Salaam. International Foundation for Science (IFS), Uppsala, Sweden. p. 163-169.
- Monroy-Rivera, J. A. 1990. Eliminación de compuestos cianogénicos durante el secado de yuca. Informe de los trabajos realizados en el CIAT. Ecole nationale supérieure des industries agricoles et alimentaires (ENSIA), Massy, France. 51 p.
- O'Brien, G. M.; Taylor, A. J.; and Poulter, N. H. 1991. Improved enzymic assay for cyanogens in fresh and processed cassava. *J. Sci. Food Agric.* 56:277-289.
- Tanzania Bureau of Standards. 1989. Tanzania wheat flour specification. TZS 439:1989. Dar es Salaam, Tanzania.

# CASSAVA FLOUR IN MALAWI: PROCESSING, QUALITY, AND USES

J. D. Kalenga Saka\*

## Abstract

The quality of flour processed from cassava (*Manihot esculenta* Crantz) by two methods commonly used in Malawi was determined. The first, simple sun-drying, gives a flour known as *ntandaza*; the other—soaking in water, followed by sun drying—provides *kondowole* flour. Processing affects both the nutritional quality and cyanogen content of the final products. The soaking step significantly reduces mineral and protein contents and raises the carbohydrate level ( $P > 0.05$ ) to  $91.1\% \pm 1.1\%$  for *ntandaza* flour and  $95.3\% \pm 0.7\%$  for *kondowole*.

The soaking step, followed by sun drying, reduces the cyanogen content more than sun drying alone. In soaking + sun drying, less than 10 mg HCN/kg dry wt were detected in the final products, representing a  $98.0\% \pm 1.6\%$  reduction of initial cyanogen content. Simple sun drying reduced total cyanogen content by  $82.9\% \pm 5.2\%$ .

The uses of cassava flour in bakery, brewing, and making cassava *sima* are described.

## Introduction

Cassava (*Manihot esculenta* Crantz) is a major root crop in the tropics, and its starchy roots are a significant source of calories for more than 500 million people worldwide (Cock, 1985). In Malawi, cassava is the second most important staple after maize (DEPD, 1987): about 30% of the population depends on cassava for calories (Sauti, 1982). The crop grows easily in all parts of the country, but especially along the shores of Lake Malawi where it is the most important staple food. Since the 1991/92 drought, which devastated Malawi, the Government has intensified the country's production of cassava, a drought-resistant crop, to guarantee food security.

Cassava is eaten in various forms; these determine the methods of processing, which aim to (1) provide products that are storable and easy to transport to market; (2) improve the taste of final products; (3) reduce potential cassava toxicity; and (4) provide products such as flour for subsequent conversion to a variety of end products (Hahn, 1989; Lancaster et al., 1982). In Malawi, two methods are employed to make cassava flour, resulting in two kinds of flour: *kondowole* and *ntandaza* (Saka, n.d.; Williamson, 1975).

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*Kondowole* flour is prepared by soaking peeled cassava roots for 2 to 7 days; sun drying the soft mass (called *maphumu*) and pounding the dried mass to make the flour (Figure 1). This product is popular among lakeshore populations living in Karonga District to as far south as Nkhotakota District (Figure 2). The soaking of unpeeled roots is also practiced, but the flour gives products which taste bitter and appear darker. The flour is used in its pure form or is mixed with cereal flours (maize, sorghum, millet, wheat, or rice).

Among other things, the flour is used to make *sima*. Its preparation involves adding the flour to simmering water and stirring the paste to consistency. Both pure and composite flours are used for brewing sweet and alcoholic beverages. When mixed with wheat flour, the composite flour is widely used to bake breads, scones, cakes, and biscuits. The pure *kondowole* flour is also used in baking. When mixed with cereal flour, the nutritional value of the

cassava-based products improves (Sauti et al., 1989).

*Ntandaza* flour is made by sun drying peeled and/or partially peeled roots for 1 week or several months. The roots may be dried whole, as cut pieces, or after pounding; the last dries fastest. The dried product is called *makaka* and the resultant flour is commonly known as *ntandaza*. The flour is also referred to as *ntandasha* and *mtandasha*, depending on the locality.

This method of processing cassava is predominant in central and southern Malawi (Figures 2 and 3). A variation of the methodology involves first covering the cassava roots with banana leaves to induce mold formation. The moldy product is then sun dried to provide a darker and moldy *makaka* (Van Drongelen, 1992).

Although the *ntandaza* flour is used in the same way as *kondowole* flour, its most important use is in

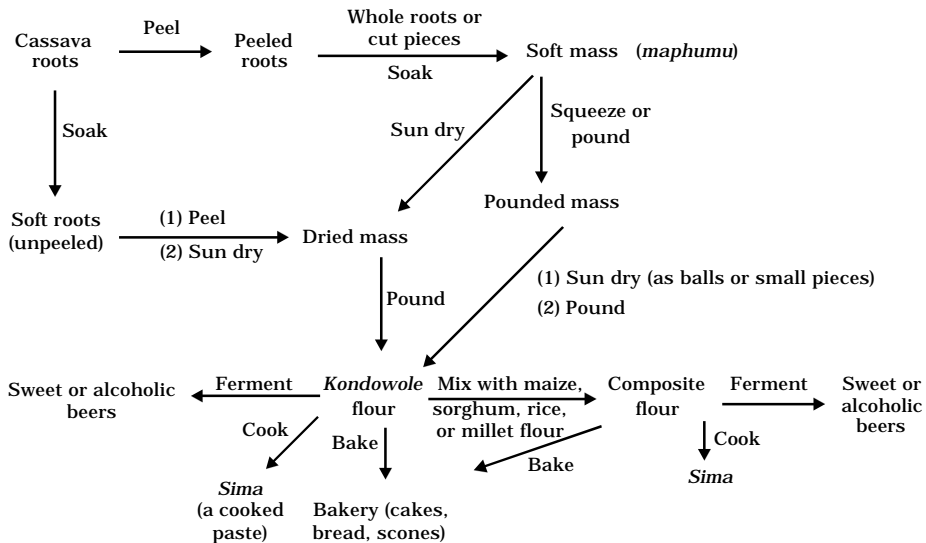


Figure 1. Processing *kondowole* flour from cassava roots, and its uses, Malawi.

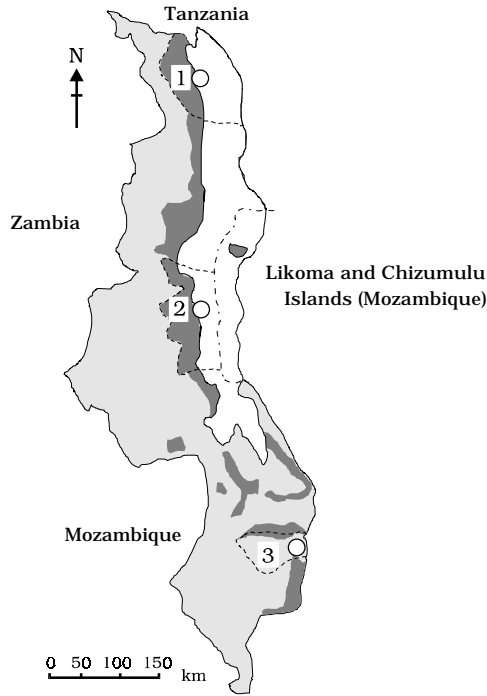


Figure 2. Cassava-growing areas in Malawi (■ = major growing areas; □ = scattered crops; □ = lake). 1 = Karonga District; 2 = Nkhhotakota District; 3 = Zomba District; ○ = town of same name as district. (After Nyirenda.)

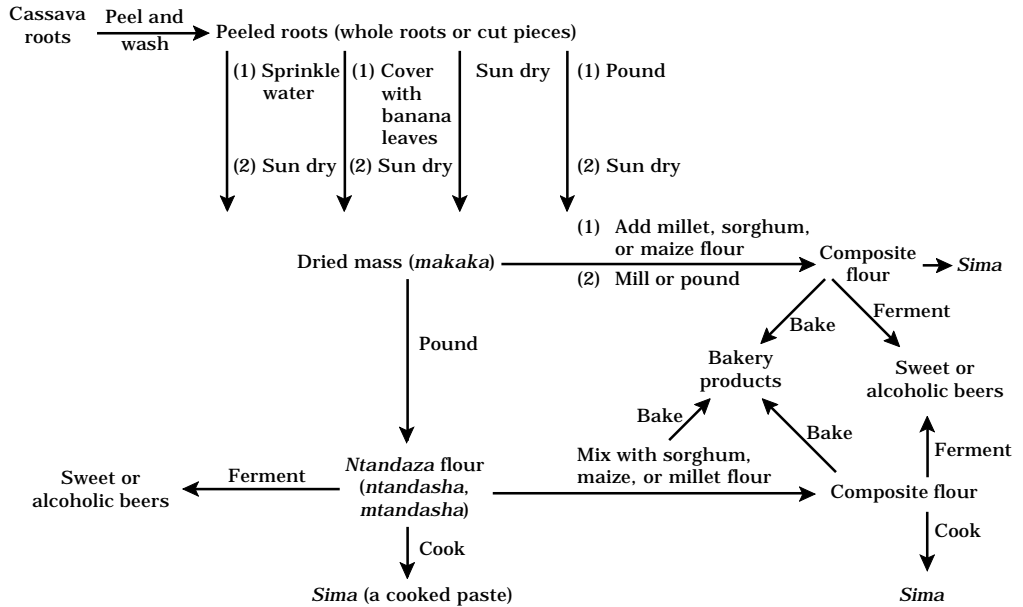


Figure 3. Processing *ntandaza* flour from cassava roots, and its uses, Malawi.

brewing. The resulting beer is reported to be of superior quality.

Information on the quality of cassava flour produced in Malawi was limited until 1986, when our work began (Saka, n.d.). The processing of cassava into various forms affects the nutritional value of the final products (Longe, 1980). The levels of total cyanoglucosides, linamarin and lotaustralin are also affected during processing (Lancaster et al., 1982).

Hydrolysis of cyanoglucosides by an endogenous enzyme, linamarase, liberates the highly toxic substance, hydrocyanic acid (HCN) via acetocyanohydrin (de Bruijn, 1971). The presence of nonglucosidic cyanogens (NGC; acetocyanohydrin and HCN) limits cassava use (Nartey, 1978). Cyanide has a lethal dose of 0.5 to 3.5 mg HCN/kg of body weight. Although the reports of acute cyanide intoxication and death among cassava-eating populations are infrequent, ample evidence exists that goiter and cretinism (due to iodine deficiency) are exacerbated, and that diseases such as tropic ataxic neuropathy and epidemic spastic paraparesis (*konzo*) are caused by long-term ingestion of cyanide from cassava (Rosling, 1987).

We studied the nutritional value and cyanogen content of the two Malawian cassava flours to ascertain their quality.

## Material and Methods

### Cassava samples

Tuberous roots were obtained from the Makoka Agricultural Research Station, Zomba, and from the "D. C. Munthali" Research Farm, Biology Department, Chancellor College, Zomba. The roots analyzed for nutritional value were from

12-month-old plants, whereas those processed into *kondowole* and *ntandaza* flours for cyanogen determination varied from 20 to 22 months in age.

### Processing the flours

**Kondowole.** Four roots from each of three plants, totalling 12, from each of three varieties were peeled, washed, and soaked in deionized water (volume not recorded) in plastic wash basins for 7 days. The resulting soft mass was washed with clean water, broken down (by hand) into small pieces while removing floury material in the process, and left to dry on trays in the sun for 7 days. The dried product was then ground in a blender and sieved.

The data (Tables 1 and 2) obtained for *kondowole* flour were taken from 20 to 22-month-old plants and the soft, soaked roots were made into balls and sun dried for 67 h. Samples of *kondowole* flour were provided by the Cassava Commodity Team, Makoka Agricultural Research Station.

**Ntandaza.** Twelve roots were selected as above, peeled, and either pounded or cut longitudinally and transversely to produce chips. The chips were sun-dried on trays and the dried material (*makaka*) was processed into flour, using a blender and sieve. The pounded roots were sun dried for 2 to 3 days (Table 1).

### Chemical analysis

Analar grade chemicals and solvents were used. Fresh roots and cassava flours were analyzed for moisture, ash, crude fiber, fat, crude protein, and minerals (Ca, P, Mg, and K), using standard procedures (Osborne and Voogt, 1978). The carbohydrate content was calculated by difference.

Table 1. Cyanogen content of cassava flours (mg HCN/kg dry wt) produced in Malawi. Values are means of samples, with SE in parentheses.

Flour type	Moisture (%)	Cyanogens			Total cyanogen reduction (% of initial content)
		Total	Non-glucosidic	Free	
<i>Kondowole</i> (n = 21)	11.8	2.91	0.75	0.69	98.0
<i>Ntandaza</i> (n = 8):					
Pounded <sup>a</sup> , sun dried	11.4 (1.2)	116.8 (6.2)	25.5 (0.7)	1.6 (0.2)	79.7 (1.3)
Pounded <sup>b</sup> , sun dried	4.88 (0.12)	54.4 (2.5)	4.80 (0.20)	0.39 (0.06)	80.0 (2.5)
Chips <sup>c</sup> , sun dried	14.6 (0.5)	51.6 (3.1)	12.4 (0.6)	3.05 (0.20)	88.9 (1.0)

a. 'Nyambi', a bitter variety, was peeled, pounded, and sun dried at  $30 \pm 1$  °C for 48 h.

b. 'Gomani', a bitter variety, was peeled, pounded and sun dried at  $30 \pm 1$  °C for 72 h.

c. 'TMS 1230158 (OP)', a bitter variety, was peeled, cut into chips and sun dried at  $30 \pm 1$  °C for 72 h.

Table 2. Composition of cassava roots and products from our work and some literature sources (on dry wt basis). Each value is the mean of 12 roots with  $\pm$  SE.

Component	Roots (Malawi study)	<i>Ntandaza</i> flour		<i>Kondowole</i> flour		
		Malawi study	Longe, 1980	Malawi study	Williamson, 1975	Longe, 1980
Moisture (%)	55.9 $\pm$ 4.9	13.44 $\pm$ 2.66	11.80	10.77 $\pm$ 2.72	12.00	12.00
Ash (%)	2.21 $\pm$ 0.45	2.15 $\pm$ 0.18	2.05	0.91 $\pm$ 0.30		1.79
Crude fat (%)	1.23 $\pm$ 0.44	0.87 $\pm$ 0.33	0.46	0.70 $\pm$ 0.30		0.24
Crude fiber (%)	2.29 $\pm$ 0.39	2.30 $\pm$ 0.70		1.62 $\pm$ 0.30		
Crude protein (%)	3.17 $\pm$ 0.62	3.39 $\pm$ 0.73	2.04	1.46 $\pm$ 0.30	1.70	1.51
Carbohydrate (%)	91.1 $\pm$ 1.2	91.0 $\pm$ 1.1	90.30	95.3 $\pm$ 0.66	95.50	94.40
P (mg/100 g)	82 $\pm$ 35	93 $\pm$ 27		40 $\pm$ 20		
Ca (mg/100 g)	54 $\pm$ 27	26 $\pm$ 12		17 $\pm$ 8	63.00	
Mg (mg/100 g)	40 $\pm$ 17	58 $\pm$ 16		32 $\pm$ 13		
K (mg/100 g)	768 $\pm$ 354	877 $\pm$ 358		330 $\pm$ 138		

### Cyanogen extraction and analysis

To 30 g of flour (60 g fresh roots) in a blender was added 0.1 M of chilled orthophosphoric acid ( $H_3PO_4$ ) (200 cm<sup>3</sup>), with subsequent extraction according to Cooke's (1978) method. The milky liquid was poured into centrifuge tubes. Their weights were adjusted until equal and the tubes

were then centrifuged at  $8 \times 10^3$  g for 10 minutes. The supernatant was collected in sample bottles and deep-frozen until analysis. The fresh cassava was extracted in four replicates and the processed cassava in duplicates. For the assay of total cyanogen content, samples were prepared according to the acid hydrolysis method of Bradbury et al.

(1991). For NGC (cyanohydrin plus free HCN) and free cyanide, the procedure of O'Brien et al. (1991) was used. In all cyanogen assays, a sodium isonicotinate-sodium dimethylbarbiturate coloring reagent was used (Saka, 1992).

The moisture contents of fresh and processed cassava were determined gravimetrically after oven drying three replicate, 10-g-sample aliquots at  $110 \pm 5$  °C for 16 h.

## Results and Discussion

Table 2 presents the mean chemical data for *kondowole* and *ntandaza* flours and the literature data for cassava flours similarly processed. The results show that, despite certain similarities, the chemical compositions of the two flours were significantly different at  $P = 0.05$ .

At 1% level, neither the fat values nor the Ca content were significantly different. The chemical data in Table 2 reveal that, compared with fresh roots, the two cassava flours are equally important sources of carbohydrates, but with generally lower values in protein, fat, and fiber. Their mean nutritional values compare well with published data (Longe, 1980) but higher fat levels were obtained by Saka (n.d.). The present data fill several gaps and also confirm the limited available information on Malawi cassava flour (Williamson, 1975).

Comparison of the chemical composition of fresh roots (Saka, n.d.) and the two cassava flours (Table 2) indicates that sun drying alone, and soaking in water followed by sun drying, affect the nutritional value of cassava. Simple sun drying produced *ntandaza* flour, whose dry matter, fat, Ca, and Mg levels were significantly different (at  $P = 0.05$ ) from those of

fresh roots. Whereas the dry matter and Mg contents were increased, the fat and Ca levels were decreased.

Soaking and subsequent sun drying of cassava provided *kondowole* flour, whose composition was significantly different (at both  $P = 0.05$  and  $0.01$ ) from that of fresh roots. During this process, the carbohydrate content became significantly higher while the rest of the analyzed constituents decreased. These were lost as dissolved material during soaking. These findings are consistent with those reported by Longe (1980).

Table 1 provides the levels of total, nonglucosidic, and free cyanogens of *kondowole* and *ntandaza* flours and presents the percentage reductions in total cyanogen content. The results show that the method used to prepare *kondowole* flour (involving a submerged fermentation stage) was more efficient in reducing total cyanogen content than that employed for *ntandaza* flour. The production of *kondowole* resulted in  $98.0\% \pm 1.6\%$  loss in the total cyanogen content while an  $82.9\% \pm 5.2\%$  reduction was achieved during the processing of *ntandaza* flour.

Mahungu et al. (1987) also noted a 99% reduction in cyanogen content with methods that involve soaking roots in water. Saka (1992) recently eliminated 70% to 80% of total cyanogen content by sun drying 1-cm<sup>3</sup> cassava chips for 48 h. The residual, total cyanogen content of *kondowole* flour was  $2.91 \pm 1.44$  mg HCN/kg dry wt and of *ntandaza* flour,  $51.6 \pm 3.1$  to  $116.8 \pm 6.2$ . Thus, the *ntandaza* flour contained much higher residual cyanogen content than did the *kondowole*. The final cyanogen content depends on whether the variety contains low ("sweet") or high ("bitter") cyanogen.

The less bitter, or sweet, varieties have lower residual cyanogen content when sun dried (Saka, n.d.).

The composition of the three forms of cyanogens indicates that free HCN is a major component of the NGC in *kondowole* flour. In contrast, in *ntandaza*, cyanohydrin is the major component. Cyanoglucosides also predominate in *ntandaza* flour.

High levels of acetocyanohydrin in sun-dried chips have also been observed by others (Mlingi et al., 1992). Consumption of this type of cassava appears to lead to high thiocyanate levels in human urine (Mlingi et al., 1992). Plans are currently under way to develop or upgrade methods for reducing total residual cyanogen and cyanohydrin to levels comparable with those in *kondowole* flour.

## Conclusions

Cassava and its flours are major sources of carbohydrates, but have low values in protein, fat, and minerals. The protein content could be improved by fortifying with cereal and legume grains. The use of cassava flour in Malawi remains restricted to cooking *sima*, baking, and brewing. Diversifying and promoting cassava flour use is desirable.

Soaking and subsequent sun drying of cassava roots greatly reduce the high cyanogen levels to low, safe values for human consumption. This method increased the carbohydrate content of the cassava, but other nutrients were reduced considerably. Simple sun drying was less effective in reducing total cyanogens, especially when the initial cyanogen content

was high. The final products may remain potentially toxic for human consumption. Pounding of fresh cassava and its subsequent sun drying seem to offer better prospects in achieving low cyanogen content.

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## References

- Bradbury, J. H.; Egan, S. V.; and Lynch, M. J. 1991. Analysis of cyanide in cassava using acid hydrolysis of cyanogenic glucosides. *J. Sci. Food Agric.* 55:277-290.
- Cock, J. H. 1985. Cassava: new potential for a neglected crop. International Agricultural Development Service (IADS) development-oriented literature series. Westview Press, Boulder, CO. 191 p.
- Cooke, R. D. 1978. An enzymatic assay for the total cyanide content of cassava (*Manihot esculenta* Crantz). *J. Sci. Food Agric.* 29:345-352.
- de Bruijn, G. H. 1971. Etude du caractère cyanogénétique du manioc. Papers. Wageningen Agricultural University, Wageningen, the Netherlands. 140 p.
- DEPD (Department of Economic Planning and Development). 1987. Agriculture and animal husbandry. In: Republic of Malawi Statement of Development Policies 1987-1996. Government Printer, Zomba, Malawi. 22 p.
- Hahn, S. K. 1989. An overview of African traditional cassava processing and utilization. *Outlook Agric.* 18(3):110-118.

- Lancaster, P. A.; Ingram, J. S.; Lim, M. Y.; and Coursey, D. G. 1982. Traditional cassava-based foods: survey of processing techniques. *Econ. Bot.* 38:12-45.
- Longe, O. G. 1980. Effect of processing on the chemical composition and energy value of cassava. *Nutr. Rep. Int.* 21(6):819-828.
- Mahungu, N. M.; Yamaguchi, V.; Almazan, A. H.; and Hahn, S. K. 1987. Reduction of cyanide during processing of cassava into some traditional African foods. *J. Food Agric.* 1:11-15.
- Mlingi, N. L. V.; Assey, V. D.; Poulter, N. H.; and Rosling, H. 1992. Cyanohydrins from insufficiently processed cassava induces 'konzo', a newly identified paralytic disease in man. In: Westby, A. and Reilly, P. J. A. (eds.). *Proceedings of a Regional Workshop on Traditional African Foods - Quality and Nutrition*, 25-29 Nov. 1991, Dar es Salaam. International Foundation for Science (IFS), Uppsala, Sweden. p. 163-169.
- Nartey, F. 1978. *Manihot esculenta* (cassava): cyanogenesis, ultrastructure and seed germination. Munksgaard International Pubs., Copenhagen, Denmark. 262 p.
- O'Brien, G. M.; Taylor, A. J.; and Poulter, N. H. 1991. Improved enzymic assay for cyanogens in fresh and processed cassava. *J. Sci. Food Agric.* 56:277-289.
- Osborne, D. R. and Voogt, P. 1978. *The analysis of nutrients in foods*. Academic Press, London, UK. 251 p.
- Rosling, H. 1987. *Cassava toxicity and food security*. Tryok Kontakt Pubs., Uppsala, Sweden. 40 p.
- Saka, J. D. K. 1992. Determination of cyanogen content of cassava (*Manihot esculenta* Crantz), using sodium isonicotinate-sodium dimethylbarbiturate. Paper presented at the Fifth International Chemistry Conference in Africa, 27-31 July, University of Botswana.
- \_\_\_\_\_. n.d. Nutritional value and hydrocyanic acid content of Malawi cassava (*Manihot esculenta* Crantz) and cassava flour. *Malawi J. Sci. Technol.* (In press.)
- Sauti, R. F. N. 1982. Country report: Malawi. In: *Root crops in East Africa: proceedings of a workshop held at Kigali, Rwanda, 23-27 Nov. 1980*. International Development Research Centre (IDRC), Ottawa, Canada. p. 104-106, 122-128.
- \_\_\_\_\_; Saka, J. D. K.; and Kumsiya, E. G. 1989. The composition and nutritive value of cassava-maize composite flour. In: Alvarez, M. N. and Hahn, S. K. (eds.). *Proceedings of the Third Eastern and Southern Africa Regional Workshop Root and Tuber Crops*, 7-11 Dec., 1988, Mzuzu. International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria. p. 71-75.
- Van Drongelen, A. 1992. Reasons for choices in cassava processing, the case of Mulanje. Wageningen Agricultural University, Wageningen, the Netherlands. 67 p.
- Williamson, J. 1975. *Manihot esculenta* Crantz: useful plants of Malawi. University of Malawi, Zomba, Malawi. p. 155-157.