# CASSAVA PRODUCT SYSTEMS: TECHNOLOGY AND COSTS

by

Abigail Andah
Food Research Institute,
P. O. Box M.20,
Accra, Ghana.

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# TECHNOLOGY AND COSTS

## INTRODUCTION

Cassava (Manihot esculenta Crantz) is the principal source of carbohydrate in human diet in many tropical countries(8).

The crop is processed into dried products in a variety of ways in different parts of the tropical world including Africa. Some of these dried products are cassava chips, cassava flour, gari, starch and tapioca all of which keep for months provided that they are sufficiently dry and well packaged (3) (10).

To achieve efficient operation and ensure regular supply of raw material it is essential that a cassava processing plant is located within a cassava producing area. This is necessary in view of the bulkiness (65-70% moisture content) of the tubers. Transportation costs are thus minimised. Another significant factor is the difficulty of storing cassava for even a few days without severe rotting. This makes it imperative for a processing plant to be as close as possible to its source of raw material. In this regard, it is recommended that a cassava processing plant should be linked with existing farms or a plantation capable of supplying 50% raw material requirement.

The incorporation of cassava in bread as a partial substitute for wheat flour is the most recent development in terms of food use of this crop (8). The main objective of these efforts is to help developing countries which import wheat for breadmaking to reduce wheat imports which cause a serious drain on scarce foreign exchange.

In this section the technology and costs of the most common product systems which have the potential for industrial development in Africa are discussed. These are systems for the production of gari, cassava starch and composite flour bread with gari as a partial substitute for wheat flour.

It must be remembered that selection of any particular product system must take into account the realities of local conditions. Only those systems that can be efficiently supported by available local resources such as capital, raw materials, labour, supply of energy and water should be considered.

## PROCESS DESCRIPTION OF GARI MANUFACTURE

Figure I shows the various stages used in the manufacture of gari.

### Tuber Preparation

Cassava tubers are hand-peeled by removing the thin outer skin and the inner skin from the fleshy central pith. Mechanised peeling has been found to be less efficient than manual peeling which is recommended for this system.

Peeled tubers are weighed and conveyed to a washer in which they are washed with water to remove soil particles and other impurities.

The material is then fed into a hammer mill where it is milled into a mash.

### Fermentation

The mash is left for up to 5 days to ferment. Organic acids produced cause the hydrolysis of toxic cyanogenic glycosides to liberate gaseous HCN. Aldehydes and esters which are produced at the latter part of the fermentation contribute to the characteristic taste and aroma of gari (4)

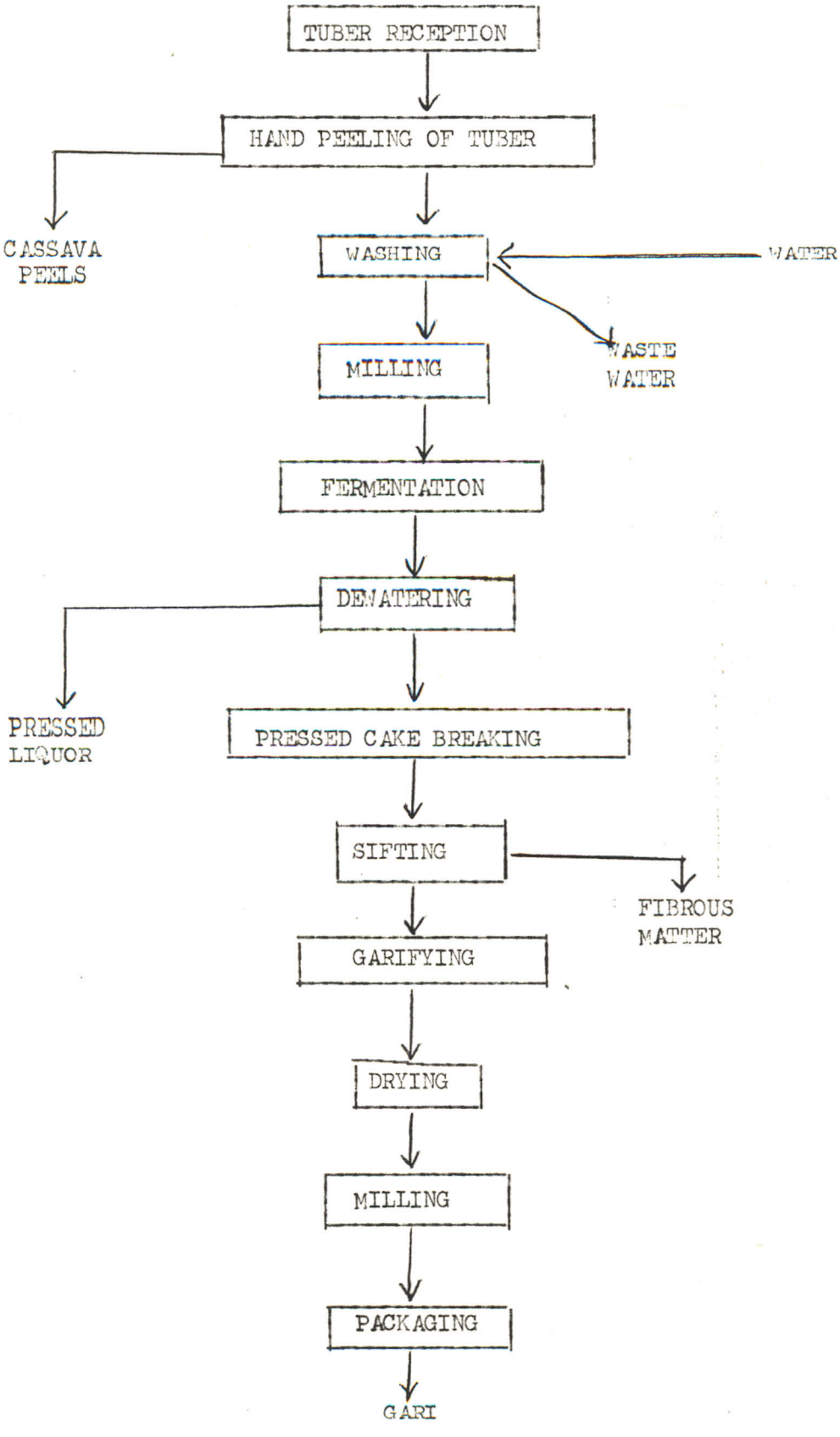
### Dewatering

By means of a hydraulic press the moisture content of the fermented mash is reduced from about 70% to about 50%. A hammer mill is used to break up the pressed cake before it is sifted. Stringy fibrous material is discharged as a by-product to be used for animal feedstuff.

### Garifying

The garifier unit converts the sifted cake into gari by partial gelatinisation of the starch content.( ).

FIG. / INDUSTRIAL MANUFACTURE OF GARI



Drying

The partially gelatinised granules are dried to a moisture content of 8-10% in the drier ( ).

During drying the remaining cyanide compounds are driven off.

Milling and Packaging

After the dried gari has cooled to ambient temperature, it is milled into the desired particle size, weighed and packaged in jute sacks or polythene bags.

## COST ANALYSIS OF GARI PRODUCTION

The system of gari production as described here is based on observations made by the author in a presently defunct gari factory in Assin Fosu, Ghana, and on information and quotations provided by equipment manufacturers (11).

It is assumed that

- equipment is purchased duty free and shipped to site.
- the plant operates 24hrs/day for 250 days in a year.
- 90% of total capital (including 2 months working capital) is borrowed from a bank.

Raw material requirement is 2240kg/hr. Output of gari is 440kg/hr.

Cost estimates are based on average rates in Ghana in 1982. Foreign exchange rate is based on ₵2.75 = US$ 1.00 as it was officially in 1982 in Ghana.

Table 1a : Total Fixed Capital Costs of a Gari Factory

| | US$ |
|---|---|
| - purchased equipment | 392,500 |
| - equipment transporting | 45,760 |
| - installation costs | 144,710 |
| - services | 332,420 |
| - 2 trucks (5 ton each) | 31,430 |
| - land ($\frac{1}{2}$ acre) | 2,730 |
| - building ($782m^2$) | 334,250 |
| - contingency (10% of fixed cost) | 127,680 |
| Total | 1,411,480 |

Table 1b : Manufacturing Costs of Gari

| | | | US$ |
|---|---|---|---|
| (i) | Direct production costs: | | |
| - | raw material (13440t Cassava) | | 9,811,200 |
| - | packaging material (52800 sacks) | | 479,950 |
| - | direct labour (Table 2) | | 853,888 |
| - | utilities | | |
| | diesel oil (753690 litres) | 512509 | |
| | water (4125000 litres) | 1320 | |
| | | | 513,829 |
| - | Maintenance | | |
| | building (2%) | 6685 | |
| | equipment (5%0 | 45770 | |
| | trucks (15%) | 4715 | 57,170 |
| (ii) | Direct manufacturing costs: | | |
| - | indirect labour (Table 2) | | 102,192 |
| - | factory overheads (20% labour costs) | | 191,216 |
| (iii) | Indirect manufacturing costs: | | |
| - | depreciation | | |
| | building (4%) | 13370 | |
| | equipment (10%) | 91539 | |
| | trucks (25%) | 7858 | 112,767 |
| - | interest on borrowed capital (14% of $3071749) | | 430,045 |
| | Total manufacturing cost of 2640000kg gari | | 12,552,257 |
| | Manufacturing cost of 1 kilo gari | = | $4.76 |

Table 2: Manpower, Requirement and Costs

Annual rates for workers based on 250 days/annum operation. Labour rates are based on average salaries and wages in Ghana in 1982. Foreign exchange rate of ₵2.75 US$ 1.00 was used to convert Ghanaian Cedis to US$.

| (i) Indirect Labour | No. | Total Annual Cost US$ |
|---|---|---|
| - Factory Manager | 1 | 8730 |
| - Asst. Factory Manager | 1 | 6550 |
| - Chief Clerk | 1 | 2620 |
| - Laboratory Assistant | 1 | 2910 |
| - Clerks/Messengers | 3 | 5240 |

| | | |
|---|---|---|
| - Purchasing Officer | 1 | 3270 |
| - Driver | 2 | 6110 |
| - Assistant | 2 | 4370 |
| - Security Personnel | 3 | 4580 |
| - Maintenance Supervisor | 1 | 3780 |
| - " Skilled | 3 | 9160 |
| - " Unskilled | 3 | 6550 |
| | | 63870 |
| Add 60% for Social Security, Fringe Benefits etc. | | 38322 |
| Total indirect labour costs | | 102192 |
| (ii) Direct Labour | | |
| - Production Supervisor | 3 | 11350 |
| - Machine Operators | 36 | 109960 |
| - Peeling Operatives | 135 | 412370 |
| Add 60% for Social Security, Fringe Benefits etc. | | 320208 |
| Total direct labour costs | | 853888 |
| Total labour costs | = | 956080 |

## LIST OF SUPPLIERS AND MANUFACTURERS OF PROCESSING EQUIPMENT FOR GARI (9)

1. Complete Plant

Agricultural Engineers Ltd.
Ring Road West Industrial Area
P. O. Box 3707
Accra - Ghana.

Maquina D'Andrea
Rua Jose Bonifacacio
29-9° - Sala 91
Sao Paulo, Brazil.

Newell Dunford Engineering Ltd.,
Newell Dunford House
Portsmouth Road
Surbiton
Surrey, KT6 5QF
United Kingdom.

Nivoba BV
Postbus 40
9640 AA Veendam
The Netherlands.

Projects Development Institute
(PRODA)
National Science & Technology Development Agency
3 Independence Layout
P. O. Box 609
Enugu
Nigeria.

2. Grater

Robt Friess Kg
Landmachinen Fabrik
Malsmsheim Krs.
Leonberg, Nr. Stuttgart,
Federal Republic of Germany.

Simon Barron Ltd
Bristol Road
Gloucester
England.

S. Corbett & Son
Park Street Works
Wellington, Shropshire
England.

3. Hammer Mill

(for gari manufacture)

Ascot Mec Works
Ayr
Scotland.

# PROCESS DESCRIPTION OF CASSAVA STARCH MANUFACTURE

Figure 2 shows the stages involved in the manufacture of starch from cassava tubers.

## Tuber Preparation

Woody ends of tubers are removed by hand with sharp knives in order to prevent damage to rasping machine. In the washing machine the tubers are washed to remove adhering dirt. The thin outer skin of the tubers is removed in the peeling machine. Most of the thick inner skin which contains some amount of starch is retained.

## Disintegration

The peeled tubers are chopped into pieces before they are rasped into a pulp.

## Extraction

The pulp is washed over a series of sieves with increasing fineness using water that is sprayed counter-current to the flow of the pulp. The wet waste-pulp is either pumped onto fields as fertilizer or is dewatered, dried and sold as fodder.

## Purification

Crude starch milk is passed through a sand cyclone to remove sand and other dirt particles. The material then passes through two successive centrifugal separators in which soluble contaminants are removed from pure starch.

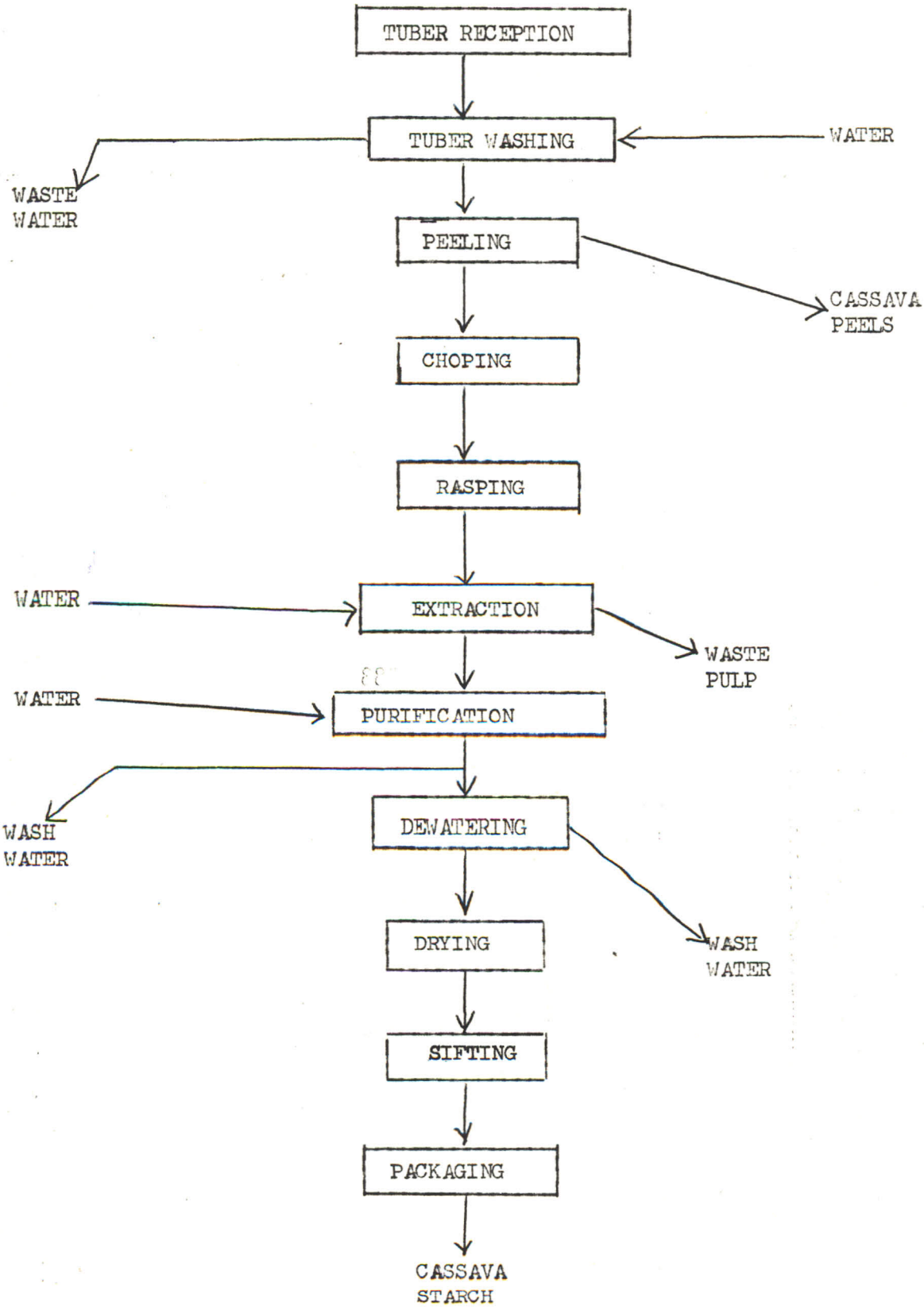
## Starch dewatering and drying

Before the starch is dried it is dewatered with a vacuum filter to reduce the moisture content to 40-45%. The final moisture content of the starch (10-13%) is attained by drying in a flash-drier. Dry starch is sifted and packed in jute bags.

## Sulphur dioxide

To avoid microbial contamination of the material, sulphur dioxide solution obtained by burning raw sulphur is added to the mash after the rasping stage at a concentration of 0.05%. Thereafter the acid is washed out in pure water during the purification stage.

FIG. 2 INDUSTRIAL PRODUCTION OF CASSAVA STARCH



## COST ANALYSIS OF CASSAVA STARCH PRODUCTION

The following cost breakdown is based on previous studies (5)(7)(8) and information obtained from traditional processors and equipment manufacturers.

It is assumed that

- equipment is purchased duty free and transported to site;
- the plant operates 24hrs/day for 250 days in a year;
- 90% total capital (including 2 months working capital) is borrowed from a bank.

The starch factory has the capacity to process 2 tonnes cassava per hour and an output of 400kg dry starch per hour. Average rates in Ghana in 1982 are used as basis for cost estimates. Official foreign exchange rate of ₵2.75 = US$1.00 as it was in 1982 was used.

Table 3a: Total Fixed Capital Costs of a Starch Factory

| | US$ |
|---|---|
| - Purchased equipment | 539,220 |
| - Equipment transporting Costs | 64,700 |
| - Installation costs | 211,460 |
| - Services | 455,380 |
| - 1 Truck (7 ton) | 21,430 |
| - Land (1 acre) | 5,460 |
| - Building (1260m$^2$) | 549,820 |
| - Contingency (10% of fixed cost) | 184,750 |
| | 2,032,220 |

Table 3B : Manufacturing Costs of Cassava Starch

| | | | US$ |
|---|---|---|---|
| (i) | Direct Production Costs: | | |
| | - raw materials | | |
| | Cassava tubers (12000t) | 8760000 | |
| | Sulphur (13.2t) | 23230 | 8783230 |
| | - packaging material (48000 sacks) | | 436320 |
| | - direck labour (Table 4) | | 64944 |
| | - utilities | | |
| | electricity (718390KW/h) | 138192 | |
| | Water (96000000 litres) | 30740 | |
| | diesel oil-drying & vehicle (204292 litres) | 139000 | 307932 |
| | - Maintenance | | |
| | building (2%) | 10996 | |
| | equipment (5%) | 63538 | |
| | truck (15%) | 3220 | 77754 |
| (ii) | Direct manufacturing costs: | | |
| | - indirect labour (Table 4) | | 124064 |
| | -,factory overheads (20% labour cost) | | 37802 |
| (iii) | Indirect manufacturing costs: | | |
| | - depreciation | | |
| | buildings (4%) | 21993 | |
| | equipment (10%) | 127076 | |
| | truck (25%) | 5360 | 154429 |
| | - interest on borrowed capital (14% of $3305061) | | 462709 |
| | Total manufacturing cost of 2400000kg starch | | 10449184 |

Manufacturing cost of 1 kilo starch = $4.35

Table 4 : Manpower Requirements and Costs of A Starch Plant

Labour requirements are based on 250 days/annum operation. Average salaries and wages in Ghana during 1982 are used as basis for labour costs. Foreign exchange rate of ₵2.75 to US$1.00 is used to convert Ghanaian cedis to US$ as in 1982.

| (i) Indirect labour | No. | Annual Costs US$ |
|---|---|---|
| - Factory Manager | 1 | 8730 |
| - Assistant Manager (Technician) | 1 | 6550 |
| - Clerk | 2 | 3500 |
| - Laboratory Assistant | 1 | 2910 |
| - Purchasing Officer | 1 | 3270 |
| - Maintenance, Mechanical | 3 | 9160 |
| - " Electrical | 3 | 9160 |
| - Lorry Driver | 1 | 3050 |
| - Driver's Assistant | 1 | 2190 |
| - Foreman | 3 | 11340 |
| - Security Personnel | 3 | 4580 |
| - Unskilled labour | 6 | 13100 |
| | | 77540 |
| Add 60% for Social Security, fringe benefits etc. | | 46524 |
| Total Indirect labour | | 124064 |
| (ii) Direct Labour | | |
| - Supervisor | 3 | 11350 |
| - Operatives | 6 | 18330 |
| - Unskilled labour | 5 | 10910 |
| | | 40590 |
| Add 60% for Social Security and Fringe benefits etc. | | 24354 |
| Total direct labour | | 64944 |
| Total labour costs | | 189008 |

# Suppliers and Manufacturers of Equipment for Cassava Starch Production (2)(9)

Alfa-Laval Ltd. (of Sweden)
Great West Road
Brentford
Middlesex
TW8 9BT
England

Bernauer
Secadores Industries Ltda
Praca Wilhelm Bernauer
37-Villa Prodente-CEP 03127
3748 CEP 01000
Sao Paulo
Brazil

Continental Engineering Ltd.
Lutmastraat 2
Amsterdam
The Netherlands.

Maquina D'Andrea
Rua Jose Bonifacio
29.9 - Sala 91
Sao Paulo
Brazil

Otto Wolf Co.
63 Commerce Street
Chambersburg
Pennsylvania
USA

Starcosa GmbH
Postfach 5105
3300 Braunschweig
Fed. Rep. of Germany

Westfalia (Separators) Ltd.
D-4740 Olde, Westfalia
Werner-Habig-Str. 1
Fed. Rep. of Germany.

Adolf Hubrich
Maschinenbau
2000 Hamburg 1
Ernst-Merckstrasse 12-14
Federabl Rep. of Germany.

Braunschweigische Maschinenbaustalt
3300 Braunschweigh
Postfach 295
Fed. Rep. of Germany

Dorr-Oliver
Baden Powellweg 305
P. O. Box 9090
Amsterdam 1006 AB
The Netherlands

Nivoba BV
Postbus 40
9640 AA Veendam
The Netherlands.

Projects Development Institute (PRODA)
National Sci. & Tech. Dev. Agency
3 Independence Layout
P. O. Box 609,
Enugu,
Nigeria.

Starketechnik Grindel & Co.,
2 Hamburg 20
Heinickorstrasse 4
Fed. Rep. of Germany.

## PROCESS DESCRIPTION OF CASSAVA/WHEAT BREAD MANUFACTURE (FIG. 3)

### Formula

| Ingredients | Parts (Based on % total Flour weight) |
|---|---|
| Wheat flour | 85 |
| Gari | 15 |
| Granulated sugar | 7.3 |
| Salt | 1.0 |
| Activated dried yeast | 0.2 |
| Margarine | 1.0 |
| Water | Variable |

### Breadmaking process

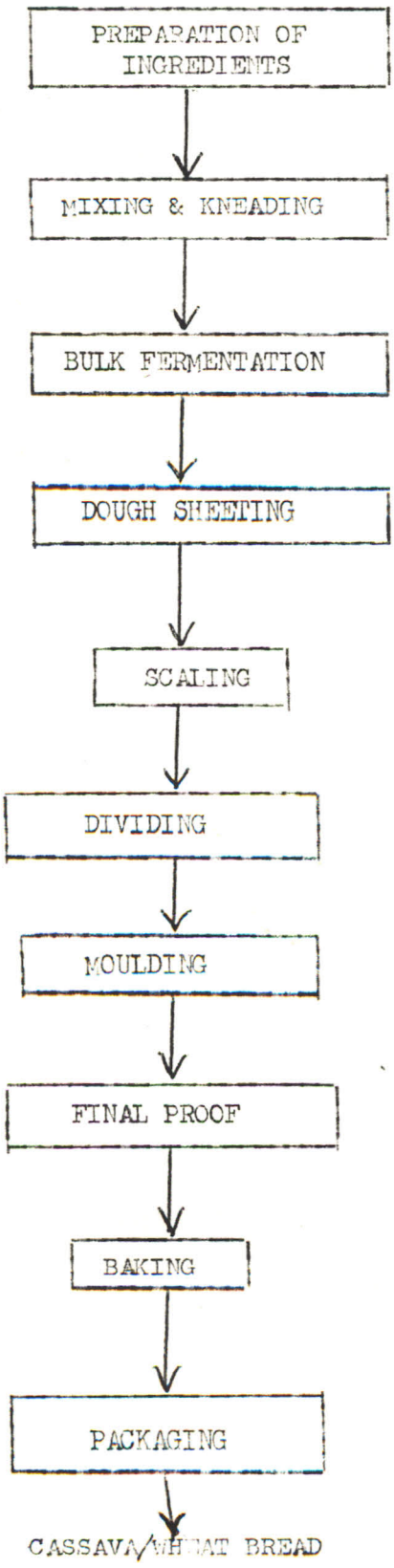
All the ingredients are weighed separately. The yeast is left in part of the water for about 15 minutes to disperse it. The gari is soaked in predetermined quantity of water for about 30 minutes. All the ingredients are thoroughly mixed and kneaded together in open-pan type mixers for a predetermined length of time.

The dough is left to ferment for about one hour at room temperature (25-27°C). Dough pieces are then developed by sheeting and folding about 10 times in the roller sheeting machines

After resting the dough for about 20 minutes, it is scaled to the desired weight which is in turn cut into smaller pieces with the hand operated dough dividers The dough pieces are rounded by hand, rested for a few minutes before they are fed into the moulding machine or are moulded by hand and then panned.

They are left for 6-8 hrs on racks in an enclosed chamber at room temperature (25-27°C) to expand in volume before they are baked at 230°C for 30 minutes. The baked loaves are then cooled and packaged in polythene bags.

FIG. 3 CASSAVA/WHEAT BREAD MANUFACTURE



## COST ANALYSIS OF CASSAVA/WHEAT BREAD PRODUCTION

The technology and cost of production of gari/wheat bread described here are based on the operations of the bakery project of the Ghana National Trading Corporation (G.N.T.C.), a state owned enterprise located in Accra. Cost estimates are adapted from a feasibility report prepared in 1977 and re-appraised in 1981 soon after the bakery was commissioned (6). The materials and procedure for breadmaking described above are generally used in Ghana by the large-scale bakeries (1). It is assumed that the bakery operates 24 hrs/day for 250 days in a year. 1981 average rates are used as basis for cost estimates. Foreign exchange rate of ₵2.75 = US$1.00 is used to convert Ghanaian cedis.

Table 5a: Total Fixed Capital Costs of Bakery Plant

| | |
|---|---|
| - purchased equipment | US$234300 |
| - equipment ransporting costs | 42370 |
| - installation costs | 12750 |
| - Services | 18180 |
| - delivery truck | 18180 |
| - building | 127270 |
| - land (½ acre) | 2730 |
| - contingency (10% of fixed costs) | 45578 |
| Total | 501358 |

Table 5b : Manufacturing Costs of Cassava/wheat bread

| | | US$ |
|---|---|---|
| (i) Direct production costs | | |
| - Raw materials | | |
| wheat flour (2142t) | 1799280 | |
| gari (321.3t) | 1096200 | |
| sugar (156.4t) | 247272 | |
| Salt (21420kg) | 19243 | |
| yeast (4284kg) | 42336 | |
| margarine (21420kg) | 82656 | |
| | | 3286987 |
| - packaging material (3600000 pieces) | | 900000 |
| - direct labour (Table 6) | | 37984 |
| - utilities | | |
| water | 3273 | |
| electricity | 4364 | |
| fuel | 10909 | 18546 |
| - Maintenance | | |
| building (2%) | 2545 | |
| equipment (5%) | 15380 | |
| vehicle (15%) | 2727 | 20653 |
| (ii) Direct manufacturing costs: | | |
| - indirect labour | | 66096 |
| - factory overheads (20% total labour costs) | | 20816 |
| (iii) Indirect manufacturing costs: | | |
| - depreciation | | |
| building (4%) | 5090 | |
| equipment (10%) | 30760 | |
| vehicle (25%) | 4545 | |
| | | 40395 |
| - interest on borrowed capital 18½% of 331710) | | 61370 |
| Total manufacturing costs of 3600000 kg bread | | 4452847 |

Manufacturing cost of 1 kilo bread = $1.24

Table 6 : Manpower Costs of Cassava/Wheat Bread Production

Manning levels are based on 3 shifts of 8 hrs each/day for 250 days/year. Salaries and wages are based on 1981 rates in Ghana. Foreign exchange rate of ₵2.75 to US$1.00 is used to convert Ghanaian cedis.

| Direct Labour | No. | Annual Salary US$ | Total Cost US$ |
|---|---|---|---|
| Master baker | 1 | 3640 | 3640 |
| Assistant Baker | 3 | 1770 | 3510 |
| Bakery hand | 3 | 1050 | 3150 |
| Labourers | 12 | 970 | 11640 |
| Total direct labour costs | | | 23740 |
| Add 60% fringe benefits and social security | | | 14244 |
| Total direct labour costs | | | 37984 |
| Indirect Labour | | | |
| Sales | | | |
| Salesman | 1 | 1680 | 1680 |
| Driver/Salesman | 1 | 1450 | 1450 |
| Accounts | | | |
| Senior Accounts Manager | 1 | 3640 | 3640 |
| Typist | 1 | 1230 | 1230 |
| Clerk | 2 | 1450 | 2900 |
| Cashier | 1 | 1450 | 1450 |
| Messenger | 1 | 1050 | 1050 |

Table 6 cont'd

| Indirect Labour | No. | Annual Salary US$ | Total Cost US$ |
|---|---|---|---|
| **Administration** | | | |
| Factory Manager | 1 | 5090 | 5090 |
| Secretary | 1 | 1680 | 1680 |
| Clerk | 1 | 1450 | 1450 |
| Messenger | 1 | 1050 | 1050 |
| Day Watchman | 1 | 1080 | 1080 |
| Night Watchman | 2 | 1090 | 2180 |
| Security Officer | 1 | 1450 | 1450 |
| Driver | 1 | 1180 | 1180 |
| **Technical** | | | |
| Maintenance Supervisor | 1 | 2910 | 2910 |
| Mechanic | 3 | 1640 | 4920 |
| Electrician | 3 | 1640 | 4920 |
| Total Indirect Labour Costs | | | 41310 |
| Add 60% fringe benefits | | | 24786 |
| Total Indirect labour cost | | | 66096 |
| Total Labour costs | | | 104080 |

## LIST OF MANUFACTURERS & SUPPLIERS OF BAKERY EQUIPMENT

| NAME OF MANUFACTUPER/SUPPLIER | EQUIPMENT |
|---|---|
| Bakers Equipment/Winkler,<br>210 Sylvan Avenue,<br>Englewood Cliffs,<br>New Jersey 07632,<br>USA. | Dough mixers, fermentation cabinets, dough moulders, sheeting rolls, ovens. |
| Excelsior Industrial Corporation<br>130 Broad Ave. Fairview,<br>New Jersy 07022,<br>USA | Dough mixer |
| F. Aeschbach S.A.,<br>Industriestrasse 20,<br>Aurau,<br>Switzerland. | Dough mixer |
| G & R. Gilbert Ltd.,<br>Restmore Way,<br>Hackbridge Road,<br>Hackbridge, Surrey,<br>England. | Dough mixers,<br>baking ovens |
| Lockwood Manufacturing Co.,<br>3170 Wasson Road,<br>Cincinnati,<br>Chio 45208,<br>USA | Bread and cake pans |
| Mettler Instruments A.G.,<br>CH-8606 Greifensee,<br>Zurich,<br>Switzerland. | Scales |
| National Manufacturing Company,<br>Lincoln, Nebraska,<br>USA | Dough mixers, fermentation cabinets, dough moulders, dough sheeting rolls. |
| Readhurst Equipment Ltd.,<br>Hanover House,<br>Marine Court,<br>St. Leonards-on-sea<br>East Sussex TN 38 0XP,<br>England. | Dough mixers, sheeting rolls, dough dividers, dough moulding machine, baking ovens. |
| Societé Pavailler S.A.<br>26 Bourg-les-Valence,<br>Drômes, France. | Baking ovens |

| NAME OF MANUFACTURER/SUPPLIER | EQUIPMENT |
|---|---|
| T. Errington & Sons Ltd.,<br>South Sea Works<br>Rodney Road<br>Portsmouth<br>England. | Bread and Cake pans |
| Thomas Collins & Co. (Bristol)Ltd.<br>Bristol, England | Baking Ovens |
| Tom Chandley Ltd.,<br>Durelect Oven Works<br>Windmill lane, Denton,<br>Manchester M34 3RN<br>England. | Baking Ovens |
| Tweedy of Burnley Ltd.,<br>Gannow Lane<br>Burnley,<br>Lancashire,<br>England. | Dough mixers, dough moulding machines. |

## A C K N O W L E D G E M E N T S

The author wishes to thank the management of Ghana National Trading Corporation (GNTC) for permission to extract information from the Feasibility Report and the Re-appraised Feasibility report on the GNTC bakery project. She is grateful to the Ministry of Industries, Ghana and processors for providing information on cassava processing in Ghana. She expresses appreciation to the many manufacturers who provided information on equipment and methods. Thanks are also due to the many colleagues who in various ways helped in the preparation of this text.

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Stanford University Press, California.

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