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A. PROLOGUE

This is the first part of a two-volume document which constitutes the final report for the pilot project phase of the project "Production and marketing of cassava flour for human consumption". This first volume presents the summaries of reports for each project component, and also some general aspects. The complete reports, nine, are presented in volume two.

The content is the result of the collaboration between the International Center for Tropical Agriculture (CIAT), Universidad del Valle (UNIVALLE), and the Integrated Rural Development Fund (DRI) of Colombia's Ministry of Agriculture. The project team members were the following:

1. CIAT

   Rupert Best (Project Coordinator in year 1)

   Christopher Wheatley (Project Coordinator in years 2 and 3)

   Raul Moreno, Jose Martelo (Cassava Agronomy)

   Carlos F. Ostertag, Miguel A. Viera, Lisímaco Alonso, Teresa Sánchez de Salcedo (Cassava Utilization)

2. UNIVALLE

   Alejandro Fernández[1], Carlos Vélez, Aida de Stouvenell (Sección de Alimentos)

   Adolfo León Gómez (Ingeniería Mecánica)

3. Integrated Rural Development Fund

   Luis Alberto Medina, Galo Montenegro-Coordinator (Production section)

Since this report includes figures in Colombian pesos (Col$), TABLE 1 presents the exchange rate Col$:US$ used by CIAT during 1989-1991.

CIAT, UNIVALLE and DRI would like to thank the National Resources Institute (NRI) of Great Britain for the support offered to the project. NRI contributed, financed with their own resources, in the project diagnosis which is presented as Report 6.2. Carlos F. Ostertag and Christopher Wheatley, the editors, would like to thank Ilba Rico and Stella Narváez for their secretarial

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[1] Coordinador institucional

The main problems that arose in the pilot plant were the deficient quality of the raw material due to the presence of bacteriosis in the region and of the final product, the flour. In general, the flour did not comply consistently with ICONTEC norms or with industrial clients' requirements regarding microbiological quality. A diagnosis conducted with NRI identified a high level of infection in the fresh roots, which was not reduced during the washing, chipping or drying steps. The drying system did not produce enough heat to achieve the expected drying time (8 hours), and resulted in higher costs and hurt product quality. Based on these conclusions, modifications to the pilot plant were introduced which will be operational beginning 1992.

Pilot plant operation was adequate for determining the specifications of process operations regarding use of energy, labor, time, etc. and for defining the current cost structure. The milling conducted in Medellin, which achieved an 87% flour extraction rate, also served this purpose.

The market study carried out nationally employed a participative methodology with the firms that utilize flours or starches as raw materials, who received samples for trials. The study indicated that the most promising food categories for cassava flour use are: processed meats, sweet biscuits or cookies, ice-cream cones, "empanadas", soup pasta, soup and sauce mixes, etc. In addition, cassava flour exhibits functional advantages in the first three categories. Eighty percent of the estimated demand of 15-30.000 tons per annum would be for substitution of wheat flour. Based on these results, strategies for distributing the product locally and in Medellín were proposed and a pricing policy was developed, to sell at a 15-20% discount versus wheat flour.

As part of UNIVALLE/CIAT support research, a small-scale equipment for the production of cassava flour was developed, based on the evaluation of currently available equipment. It was discovered that no commercial mill achieved both a high flour-extraction rate (the goal was 85%) and an adequate flour quality, as regards a white color without specks. Consequently, a prototype was designed and built based on the crushing effect discovered in a cylindrical sieve previously evaluated. Initial trials demonstrated the high extraction rate (85%) and good quality of the flour produced with this equipment. Among other studies conducted, the evolution of flour quality during a 12-month storage period in three environments was researched. A decrease in microbial counts after 2-3 months of storage and minimal changes in the physical-chemical quality was discovered. The results of studies on moisture-measurement systems and the physical-chemical characterization of flours derived from different cassava varieties are presented in the corresponding reports.

Since 1989, 119 preproduction plots were established with cassava/maize and cassava/maize/yam in Córdoba, Sucre and Bolívar to demonstrate improved production technology. The recommended technology obtained better yields than the traditional one, regarding maize and cassava. Maize production increased for both technologies the second year because planting density was raised, causing lower cassava yields. Yam yields were low due to anthracnosis. Improved technology adjusts the use of the pre-emergence herbicide, applies a nitrogen fertilizer targeted to maize and makes a slightly more intensive use of labor.

A profitability model of the plant was developed for support in decision-making. The Financial Rate of Return (FRR) is used as the profitability parameter. By making certain assumptions but using real costs, the model indicates that the FRR is 22%, below the opportunity cost of capital in Colombia. However, the analysis of FRR sensitivity to various process parameters allowed the development of a strategy to increase the FRR to 50%, that includes investment reduction, redesign of the drying system, implementation of in-plant milling, and capacity expansion.

As the project conclusion, the feasibility study of the cassava flour agroindustry considers the following four areas: technical feasibility (the process), commercial feasibility (the market), feasibility of management by farmers, and the financial feasibility (return on investment). The main recommendations proposed to promote the project's feasibility are: to lower microbial contamination of roots, reduce labor consumption in the preparation operation to 20 man-hours, redesign the drying system inspired in the one at CIAT, guarantee the supply of raw material during the period from June to September, to hire a professional with knowledge of food technology who can coordinate marketing, implement the profitability strategy to raise the FRR above 50%. These improvements or modifications are expected to be implemented during 1992.

It is important to point out that, in the Research phase, the main market was considered to be the bread-making category, where 15% of the wheat flour would be substituted with cassava flour. However, because the bread-maker perceives a high risk of hurting his product quality when utilizing cassava flour, it was decided to focus Phase 2 towards other food categories where cassava flour will not offer functional disadvantages.

Phase 2 or the Pilot Project phase, executed by CIAT, Universidad del Valle, and the Integrated Rural Development Fund (DRI), attempted to integrate the production, processing, and marketing of the cassava flour system under the real socioeconomic conditions of Chinú, a cassava-growing region. The results will be utilized by NRI and other public and private agencies, if applicable, to promote the replica of rural cassava-flour producing plants and
the use of the product by the national food industry.

The specific objectives were the following:

- to implement, adjust and evaluate the technology developed for the production of dry cassava chips and cassava flour at a pilot scale in a rural contest

- to test, at a commercial scale, and to demonstrate to farmers an improved and sustainable technology for the production of cassava in association with yam and/or maize in the Atlantic coast region, and also, in this manner, to ensure an adequate supply of roots for the pilot plant

- to identify and study the market for cassava flour and promote its use in these markets

- to assess the feasibility of establishing a rural cassava flour agroindustry

D. SUMMARY OF RESULTS

The pilot phase results are presented in nine reports which are summarized below. The recommendations made to promote the feasibility of the cassava flour agroindustry appear in the summary of Report 9 which corresponds to the Feasibility Study.

REPORT 1. ESTABLISHMENT OF THE PILOT PLANT

1.1 Characteristics of the original pilot plant design

The original pilot plant design envisioned a production capacity of one ton of dry chips per day, by implementing a batch process with the operations of root reception, selection and preparation, washing, chipping, drying, premilling, packaging and storage. It contemplated both natural drying in inclined trays (December-April) and artificial drying in a fixed bed chamber (May-September). The area of the plant amounted to 1421 m^2, of which 62% was destined for natural drying in trays.

1.2 Criteria and site selection exercise

Appropriate site selection criteria were chosen to evaluate four potential sites in the Atlantic Coast. A questionnaire was designed and executed for this purpose. TABLE 1 presents the selection criteria used and the results obtained.

Of the three farmer organizations in the site chosen (Chinú), COOPROALGA was deemed the most suitable executor. It is considered that Betulia and Pivijay can be replication sites.

1.3 Modification of the pilot plant design

A preliminary CIAT design of the pilot plant that took into account the conditions at Chinú and eliminated the natural drying area was handed to an architectural firm in Sincelejo in June 1989. This firm was hired for Col$400.000 to design the plant, consisting of architectural and technical plans, construction material requirements and budget. The first design, budgeted at US$80.000, was down-scaled to reduce the value to US$50.000 without decreasing production capacity.

The plant design includes an office, bathroom, tool room, warehouse, coal storage area, root reception area, washing and chipping area, and artificial drying area for a total construction area of 371 m^2. It also contains two water storage tanks, an underground one with a 39.000 lt capacity and an elevated one for 6.000 lts.

The building materials encompasses reinforced concrete for the structure, cement blocks for the walls, metal beams for roof structure, roof in asbestos cement, and cement floor.

1.4 Engineering studies

Before construction began, the building site was surveyed and a soil study was conducted at a cost of Col$75.000 and Col$100.000 respectively (May 1989).

TABLE 1. Scores of site selection criteria for the cassava flour pilot plant

Criteria		Score			
		Chinú	Betulia	Palmar	Pivijay
1. Production	a. Land availability	3	3	3	3
	b. Potential for increasing productivity	3	3	2	2
	a. Raw material availability	3	3	1	2
	b. Potential for harvesting twice per year	3	1	2	2
2. Process	c. Service infrastructure	3	3	3	2
	d. Proximity to terminal markets	3	3	3	3
	e. Institutional presence	3	3	2	2
3. Project impact	a. Social and economic importance of cassava	3	3	3	3
	b. Current institutional support	3	3	2	2
Total score		27	25	21	21

* A score of three means "good", two "average" and one "bad"

1.5 Construction and costs

Building plans, material requirements and specifications were provided to six constructors but only three presented quotations, of which only two were acceptable; finally, a civil engineer with great construction experience was chosen in November 1989. A list of additional items was prepared and a quotation was requested from the chosen constructor. Subsequently, a contract was prepared by the CIAT lawyer and was signed by the builder and CIAT.

Construction lasted three months, as proposed in the quotation, and ended on March 22, 1990. A local project-hired builder and a CIAT-employed civil engineer supervised the process. Other minor

TABLE 2. Investment at the pilot plant at Chinú

1. Engineering	Col$Jan/90
a) Plant design	500.000
b) Soil study	100.000
c) Surveying	75.000
d) Supervision (inspector for 4 months)	750.000
e) Equipment installation	462.479
SUBTOTAL	1.887.479
2. Assets	
a) Construction (approx.)	17.000.000
b) Equipment *	5.100.000
SUBTOTAL	22.100.000
TOTAL	23.987.479

* Excludes transformer and substation (approximate cost Col$2.500.000)

construction was carried out in 1990. TABLE 2 presents a summary of the investment at the Chinú pilot plant.

1.6 Equipment design, construction and costs

A procedure for designing and building equipment was followed with UNIVALLE Mechanical Engineering thesis students supervised by a professor. The main equipment designed for the pilot plant was a selection table, washing and chipping machines, chip-transporting vehicle, premilling machine, drying bin and packaging funnel. The equipment was built at a Cali workshop.

The root washer is a rotating drum in perforated metal sheet; batches of 120 kg of roots are fed through a peripheric door and a water/sodium hypochlorite solution under pressure is applied during 5 to 8 minutes. The washed roots are discharged by means of a chute towards the chipping machine. Most of the brown bark and some parenchyma is removed.

The chipping machine is a metal structure containing a feeding hopper and a rotating disc with six blades. The blades impact upon the roots and chip them. The machine's chipping capacity is 7.2 tons/hour if operated separately; but, since it is coupled to the washer, its actual capacity is one ton per hour. An electric motor moves both machines.

The small vehicle is coupled to the chipper to collect the chips falling and is used to transport the chips to the drying bin.

The premilling machine consists of two rollers lined with metal meshes that rotate in opposite directions, thus breaking the chips. The space between the rollers can be adjusted to obtain different chip sizes. The chips are fed by gravity into a hopper.

Although CIAT had experience in the design, construction and operation of brick coal-fired burners with heat exchangers, it was decided to purchase a commercial unit to enhance project replicability. Burner manufacturers in four cities were visited; the centrifugal fan, coal-fired metal burner, heat exchanger and ducts were finally purchased from INGESEC (Bogotá).

The fan generates an airflow of 300 m^3/minute at a static pressure of 4 inches water gauge. The heating unit provides a heat load of 983.200 Kj/hour to heat an air flow from 25°C up to 60°C.

The drying bin is made up of two 1 x 10 mt chambers with a perforated metal sheet bed at a height of 0.8 mt; the hot air enters below this bed and a plenum is formed.

1.7 Pilot plant organization within the cooperative's structure

The 35 COOPROALGA members are small farmers growing maize and cassava. The majority are tenants and the rest (20%) are owners or have been granted land by INCORA. Currently, the cooperative operates both the cassava chip and cassava flour plants. The natural leader of the organization is the cooperative manager who also directs both plants.

During project execution, the plant will operate with project funds and will be jointly managed by CIAT and COOPROALGA. When the pilot project phase ends, the processing plant will be transferred to COOPROALGA and ANPPY.

1.8 Training of plant personnel

In-service training to the plant administration and workers was offered permanently by the CIAT representative at the plant. A CIAT technician instructed workers in equipment maintenance. Furthermore, the plant manager at the time received a two-week training course at CIAT which include topics such as plant operation, quality, hygiene, cost structure and marketing.

1.9 Initial institutional support

Several institutions, such as the DRI Fund, ANPPY and CORFAS collaborated with the project in 1989 and 1990. DRI helped in providing information during the site selection process and in contacting potential constructors. It also contributed valuable logistical support.

1.10 Plant start up

The start up phase began on 23 April 1990 until 31 May 1990. Previously, the cooperative's Administrative Council had selected and hired the pilot plant personnel. The equipment was tested and adjusted, and the plant was conditioned for operation.

On April 25, a round table was held with participation of plant personnel and CIAT staff to discuss project objectives and job descriptions. Workers were trained in service. Data collection formats were tested and modified.

In this period, 24 lots were processed and 14.2 tones of dry chips were produced. Because of inter-village rivalries, water was available for the initial three lots only. Roots were purchased from pre-production plots at above-market prices.

1.11 Plant operation in 1990

The pilot plant operated from April to September 1990 and processed 78 lots amounting to 184 tons of fresh roots to produce 69.1 tons of dry chips, or a conversion factor of 2.67. Because of lack of water, all production was destined to the animal feed market and was sold to SOLLA in Medellín at an average price of $76.210/ton. The only operation performed in the plant was artificial drying; there was no selection, preparation and washing, and chipping was conducted at the adjacent plant. In addition, some lots were sun-dried.

Root supply was good during this period; the main varieties processed were Venezolana (48%) and P-12. The area of origin was mainly Chinú (68%). A high proportion of roots were purchased from preproduction plots at above-market prices.

The great variations in production costs per lot can be explained by differences in root prices, the two drying schemes used and worker's inexperience. TABLE 3 presents data on production costs per month.

The most valuable experiences in this period were (i) purchasing of fresh roots (identifying sources of supply and negotiation), (ii) operation of drying system, and (iii) acquaintance with farmers' attitudes and behavior under new working conditions.

The period from September to December 1990, when no processing was conducted at the plant, was employed in plant maintenance and repairs, and in the installation of a constant water supply.

TABLE 3. Total production costs of cassava chips at the Chinú pilot plant (1990)

Period	Fresh cassava kg	Dry cassava kg	Conversion factor	Raw material $/ton	Coal		Total cost $/ton
					kg/t	$/t	
April	10.729	3.039	3.53	100.433	1.032	21.156	145.903
May	36.481	11.181	3.26	104.150	822	16.851	155.084
June	32.525	12.161	2.67	71.822	119	4.522	107.286
July	50.938	20.853	2.44	54.379	169	6.422	80.876
August	33.333	13.671	2.44	49.663	87	3.306	81.277
September	20.193	8.198	2.46	51.285	15	570	82.658
TOTAL	184.199	69.103	2.67	66.227	--	--	100.681

1.12 Water supply

The pilot plant is located in the village of Algarrobos (Chinú); together with San Mateo and Pajonal, it shares an aqueduct situated at San Marcos. In the second quarter of 1990, this latter community refused to supply water to the pilot plant with the excuse that its consumption was too high. COOPROALGA decided to build its own water well and pipeline for the plant, at a cost of $4.800.000 (Sept/90). The cooperative received a loan from CIAT amounting $3.200.000. Water supply was available on November 1990.

REPORT 2. OPERATION OF THE PILOT PLANT DURING 1991

2.1 General aspects

This campaign was the first experience in the production of premilled cassava chips under real conditions. Multiple problems prevented the plant's operation under design specifications that anticipated a capacity of one ton of premilled chips per day.

The main problems were: poor quality of raw material, discontinuous supply of roots, inefficient drying system resulting in a lengthy drying period, and electricity cuts.

The pilot plant operated in 1991 from January to July and from November to December (nine months) and produced 42.9 tons of dried cassava chips with a conversion factor of 2.92.

2.2 Training of plant personnel

The new production chief and three workers were trained in-service on the processing technology by the CIAT representative. Five young cooperative members were also trained on accounting during five months. The best student continued until December and is currently the production chief and bookkeeper.

2.3 Raw material

2.3.1 Supply

In Chinú, the area planted in cassava increased in 1991 by more than 40%, to 1400 tons per year. Cement-floor area for cassava drying also expanded significantly, to 14.500 m^2.

Local root supply is high from December to April, but from May to October it is brought by middlemen from other zones. In 1991, four purchasing procedures for cassava were implemented; the principal differences lay in whether the adjacent natural drying plant or the pilot plant paid for the rejected roots. The fourth procedure comprised root preselection in the field and its purchase at the agroindustrial market price.

Almost 70% of the cassava roots processed by the plant in 1991 were purchased locally; the main varieties were "Revoltura" (mixture of P-12 and Venezolana) and P-12 (almost 80%).

2.3.2 Seasonality

Towards the end of 1991, three neighboring cooperatives, led by COOPROALGA, decided to rent 30 hectares of land to plant cassava destined to be harvested in the low-supply months.

2.3.3 Prices

The plant paid $23-25 per kg of root in the high-supply months and $24-26 in the other period. This was the price level in the area of influence of the drying agroindustry, but it is possible to purchase cassava at lower prices in more distant zones.

2.3.4 Quality

Cassava roots processed from January to March was poor, due to bacteriosis and termite attacks on the local root production. The roots processed from May to June, coming from nearby humid lowlands, were susceptible to fungi attack. These roots were not fresh either. However, roots purchased in April, July, November and December were of good quality. In addition, it was discovered that the roots were contaminated with fecal coliforms due to the poor sanitary conditions of the farmers.

The quality requirements for cassava roots to be processed in the flour plant are the following: (a) must be fresh and the parenchyma should have its distinctive color, (b) must be a sweet variety, (c) the roots should be between 10 to 12 months old, (d) must be free of secondary roots and wounds, and (e) must be free of insect attacks, diseases, rots, fungi and strange odors. The root must arrive in the day of harvest and should be processed before the third day after harvest time.

2.4 Processing

2.4.1 Process description

The process implemented in 1991 comprised the following operations: root harvest and transportation to plant, root reception and weighing, selection and preparation, washing, chipping, drying, premilling and storage. (See FIGURE 1).

Harvest and transportation

The procedure is the following: sisal sacks are handed previously to the farmer and a delivery date is assigned. A day before harvesting, the farmer prunes the plants; the next day the roots are harvested, packaged, and delivered in the morning or at noon time. Transportation can be by donkey, tractor, jeep or truck, depending on the distance.

Reception and weighing

The roots are received in 50-60 kg sacks and weighed. This operation must be supervised by the chief of production.

Selection and preparation

The roots are moved to a selection table and small, diseased roots or ones with symptoms of insect attack are rejected. Roots that are too large are split in half and woody stems are eliminated.

Washing

This step eliminates dirt and 90% of the brown peel. The washing machine is a metal drum that rotates on four metal rollers at 30 rpm. 120 kg batches of roots are fed through a peripherical opening in the drum. Water is applied under pressure at a rate of 32 liters/minute for five minutes. A metal screen below the drum separates wastes from water. To improve microbiological quality, a solution of sodium hypochlorite acid was applied towards the end of the washing operation.

Chipping

The main component of the chipping machine is a disc that rotates at 1200 rpm and is mounted vertically in a metal structure. The razors mounted in the disc cut the roots as they fall from the feed hopper. The washing machine's tilted hopper unloads the washed roots directly into the chipper's feed hopper. The chips fall into a metal car with wheels coupled to the chipping machine.

Drying

This operation reduces the chip's moisture content to 14%. The drying system consists of a coke-fired burner, heat exchanger, fan, drying chamber and ducts. Drying is obtained by circulating hot air through a layer of chips placed in the chamber's false floor. The air is heated by the coal burner and heat exchanger and is thrust into the system by means of a centrifugal fan connected to an electrical motor. The chamber's floor is made of perforated metal sheets. Air flow is controlled by means of dampers placed between the fan and drying chamber. The chips are turned every 2-3 hours to facilitate homogeneous drying.

Premilling

This operation is necessary to facilitate milling at the wheat mill and to reduce product volume. The machine consists of two wire-mesh lined rollers that rotate in the opposite direction; it has a capacity of 600 kg/hour. The chips are gravity-fed and after passing through the rollers are discharged unto a hopper to be packaged in 25 or 50 kg polypropilene bags. The bags are sewed manually.

Plant hygiene

The workers have two sets of uniforms: one for handling roots and the other for chips. The floor and machines are washed and disinfected after processing. The cutting disk is dismounted and disinfected and is not mounted until before the next chipping operation.

2.4.2 Processing parameters

In this section, the main parameters for each operation are presented.

Selection and preparation

During 1991, refuse (roots and dirt) represented from 5 to 40% of initial weight. It can be concluded that this proportion can be reduced to 5%, assuming good quality roots and preselection in the field. Labor requirements for this operation were high in this period; they ranged from 17 to 87 man-hours/ton of dry chips. The objective for labor demand in this operation is 20 man-hours/ton of dry chips, given an adequate preselection and qualified personnel.

Washing and chipping

Refuse in the washing operation consists of peel, dirt and fractions of parenchyma. During 1992, it amounted to 2-3% for 8-to-12-month roots but is higher, up to 8%, for younger roots. The target waste percentage is 5%. Water consumption levels were from 1-2 m^3/ton of fresh cassava; washing time fluctuated from 5-7 minutes and flow was constant at 0.03 m^3/minute. A goal would be to consume 2.0 m^3/ton of fresh cassava. Labor demand in 1992 varied from 6.8-14.5 man-hours/ton of dry chips, including the transportation of chips to the dryer. The standard in this case should be 9 man-hours/ton of dry chips.

Drying

Drying loading density ranged from 50-150 kgs/m^2. Drying time fluctuated from 10-22.5 hours. Temperature of air entering the drying chamber ranged from 40-65°C. Coke consumption varied from 300-800 kgs/ton of dry chips. The air flow thrust by the fan into the drying chamber oscillated between 300-340 m^3/minute; however, the heat unit was incapable of raising temperature up to the required 65°C. This was the principal cause for the extended drying time. The evaluation of the drying system is presented in section 6.2 of REPORT 6. The target parameters for the drying system should be: a loading density of 150 kg/m^2, an air temperature of 65°C at a flow of 340m^3/minute, and a drying time of 8 hours.

The percentage of water removed in the drying operation ranged from 54-70%. Labor consumption for this operation was too high, between 25-70 man-hours, for two main reasons: excessive drying time and loading density was usually too low. It must be noted that, in this case, labor was not dedicated exclusively to this operation but also to parallel activities. The target labor requirement, including any parallel activity, is 25 man-hours/ton of dry chips.

TABLE 4. Production costs of dried cassava chips at the Chinú pilot plant (1991).

Month	Fresh cassava (kg)	Dried cassava (kg)	Con-versio factor	Raw mater. ($/t)	Coal		Water		Packaging		Elec-trici-ty $/ton	Labor $/t	Variable costs $/t	Total costs $/t
					kg/t	$/t	m3/t	$/t	U/t	$/t				
Jan	17.035	6.320	2.69	64.560	357	13.566	5.0	1.25	37	5.180	6.956	14.000	105.512	127.964
Feb	13.715	5.001	2.74	64.390	450	16.875	4.6	1.15	35	3.500	14.400	20.160	120.475	156.284
March	16.379	4.815	3.40	79.900	462	17.325	7.4	1.85	26	3.640	15.120	20.860	138.695	177.443
April	4.298	1.337	3.21	82.803	508	19.050	6.3	1.58	37	5.180	15.840	20.860	145.308	283.853
May	22.523	8.475	2.66	66.500	475	17.812	4.5	1.13	27	3.780	7.360	8.580	105.157	126.629
June	21.051	7.002	3.00	72.600	455	17.745	6.7	1.68	24	3.360	8.350	9.690	113.847	142.913
July	4.709	1.557	3.00	72.000	443	17.270	8.9	2.23	25	3.500	9.450	21.760	162.205	250.418
Nov	14.712	4.716	3.12	81.120	527	21.080	9.2	2.30	26	3.900	9.000	13.940	131.340	172.657
Dec	10.755	3.660	2.93	73.250	510	20.400	6.4	1.60	26	3.900	6.210	13.940	119.300	165.819
Mean/ total	125.177	42.883	2.92	71.540	458	17.610	6.2	1.15	29	3.926	9.577	14.198	119.590	156.451

Another important parameter is the conversion factor; the average value in 1992 was 2.92, abnormally high due to the impact of the bacteriosis attack on roots. The target conversion factor is 2.75, assuming healthy roots are processed. It must be noted that refuse from the preselection and preparation operation is not taken into account in this calculation because it is sold to the adjacent natural drying plant.

2.4.3 Processing costs

TABLE 4 presents monthly costs and a weighted average for 1991. It must be noted that it only shows variable costs incurred within the pilot plant; in REPORT 8, the financial model includes all the items, both internal and external. External costs include transportation, milling, etc.

Raw material represents 60% of internal variable costs. Other important items are coke (15%), labor (12%) and electricity (8%). In terms of cost per ton of dried chips, it can be concluded that raw material costs are too high mainly due to the bacteriosis attack; labor costs are excessive too, caused mainly by the low capacity utilization rate and exaggerated drying times.

The total cost of TABLE 4 is the sum of variable and fixed costs; however, this last figure is not very representative because of the low capacity utilization rate. Fixed costs includes administration and watch man expenses, maintenance, depreciation, etc. The total cost per ton was $156.451; to compare this figure with the one in the financial model, we must add external variable costs and subtract depreciation. The resulting value is $179.467 versus the model's $156.639.

2.4.4 Equipment performance and changes implemented

Minor modifications in the equipment were necessary after the plant initiated operations. These were as follows:

- The washing machine broke down in the universal joint and two elements were changed. The cause, a vertical movement by the journal bearing, was eliminated.

- The chipper was elevated 15 cm to facilitate cleaning.

- The wall separating the two original 1 x 10 m compartments of the drying chamber was eliminated to obtain a 2 x 10 m compartment. This facilitated chip turning.

- Each compartment had a different false floor, consisting of perforated sheets of 3 and 30%. The 30% sheets were eliminated to improve uniformity of drying time.

- The internal metal wall of the burner cracked twice and had to be welded to prevent entry of combustion gases into the chamber.

- The wire-mesh lining on the premilling machine's rollers would loosen and so its system of attachment to the roller was modified, using screws instead of welding.

2.4.5 Maintenance requirements for equipment and plant

Daily and weekly maintenance practices were designed for the washing and chipping machines, fan and premilling machine. Plant facilities require general maintenance once a year, to be executed in the idle months (September or October).

2.4.6 Capacity utilization

The theoretical capacity for the pilot plant is 200 tons per annum, assuming operation during ten months. In 1991, the plant functioned during nine months, but in April and July processing was minimal due to equipment breakdowns. Global capacity utilization in 1991 was 21.4%. Major limitations were the following: poor root quality, inefficient drying system, equipment breakdowns, insufficient working capital, energy cuts, etc.

2.4.7 Quality control

In the case of cassava flour, quality control can be divided into sanitary and physical-chemical control. Sanitary procedures include treatment of washing water with sodium hypochlorite, root disinfection, cleaning of equipment, enforcing rules for workers' hygiene and specifications for raw material quality, and fulfillment of parameters for drying temperature and duration. The physical-chemical control strategy comprises adequate washing of roots, correct adjustment of distance between the premilling machine's rollers and measurement of final moisture content of chips.

2.4.8 Analysis of heat sources

The heat source originally proposed for cassava flour plants was coal; however, now natural gas is a better alternative because of its increased availability. Its advantages include low cost, low contamination, efficient burners, and automatic control. Coal must still be considered for distant plant sites.

2.4.9 General evaluation of process

It can be concluded that, in general, the equipment and operations are appropriate and that, with some reforms, it will be possible to produce a product that satisfies market requirements. The reforms, already mentioned in Section 2.4.2, are as follows: (i) labor demand for in-plant root selection and preparation must be limited to a maximum of 20 man-hours per ton, (ii) an operation must be added to reduce microbiological contamination of roots or chips, and (iii) the drying system must be improved to obtain temperatures above 60°C and a drying period of maximum eight hours.

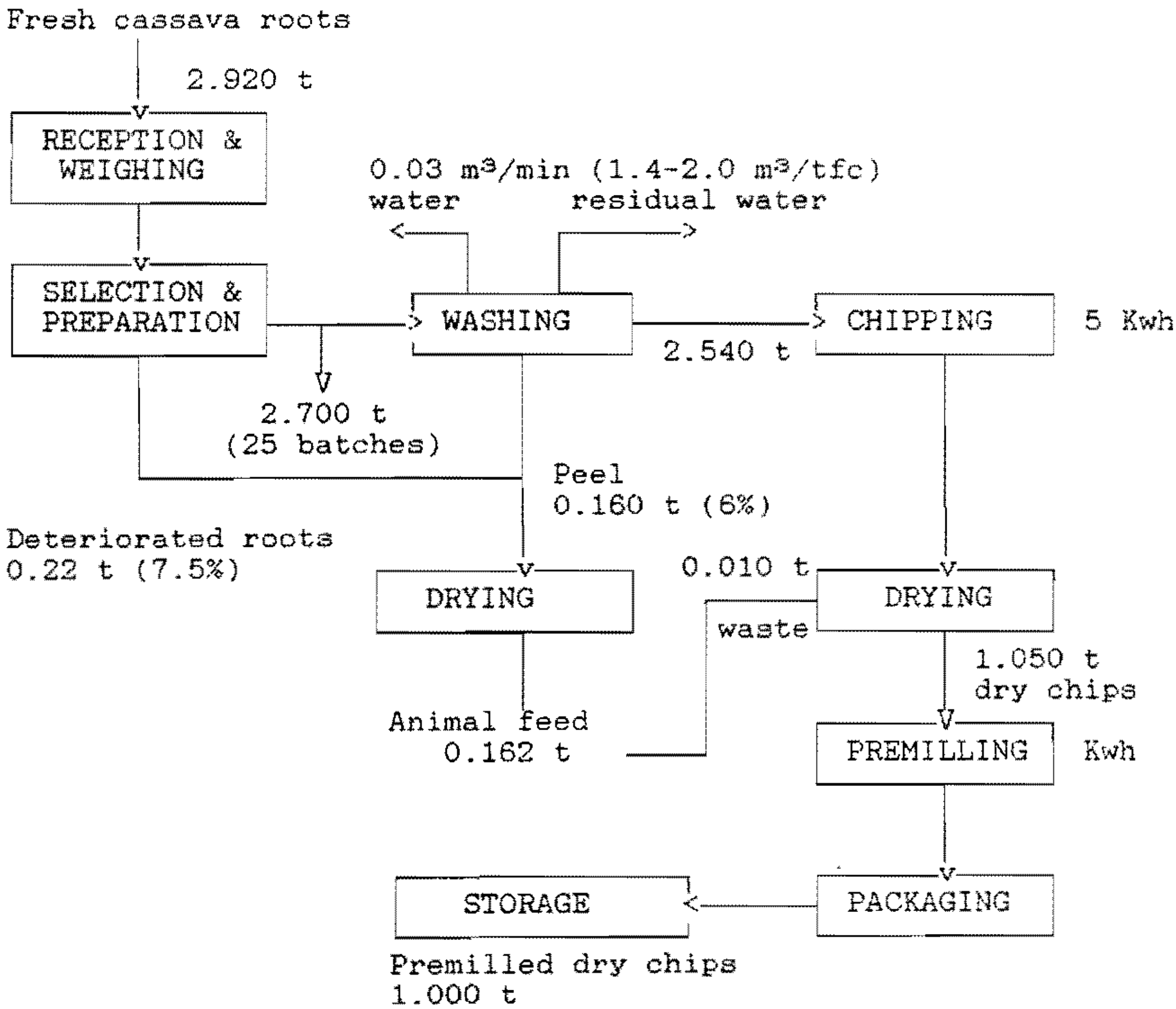

FIGURE 1. Flow diagram of the production process of premilled dry cassava chips

2.4.10 Proposal for flow of operations

FIGURE 1 shows the flow of operations based on the information collected in 1991. These operational conditions are viable and constitute the standard specifications for the process.

TABLE 5 presents a daily plan of activities for a capacity of one ton of dry chips.

TABLE 5. Program of daily activities at the pilot plant. Capacity: one ton per day

Activity	Schedule		Worker in charge
	Start	End	
1. Receive & weigh raw material	10 AM	2 PM	1
2. Clean & disinfect equipment & work area	7 AM	9 PM	1-2-3
3. Unload drying chamber and transfer dry chips from previous day towards premilling area	7 AM	9 PM	4-5
4. Wash chips and load drying chamber	9 AM	1 PM	2-3-4-5
5. Start burner	10 AM	11 PM	5
6. Drying management (turn chips every 2-3 hrs, feed burner every 1/2 hour, & control air temperature)	11 AM	7 PM	2-3-5
7. Cleaning and disinfection of equipment & work areas	2 PM	3 PM	1-2-3-4
8. Selection & preparation	3 PM	7 PM	1-2-3-4

NOTES:
1. Half an hour is allocated for breakfast.
2. Personnel has lunch from 1-2 PM
3. Premilling, general cleaning, and maintenance is done on Sunday
4. Work day = 9 hours
5. Labor requirement = 6 work days per ton

REPORT 3. PRODUCTION OF REFINED CASSAVA FLOUR AT THE WHEAT MILL IN MEDELLIN

3.1 Introduction

The feasibility of producing cassava flour in wheat mills was discovered in the experimental phase of this project. The first milling experience in the pilot project phase was performed by a wheat mill in Barranquilla. After the market study, it was decided that the Medellín market offered more potential and, therefore, a wheat mill (Harinera Antioqueña) was contacted.

3.2 Transportation costs

The cost of transporting cassava chips from Chinú to Medellín by truck was $15.000/ton.

3.3 Milling

The Medellín wheat mill processed cassava chips experimentally on three occasions: 1.5 tons in 1990, 17 and 14.1 tons in April and July 1991. The cassava chips were processed in a similar fashion as wheat; the only operations discarded were moistening and repose. The chips passed through four stages of grooved cylinders, four of plain cylinders and screening.

TABLE 6. Results of three millings of dry cassava chips at Harinera Antioqueña, Medellín (%)

Milling >	First	Second	Third
Date	August/90	April/91	July/91
Quantity milled	1.5 tons	17.0 tons	14.1 tons
First grade flour	93.3	77.6	74.3
Second grade flour	2.7	4.9	12.2
Total extraction	96.0	82.6	86.5
Shorts	1.7	11.1	5.6
Bran	1.4	3.7	4.6
Subtotal	99.1	97.4	96.7
Waste *	0.9	2.6	3.3
Total	100	100	100

* Includes package weight, moisture loss, and milling waste

TABLE 6 shows the results of the milling experience at Medellín. Flour obtained in 1990 contained too much peel and fiber and so it was decided to reduce the extraction rate to 83%. Although the flour obtained was very pure, it was judged that the separation of carbohydrates and fiber was not optimal yet; note the high proportion of "shorts", which was uneconomical. In the third milling, the extraction rate was increased and fiber separation was improved. The by-products, shorts and bran, are characterized by their higher fiber and ash content compared to the flour.

After the second milling, the plant chief informed that chips should be smaller to facilitate the process. This was implemented by reducing the distance between the premilling machine's rollers.

The wheat mill charged $18.500 for the milling of one ton of dry chips (1991). This sum represents 11.8% of the production cost of cassava flour.

3.4 Quality aspects

Cassava flour has an off-white color. Proximal analysis varies with processing, milling and varietal factors, but a typical composition is as follows: water (12%), carbohydrate (80%), protein (3%), fiber (2.4%), ash (1.6%) and fat (1%). Flour color and composition can be manipulated in the milling and screening process. In general, cassava flour's particle size is smaller than wheat flour's.

Microbiological quality analyses varied across laboratories and samples and exhibited extreme results. On occasions, counts were below norms or slightly above, but sometimes they greatly exceeded legal parameters. The problem concentrated on mesophylls, coliforms and yeasts. The food industry is accustomed to high microbiological quality standards of wheat flour.

REPORT 4. MARKETING ASPECTS

4.1 Market research

A market study was conducted that would serve as a basis for determining potential demand for cassava flour in Colombia. The methodology consisted of a survey of a national sample of large, medium and small food manufacturing firms that had formulations containing starch or flour. Cassava flour samples were handed to firms so they could carry out substitution trials with cassava flour in some or all of their formulation; subsequently, they were interviewed on the results obtained. The study included Medellín, Cali, Barranquilla, Cartagena, Santa Marta, Montería, Sincelejo and the pilot plant's area of influence.

The main conclusions of the study were:

- The most promising categories for cassava flour are: processed meats, sweet cookies, ice cream cones, pasta, soup pasta, pastry, spice bases, soup and sauce mixes, meat pies, etc.

- Cassava flour offers functional advantages in processed meats, sweet cookies, ice cream cones, spice bases, soup and meat pies

- Nearly 80% of the cassava flour volume demanded would be destined for wheat flour substitution. Other raw materials substituted would be rice flour, corn starch, and sweet cassava starch.

- Of the two largest cities located relatively near the pilot plant, Barranquilla and Medellín, the latter can offer a greater market demand.

4.2 Estimation of potential demand

The next step was to quantify demand based on the aforementioned market study, secondary data, and interviews in firms in key food categories. The estimated range for market demand was 15.000-30.000 tons per annum.

4.3 Promotion among clients in Medellín

Product promotion among clients was carried out in three cycles in 1990 y 1991 and consisted of visits, an informational pamphlet, free samples and follow-up visits. In total, 16 potential clients were contacted and two potential distributors were identified: a supplier of raw materials for the processed meat industry and the wheat mill.

4.4 Feedback from clients

After recording and analyzing feedback provided by clients after using cassava flour, the following conclusions can be made: (i) the microbiological quality of the product has to be improved, (ii) companies in the food industry are quite conservative when it adopting new raw materials, and (iii) an effective promotion demands better information on characterization and functional properties of cassava flour.

4.5 Proposed distribution channels

Two distribution strategies were proposed, depending on the milling site, either in-plant or in a wheat mill. The first case comprises the direct sales at the local market and through two specialized wholesalers in Medellin, one focused on meat processors and the other on pastry. The second case is similar but excludes sales locally.

4.6 Product development

Some product attributes are described in REPORT 3. Cyanide content of cassava flour should not exceed 50 ppm. Polypropilene bags were chosen for cassava flour; the density used, 80, is greater than the density utilized for wheat flour, of 70. The weight can be 25 and/or 50 kgs. The brand name chosen was YUKARIBE, or "Caribbean cassava"; this name is not registered for products in class 30.

4.7 Marketing of by-products

Both the shorts and the bran were sold to a firm producing animal feed, at a price of $70/kg. The firm has expressed its interest in continuing purchases.

4.8 Price policy

A penetration price policy has been recommended initially, which means selling cassava flour at a price equivalent to 80-85% of wheat flour. It is deemed possible that meat processing companies will be willing to pay a higher price eventually.

REPORT 5. ORGANIZATIONAL ASPECTS

5.1 Critical aspects of management

The critical management areas of a cassava-flour-producing business are identified and the capacity of the cooperative to handle them adequately are analyzed. The critical areas are: continuous supply of raw material, efficient management of process, information systems, and marketing.

5.2 Organization of the cassava flour pilot plant

The original organizational chart for a cooperative-managed cassava flour plant included four levels, as follows: Level 1 - cooperative's board of directors; Level 2 - general manager and accounting adviser; Level 3 - chief of production and treasurer; and Level 4 - watchman and four workers. Two new positions are recommended: a marketing manager, in Level 2, employed by a second-order organization and paid by a pool of cassava flour plants, and a purchasing chief in Level 3.

5.3 Training requirements

The priorities set in the area of personnel training are the following: analysis of process data, raw material quality assurance, marketing and general management of a cassava flour enterprise.

REPORT 6. SUPPORT RESEARCH

6.1 IMPROVEMENT OF EQUIPMENT

The strategy for the design and improvement of the pilot plant's equipment is presented. Design criteria was modified in the pilot project phase to emphasize reliability, efficiency, productivity, safety and aesthetic and sanitary quality.

It was decided to employ a power transmission in the washing machine instead of a friction-based one and a cardan joint was used to absorb fluctuations of concentric rotation. A clutch system in the washing-chipping machine tandem was necessary to separate operation of each unit.

The computer was used in structural analysis and to produce graphic work.

The following are non-technical observations:

- a resistance to obey formal technical documentation was found among manufacturers

- when new functional alternatives are explored, it is valid to determine preliminary dimensions of minimum operational elements for their functional evaluation

- after developing the prototype, machine cost must be estimated again in other workshops to avoid artificial increases in production costs

6.2 DIAGNOSIS FOR IMPROVEMENT OF PROCESS AND PRODUCT QUALITY

Two professionals from the National Resources Institute (NRI) in England researched problems relating to microbiological quality and to the artificial drying system in November 1991. Plant operation was monitored during two weeks during which six batches of dried chips were produced.

None of the batches of dried chips produced at Chinú during the visit reached the cassava flour norm for microbiological quality. The chips produced in Cali did not achieve the norm either, despite lower counts. The official norm for cassava flour regarding mesophylls, a maximum of 200.000, is stricter than the one for wheat flour; to enter the most promising markets, cassava flour must obtain mesophyll counts below 100.000.

There are great factors that prevent the production of cassava flour with an acceptable microbiological quality, such as high microbiological contamination of fresh roots, incapacity of current operations and equipment of producing wet chips with low microbial counts, and the incompetence of the drying system in drying chips rapidly and at sufficiently high temperatures so as to inhibit growth of microorganisms.

It is still impossible to make recommendations that can guarantee the necessary microbiological quality; however, the following is suggested for short term consideration:

- minimize the time between harvest and washing and chipping of prepared roots

- maintain washing water at a free chlorine concentration of 10-20 mg/liter

- isolate the drying chamber from the rest of the plant and keep it clean

The following topics should be researched:

- improved design of the washing machine comprising the separation of the peeling and washing operations

- immersion of wet chips in hot water

The burner/heat exchanger exhibits good thermal efficiency, of 70%, but heat generation is insufficient for the drying load. In the short term, to obtain drying air temperatures above 60°C, another heat unit should be installed in parallel with the current one.

In the medium term, there are two areas of research:

- the effect of air flow and temperature on drying time, microbiological quality, flour quality, and concentrations of residual cyanide.

- The post-harvest heating of chips should be examined at temperatures between 60-130°C.

6.3 EVALUATION OF ALTERNATIVES FOR SIZE-REDUCTION OF CASSAVA CHIPS AND FLOUR SEPARATION FOCUSED ON THE DESIGN OF AN EQUIPMENT FOR THE PRODUCTION OF REFINED FLOUR

In the Research Phase, the performance of a hammer mill of medium capacity (0.6-1.2 t/hour) was examined and flour samples were obtained under extreme operational limits, such as a velocity of 4200 and 2400 rpm and cribs with perforations of 1/2 and 1/8". The extraction rates of first grade cassava flour achieved were below 60%. Additionally, the feasibility of producing cassava flour of good quality in wheat mills was confirmed; a high level of separation of fiber and peel was secured, which allowed the elimination of the manual peeling of fresh roots.

The latter milling technique was chosen for the pilot project phase but, since the wheat mills are quite distant from the region producing dry cassava (departments of Sucre and Cordoba) and the cost of the milling service is high, it was decided to make available a small scale, in-plant milling system. Consequently, several milling and screening machines were studied, which served as basis for planning the design and construction of a flour extraction system with a capacity of one ton per day.

The criteria chosen for selecting an adequate scheme were a high flour extraction rate with the best possible quality. Consequently, extraction levels above 85% were targeted and the quality factors considered in the flour were color, and content of peel, crude fiber, ash, and total cyanide.

In Study I, a complementary evaluation of the hammer mill examined in Phase 1 was conducted. The physical-chemical characterization of the flours produced at peripheric velocities of 66 m/second (4200 rpm) and with commercial cribs of 3/8, 1/4, 3/16, and 1/8" was carried out. It was discovered that, at the higher extraction levels, the color was inappropriate due to the flour´s brown color caused by the presence of fine peel.

Other machines were evaluated in Study II, such as a roller mill for premilling chips, a roller mill for production of flour, a low capacity (300 kg/hr) and high capacity hammer mill (2.5 t/hr) and a cylindrical screen with rotating paddles. the objective was to combine the machines in various milling schemes, seeking the maximum extraction rates and quality. It was observed that the high capacity hammer mill produced brownish flour.

An important crushing effect by the cylindrical screen was found in Study II and, hence, in Study III, milling schemes were planned which included the machine as an additional mechanism for size reduction. In this way, the concept of a machine that would integrate size-reduction and screening operations emerged, and was designed and built as an undergraduate thesis by two Mechanical Engineering students from Universidad del Valle. It has a flour production capacity of 300 kg/hr.

In Study IV, a preliminary test of the prototype machine was carried out, using the premilling machine as the initial milling device, and the quality of the flour produced was compared with those of other available mills. The evaluation of the general performance of the machine will continue during the Expansion Phase of the project, initiated in January 1992. It can be concluded that this machine combines two positive elements: a high extraction rate (85%), and a white flour with low fiber and ash contents.

The variety P-12 (CMC-76) was used in the studies. For Study IV, the varieties MCol 1684, CG 955-2, and CM 523-7 were added.

6.4 QUALITY OF DRIED CASSAVA PRODUCTS DURING PROLONGED STORAGE

The objective of this work was to (i) get acquainted with the physical-chemical and microbiological stability of the dry chips and flour, stored in polypropilene bags at ambient conditions in warehouses in different locations, (ii) determine the technical feasibility of storing the dry chips without important quality changes, and (iii) design a set of recommendations for the adequate handling of cassava products.

The chip and flour batches were packed in 30 kg polypropilene bags and were stored during 12 months in warehouses at Montería, Fontibón and Palmira under diverse ambient conditions. Samples were taken monthly for physical-chemical and microbiological analyses.

It was concluded that the physical-chemical composition varied little during storage, although a reduction in the cyanide content was noted. The initial microbiological quality (mesophylls and non-fecal coliforms) did not meet the ICONTEC 2716 norm but improved to acceptable levels after 2-3 months.

6.5 DEVELOPMENT OF MOISTURE-MEASURING SYSTEMS

As a result of the DRI-CIAT-UNIVALLE project, more than 150 plants producing dried cassava chips have been established, mainly in the Atlantic coast, processing nearly 100.000 tons of fresh roots per year.

Both processors and buyers lack the equipment that is necessary to determine dried chip moisture. It is important to guarantee a 10-12% moisture level because a lower one would imply an unnecessary cost, while a higher one would mean that the final product was not of optimum quality.

In response to this need, several moisture-measuring equipments with different operational principles were studied; the majority are commonly used to determine grain humidity.

In the first study, with the Motomco, whose functioning principle is based on the dielectric properties of products, moisture tables were generated between 8-17% b.h. and temperatures between 20-30°C. These tables are similar to the ones that appear in catalogues for grains and soybeans.

In the second study, the operational conditions of the Ohaus moisture-measuring balance and the experimental infrared equipment were examined, and positive results were obtained when compared to the standard freeze-drying method.

In the simultaneous evaluation of equipment, in the third study, the performance of three new apparatus was examined and the efficiency of the Motomco and infrared equipment for measuring moisture of dried cassava products was confirmed. The best results, in that order, were obtained with the Despatch oven (70°C, 24 hr), Motomco (25°C) and the MLW stove (103°C, 70 min). Additionally, tables showing the necessary adjustments in moisture readings were generated, based on regression models.

In this simultaneous evaluation, the infrared apparatus showed results that differed with those obtained in the previous evaluation due to irregularities in the electrical supply during trials.

The use of the experimental infrared device is recommended to control the chip's moisture content during drying in processing plants. This device allows readings in 14 minutes and at a cost of Col$250.000. For moisture measurements during storage, the use of the stove with a capacity of 30 samples is suggested, at a cost of 600.000; however smaller stoves do exist costing $200.000 which could be evaluated.

6.6 PHYSICAL-CHEMICAL CHARACTERIZATION OF EDIBLE CASSAVA FLOUR OBTAINED FROM DIFFERENT VARIETIES

This study determined the chemical composition of cassava flour of different varieties, established factors affecting the composition and evaluated the relation between composition and functional characteristics.

The dry material content, of 35%, varied little in function of the variety and age at harvest time. The average proportion of starch in the whole flour was 85% and 90% in the parenchyma; in general, this percentage increases with age. The cyanide content varies little with age.

6.7 EVALUATION OF FUNCTIONAL PROPERTIES OF EDIBLE CASSAVA FLOUR IN PRODUCT DEVELOPMENT

The study focused on the following activities: (i) examine the culinary quality of four cassava varieties to identify the potential for marketing in the fresh market, (ii) explore some of the functional properties of four cassava varieties and evaluate the influence of age and variety on these properties, an (iii) test formulations of the selected products, using cassava flour derived from the varieties under study.

The first study concluded that all the sweet varieties can be marketed in the fresh market because they received very good ratings by the taste panel. The second study concluded that the variety, location, and age variables impact little on gelatinization properties and that viscosity increases with concentration of suspensions. In addition, the viscosity of suspensions with cassava starch is greater than those with flours. In the third study, formulation trials were conducted with "coladas" (sweet porridge), "manjarblanco" (sugar and milk sweet), and "diabolines" (round, salty snacks).

REPORT 7. TWO YEARS' EXPERIENCE WITH PREPRODUCTION PLOTS IN THE NORTH COAST OF COLOMBIA

119 preproduction plots with cassava/maize and cassava/maize/yam were established since 1989 in Cordoba, Sucre and Bolivar, to demonstrate an improved production technology and enhance communication between technicians and farmers.

The recommended technology obtained higher maize and cassava yields than the traditional one. Maize production increased for both technologies in the second year because planting density was raised, which resulted in lower cassava yields. Yam yields were low due to anthracnosis.

In the improved technology, it was possible to detect 41 and 34 activities in the cassava/maize and the cassava/maize/yam production systems, while in the traditional technology 40 and 30 activities were found respectively. The improved technology adjusts the use of the pre-emergent herbicide, applies a nitrogenous fertilizer for the maize, and is slightly more labor-intensive. Otherwise, the packages are quite similar.

In the cassava/maize/yam production system, improved technology executes 20 activities versus 17 in the traditional one. The proposal of the improved technology centers in improving the use of pre-emergent herbicide and fertilizing the yam.

Production costs for both technologies in the cassava/maize system were similar during the first year but the improved technology was slightly more expensive in the second year; more than 50% of the costs were wages.

The most used inputs in both technologies were herbicides, specially the pre-emergent Diuron. In the second year, the insecticide Clorpiripos was used extensively for the control of soil pests in maize. The improved technology promotes the use of improved maize varieties, a component also existent in the traditional technology.

REPORT 8. DEVELOPMENT AND APPLICATION OF THE FINANCIAL MODEL

A computerized model of the financial profitability of the pilot plant was designed using Lotus 1-2-3. The model calculates the profitability parameter selected, the Financial Rate of Return (FRR). The FRR is "the interest rate that makes the net present value (NPV) of a series of annual cash flows to be equal to the initial investment". This interest rate should be greater or equal to the opportunity cost of capital.

To design the model, decisions were made regarding the following: project life, desired production capacity of a plant, capacity utilization, inflation rate to be used, residual or scrap value of the plant, etc. The components of the model include: required investment, basic information for calculating variable costs, variable costs, fixed costs, sales price, matrix for calculating annual cash flows, and FRR estimation.

Certain assumptions were necessary to estimate the FRR; however, real parameters and costs were used whenever possible. The model indicates that the FRR is 22%, below the opportunity cost of capital in September 1991, which was near 35%. The sensitivity analysis demonstrated that the following factors have a great impact on profitability: capacity utilization, cost of roots, conversion factor (fresh root to first grade flour), and sales price.

The model is useful in supporting decision-making in the following areas: design of a financing system for processing plants, assessing the convenience of investing in processing plants, price determination, designing strategies of profitability maximization, etc. A strategy for increasing FRR to 50% is illustrated, encompassing the following points:

(a) A 20% reduction in the initial investment, specially in construction costs, which can be pursued by modifying construction materials and reducing plant area and weight. This action can raise FRR by 5 percent.

(b) Redesign or improvement of drying system that will lower coke, labor and electricity expenses. This endeavor can elevate FRR by another 5 percent.

(c) The implementation of small-scale, in-plant milling can augment FRR by 8% because it will avoid expensive subcontracting of chip milling at wheat mills.

(d) The capacity expansion, once the market for cassava flour is fully consolidated, will reduce fixed costs per ton of flour, increasing FRR by 12%, for a total FRR climb from 22 to 50%.

REPORT 9. FEASIBILITY STUDY

As already mentioned, the denial of the water supply to the plant delayed the pilot experience significantly. In 1991, when the more normalized process was implemented, the drying system did not comply with original process specifications with regards to time and drying temperature. This limitations prevented achieving the expected production capacity and also impacted negatively on the microbiological quality of the product, which, in turn hurt marketing possibilities. This means that all of the parameters necessary for establishing the agroindustry's feasibility are still not available.

The feasibility study is divided into four parts, as follows: technical, commercial, management, and financial feasibility. Technical feasibility tries to answer the question "can the cassava flour of appropriate quality be produced efficiently?" Commercial feasibility deals with the issue "can cassava flour of appropriate quality be sold at the planned price?" Management feasibility refers to the inquiry "can farmer organizations manage the cassava flour business profitably?" Financial feasibility examines the question "is it profitable to invest in a plant that produces cassava flour?"

When these aspects were analyzed, limitations were identified and solutions were proposed. The following are recommendations to enhance the project's feasibility:

- implement a procedure that can lower root microbial contamination

- reduce labor consumption in the operation of root preparation to 20 man-hours by preselecting roots beforehand at harvest time and supervising workers

- redesign the drying system inspired on the one existing at CIAT's experimental plant

- improve the level of information regarding (i) the food technology-related characteristics of cassava flour, and (ii) the different requirements of food categories with regards to physical-chemical characteristics of cassava flour

- marketing personnel should be informed of food technology aspects when promoting the cassava flour

- execute any of the two proposed alternatives to guarantee root supply from June to September

- train the farmer group on analysis of process data

- the second grade organization should hire a professional with knowledge on food technology and sales/marketing so he can coordinate all aspects of commercialization (product development, price establishment, coordination of distribution channels, and execute promotional actions)

- implement the profitability strategy to raise FRR to 50%

E. OTHER ACTIVITIES

Consultative body

In the first phase of the project, a consultative body was formed with representatives of the government and private sectors (milling industry, breadmakers, etc.) to maintain them informed to facilitate the eventual replication in the commercial phase. During the first phase, the DRI Fund's interest in the project was outstanding, and it participated as collaborator in the second phase, securing in this manner the government support through the institution responsible for the rural sector's development.

During the second phase of the project, many contacts were made with the private sector (mills and food processors), which are detailed in the respective reports (market studies, milling, marketing, etc.). A meeting of the consultative body was scheduled at the end of the project to inform national institutions and trade organizations of pilot project results. However, due to problems with the flour's microbiological quality, it was decided to postpone the meeting to the first year of the project's third phase, when the project will have concluded satisfactorily.

Visits of project personnel

(i) Rupert Best and Christopher Wheatley had the opportunity of visiting Indonesia, where the national agricultural research program (CRIFC) and the private sector are collaborating in a project regarding the production and utilization of cassava flour for human consumption. Various models have been proposed, from an entirely industrial level to one with small farmer groups, with the development of appropriate equipment for each scale. In general, the process differs from the one proposed in Colombia's project in the following way:

- manual peeling of roots
- natural drying on trays or artificial drying with natural gas
- milling in pin mills

The flour is being used by the food industry in the production of cakes, biscuits or cookies, and in some rural bakeries located near the flour-producing plants.

Two cassava flour samples from Indonesia were analyzed; one sample had an excellent microbial quality, but cyanide content was 125 ppm. The other sample exhibited a cyanide content below 50 ppm, but microbial contamination was above norms accepted in Colombia.

(ii) Christopher Wheatley participated in three UNDP-financed workshops on the development of root and tuber-based products, in collaboration with CIP, and IITA. The workshops were held in Guatemala, the Philippines, and Nigeria. Alejandro Fernández (UNIVALLE) also participated in the Guatemala workshop with a presentation on Colombia's cassava flour project.

The level of interest of many participants in the project was very high and the following ones were the most salient:

Latin America: Ecuador, Colombia, Costa Rica, Panama
Africa: Tanzania, Kenya, Ghana, Congo
Asia: The Philippines, Indonesia, Vietnam, India

In these workshops, contacts with researchers in the most interested countries have been made and they will receive project reports. IITA is interested in the technologies developed in the project to obtain cassava flour for use in 'wheatless bread'.

Training activities

The training received by the Chinú farmer cooperative is detailed in Reports 1 and 2.

The following students conducted their undergraduate thesis on support research topics:

- Marta Cecilia Alvarez and Ximena Rodriguez, Industrial Engineering students at the Universidad Autonoma de Occidente, on a 'prefeasibility study on the establishment of a cassava flour agroindustry in the Cauca department'. This thesis included a market study in the Cali region and served as a model for subsequent studies in other regions.

- Alejandro Onori and Alvaro Ivan Duque, Mechanical Engineering students, on 'the design of a small-scale system for the production of refined cassava flour'.

Many Colombian university students have visited the Cassava Utilization Section, and have observed the process in action and the product, cassava flour. The pilot plant has been visited twice by groups of Ecuadorian farmers to receive training on the process and use of equipment.

Carlos Ostertag participated as lecturer in the course 'Role of socioeconomics on the generation of agricultural technology' held at CIAT from 16 September to 11 October 1991 with the participation of 22 economists from Latin America. In conferences on Feasibility studies, Pilot projects, and Market analysis, he referred amply to the Colombian cassava flour project.

Diffusion activities

Carlos Vélez, Professor at UNIVALLE, gave a presentation on this project at his university on June 1990. During Brazil's Cassava Congress, held at Londrinas from July 17-21/90 Mr. Vélez gave a conference on Phase 1 and 2 of this project.

Carlos Ostertag gave a presentation on this project during the 'Rural small-scale food enterprises workshop' carried out at Periconegro, Cauca from 12-13 June 1990.

F. PROJECT MANAGEMENT AND EVOLUTION

Project meeting and institutional organization

The project commenced on 1 April 1989 for a two-year period. Due to certain delays in the pilot plant start-up, the termination date was extended until 31 December 1991. The following meetings were held during project lifetime:

1. Six-monthly meeting at CIAT (31 August-1 September 1989)

2. Annual meeting at CIAT (7-8 June 1990)

3. Six-monthly meeting at Sincelejo (19-20 February 1991)

4. Final meeting at CIAT (29-30 January 1992)

The respective reports detail the results of said meetings, whose purpose was to evaluate the development of each project component, the discussion on necessary adjustments and the formulation of workplans for the following period.

The technical UNIVALLE-CIAT group has held monthly meetings to program and evaluate support research carried out at both institutions.

Financial organization

CIAT, as the lead institution, received the funds from the donor and handed them to other participating institutions according to a prearranged plan. Due to its international nature, CIAT was able to keep the external contribution in US dollars, and thus avoided the loss of purchasing power related to the high local rate of inflation.

Project evolution

The first phase of this project ended on October 1985, and the second one started on April 1989. The period between these two dates was spent on the formulation of Phase 2 and to the reorientation of marketing towards the food industry in general, instead of breadmaking. Consequently, when the project was initiated on April 1989, the first activities were the market study and the site selection for the pilot plant. The location was rapidly identified, with the help of DRI. The whole team gained valuable experience during the pilot plant's construction which ended on March 1990. The water supply limitation delayed the pilot plant's startup until the beginning of 1991. For this reason, project extension until December 1991 was requested and granted, thus allowing a sufficient period of operation of the pilot plant.

This project phase has been quite complex, comprising components of production, processing, marketing, and organizational and managerial affairs. The lessons learned by the team during these three years are many, among them:

- working capital requirements are manifold due to the low capacity utilization of the plant initially, until product quality and process efficiency are improved. CIAT had to subsidize the plant since June 1991, because the amount budgeted for this purpose had already been spent.

- it is necessary to revise the site selection criteria for processing plants, to locate them more strategically in relation to basic services such as water, energy sources, etc. The recent availability of natural gas in many towns in Colombia converts it into another fuel source for drying; its use would imply locating plants in the periphery of urban centers.

- It is vital to improve coordination of cassava production, in collaboration with the cooperative, to facilitate raw material supply.

The project had four specific objectives (see page **). The first one has not been reached satisfactorily; as explained in the feasibility study, the process must be adjusted to guarantee a constant and adequate flour quality. However, the process itself has been efficient, because the plant and workers have fulfilled the majority of operational and quality requirements of the flour and process. Process readjustment is expected to be finished during the first months of the third project phase.

The fact that the project has had problems and delays in its agenda due to deficient product quality is not totally negative. It is important to remember that the purpose of the pilot stage is precisely to avoid risks at the commercial level related to a process or product which have not been tested under real conditions.

The difference between the experimental process undertaken at CIAT during the research phase and the pilot one managed by farmers, with the problems that any rural enterprise must confront in terms of raw material supply, etc., is always very big. This pilot stage has served to identify the problems which the nascent agroindustry must brave to reach commercial success. In this manner, the methodology used until now is absolutely justified. The task during the next months is to solve the problems already identified.

The second objective has been achieved with great success regarding the evaluation of new production technologies by farmers. Preproduction plots play several roles, including facilitating the link between research, extension, and farmers. However, it was more difficult to reach a good link between plots and the pilot plant. The agronomic interest in planting plots in different coastal microregions, to sample cassava variability, did not facilitate root purchases by the pilot plant due to high transportation costs. At Chinú, the preproduction plots will be expanded beginning on 1991 by means of a ten-hectare associative planting of cassava by the cooperative.

The third objective has been completed satisfactorily, having identified key market segments for cassava flour, with companies interested in buying flour in each segment. The only element lacking is the supply of good quality flour to convert the potential demand into a real one.

The fourth objective has been accomplished, with the conclusion that feasibility is possible only if the adjustments recommended are implemented. However, it has not been possible to reach a final conclusion, but one should be ready during 1992.

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