Cassava processing

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by
M.R. GRACE
FAO CONSULTANT

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Foreword

This paper was first issued in 1956 and then reprinted in 1966 under the title Processing of cassava and cassava products in rural industries. In 1971 it was expanded for publication as FAO Agricultural Services Bulletin No. 8, entitled Processing of cassava.

Because of the great demand for information from governments and from private concerns and persons, the text has been updated to cover subsequent advances in cassava production and processing.

Introduction

Cassava was unknown to the Old World before the discovery of America. There is archaeological evidence of two major centres of origin for this crop, one in Mexico and Central America and the other in northeastern Brazil. The first Portuguese settlers found the native Indians in Brazil growing the cassava plant. and Pierre Martyr wrote in 1494 that the "poisonous roots" of a yucca were used in the preparation of bread. It is believed that cassava was introduced to the western coast of Africa in about the sixteenth century by slave merchants. The Portuguese brought it later to their stations around the mouth of the Congo River, and it then spread to other areas. In 1854 Livingstone described the preparation of cassava flour in Angola, and subsequently Stanley described its use in the Congo. Cassava cultivation increased after 1850 in the east African territories as a result of the efforts of Europeans and Arabs who were pushing into the interior and who recognized its value as a safeguard against the frequent periods of famine.

In the Far East. cassava was not known as a food plant until 1835. In about 1850 it was transported directly from Brazil to Java, Singapore and Malaya. When the more profitable rubber plantations were started on the Malay peninsula, cassava growing moved to other parts of Indonesia where it flourished. During the period 1919-41 about 98 percent of all cassava flour was produced in Java, but during the Second World War Brazil increased and improved its production.

Now grown throughout the tropical world, cassava is second only to the sweet potato as the most important starchy root crop of the tropics.

The cassava plant has been classified botanically as Manihot utilissima Pohl of the family Euphorbiaceae. In recent publications, however, the name Manihot esculenta Crantz is being increasingly adopted.

The plant is popularly known under a great variety of names: ubi kettella or kaspe (Indonesia), manioca, rumu or yucca (Latin America), mandioca or aipim (Brazil), manioc (Madagascar and French-speaking Africa), tapioca (India, Malaysia), cassava and sometimes cassada (English-speaking regions in Africa, Thailand, Sri Lanka).

The term cassava (manioc in French-speaking countries) is usually applied in Europe and the United States of America to the roots of the cassava plant, whereas tapioca denotes baked products of cassava flour. The word tapioca derives from tipioca, the Tupi Indian name for the meal which settles out of the liquid expressed from rasped tubers and is made up into pellets called tipiocet.

Because it grows easily, has large yields and is little affected by diseases and pests? the areas under cassava cultivation are increasing rapidly. The plant is grown for its edible tubers, which serve as a staple food in many tropical countries and are also the source of an important starch. Its value as a famine relief crop has long been recognized. In parts of the Far East during the Second World War many people survived on cassava roots, and in Africa it was a principal food source for workers in mining and industrial centres.

It is now grown widely as a food crop or for industrial purposes. In many regions of the tropics cassava occupies much the same position as white potatoes do in some parts of the temperate zones as the principal carbohydrate of the daily diet. The industrial utilization of cassava roots is expanding every year.

In the early decades of this century, cassava was held responsible for the rapid exhaustion of forest clearings, but later experiments in many parts of the tropics showed that it is not a soil-depleting crop. Since the Second World War, a more balanced appraisal of the crop has developed. More scientists, agriculturists and sociologists have become aware of its importance in developing countries, where it is most commonly produced. In many countries emphasis is being placed on research for the improvement of production and utilization of cassava crops.

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1. Cassava cultivation

The plant

The cassava plant is a perennial that grows under cultivation to a height of about 2 4 m. The large, palmate leaves ordinarily have five to seven lobes borne on a long slender petiole. They grow only toward the end of the branches. As the plant grows, the main stem forks, usually into three branches which then divide similarly. The roots or tubers radiate from the stem just below the surface of the ground. Feeder roots growing vertically from the stem and from the storage roots penetrate the soil to a depth of 50-100 cm. This capacity of the cassava plant to obtain nourishment from some distance below the surface may help to explain its growth on inferior soils.

Male and female flowers arranged in loose plumes are produced on the same plant. The triangular-shaped fruit contains three seeds which are viable and can be used for the propagation of the plant. The number of tuberous roots and their dimensions vary greatly among the different varieties. The roots may reach a size of 30-120 cm long and 4-15 cm in diameter, and a weight of 1-8 kg or more. The plant, its flowering shoot and its various parts are shown in Figures I and 2.

Clusters of root of the Bogor variety, ripe for harvesting, are shown in Figure 3. A cross section of the root is given in Figure 4. The peel consists of an outer and an inner part, the former comprising a layer of cork cells and the phellogen. The cork layer, generally dark-coloured, can be removed by brushing in water, as is done in the washers of large factories. The inner part of the peel contains the phelloderm and the phloem, which separates the peel from the body of the root. The texture of the transition layer makes possible an easy loosening of the whole peel from the central part, thus facilitating the peeling of the roots.

The cork layer varies between 0.5 and 2 percent of the weight of the whole root, whereas the inner part of the peel accounts for about 8-15 percent. Generally in ripe roots this is about 2-3 mm thick. The starch content of the peel is only about half that of the core. The peel is much firmer in structure, hindering a smooth rasping by primitive raspers; small factories prefer to peel the roots before working them up. The loss of starch incurred by rejecting the peel. however' is not acceptable to the larger factories. which remove only the cork layer.

Agricultural practices

PREPARATION OF THE LAND

When cassava is grown as the first crop in forest land. no further preparation is required than the clearing of the forest growth. When cassava is grown after other crops. it often can be planted without further preparation of the soil, once the preceding crop has been harvested or the soil has been ploughed two or three times until free from grass and other plants.

Clearing of forest land is done to let in more sunlight to the ground and to remove weeds and undergrowth which might otherwise compete with economic plants. The practice in tropical southeast Asia is to clear the forest soil completely, including the removal of all roots and other obstructions beneath the soil, by cutting and burning the forest cover; the land is then deeply ploughed. African practice is to burn the land cover only. Burning removes only small branches and underbush but does not consume all of the trunks and branches. It also destroys soil parasites, and the layer of ashes increases the amount of potassium salts available to the growing plants. However, some reports have indicated that complete clearing of the soil in certain parts of Africa caused deterioration due to the leaching out of nutrients.

PLANTING

Cassava culture varies with the purposes for which it is grown.

Cassava is either planted as a single crop or intercropped with maize, legumes, vegetables, rubber, oil palm or other plants. Mixed planting reduces the danger of loss caused by unfavourable weather and pests by spreading the risk over plants with different susceptibilities.

For agricultural purposes, cassava is propagated exclusively from cuttings. It is raised from seed only for the purpose of selection Seeds produce plants with fewer and smaller roots than those of the parents and as many as half of the seeds may fail to germinate. On the other hand, cuttings taken from the stalks of the plant take root rapidly and easily, producing plants identical in character with the parent plants.

FIGURE 2. Manihot utilissima Pohl.

FIGURE 4. Cross section of cassava root. Drawing by R. Soemarsono Slate Botanical Gardens. Bogor. Indonesia.

Cuttings are obtained from the stems of plants at least ten months old and 2.53.5 cm thick. After harvesting, these stems are stored in a dry place until the next planting (Fig. 5). Cuttings about 25 cm long should be taken from the lower 75150 cm of the stem after the first 20 em have been discarded. Cuttings from the upper part of the stem will grow faster, but their final yield is less. The best practice is to saw a bundle of stalks supported by a girder and then to point the cuttings thus obtained at the lower end (Fig. 6), taking care not to bruise the buds or otherwise damage the stem.

Experiments in the Philippines on the relation between the age of cuttings and yields showed that cuttings taken 75 cm or more below the apex of the stem gave the best starch yields. Other experiments concluded that older wood from the basal areas to the midpoint of the stems outyielded apical propagating material.

Key to Figure 4:

Left upper quadrant. after staining with iodine:

1. Peel

    1a. Outer cork layer
    1b. Inner layer

2. Cambium
3. Centre
4. Pith and primary xylem

(Both peel and pith contain comparatively little starch.)

Right upper quadrant, showing structural elements of the root:

5. Cork
6. Sclerenchymatous fibres
7. Latex vessels
8. Cambium
9. Xylem vessels

Inset A - Enlarged cross section of peel:

10. Cork tissue

11. Sclerenchymatous fibres
12. Starch (small grains)
13. Parenchyma cell

Inset B - Enlarged cross section of centre:

14. Cell wall (larger cells than in peel)
15. Starch (big grains)

Cuttings are planted by hand or by planting machines. Hand planting is done in one of three ways: vertical, flat below the soil surface or tilted 45" from ground level. Under low rainfall conditions. vertical planting may result in the desiccation of the cuttings, while in areas of higher rainfall, flat-planted cuttings may rot. In general, flat planting 5-10 cm below the soil surface is recommended in dry climates and when mechanical planting is used. Germination seems to be higher; tubers tend to originate from a great number of points and grow closer to the surface of the soil, making better use of fertilizers applied on the surface and also making harvesting easier. On the other hand' vertical planting is used in rainy areas and tilted planting in semi-rainy areas.

The cuttings are planted on flat soil or on ridges or hills. Some experiments have shown ridging to produce somewhat lower yields than flat cultivation; but the work of weeding and harvesting is greatly reduced by ridge planting. As machine planting would be impossible with furrows or on ridges, flat fields are the most desirable. Spacing between rows is about 80100 cm, and the plants are spaced along the rows according to local conditions. The number of plants per hectare varies in different regions between 10000 and 15000.

FIGURE 6. Scheme of cassava stalk for planting

Time of planting is influenced by weather conditions and the availability of planting material. Cassava is usually planted at the beginning of the rainy season. In order to reduce risk and to distribute the hard work of cultivation more evenly, planting is sometimes divided between the two rainy seasons. It is usually carried out throughout the year in regions with year-round rainfall. If the stalks are saved for a long time after harvest, they are not apt to root and grow well. It is therefore desirable to plant and harvest at the same time.

Experience has shown that, from the standpoint of starch production' the development of the cassava plant is most profitable when planting takes place at the beginning of a humid period (i.e., in tropical regions at the beginning of the monsoon).

CULTIVATION

Cassava is frequently cultivated as a temporary shade plant in young plantations of cocoa, coffee, rubber or oil palm. In Thailand, however, it is grown mostly as a sole crop and the farmer may for ten years or more grow cassava on the same land. If the price of cassava roots drops, the farmer may shift to another crop (e.g., sugarcane, maize or sorghum) until cassava again becomes the more profitable crop.

Water is essential until the plant is well established. In moist soil, sprouting takes place within the first week after planting. Generally about 5 percent of the cuttings will not come to development, so a corresponding surplus has to be provided for. Within a month of the beginning of planting, the substitution of new cuttings is still possible.

When cultivated as a temporary shade plant, no special attention is given to the cassava plant. When grown alone, the plants require little maintenance after planting. Irrigation may be required if there is no rain, and hoeing of the earth helps preserve the subsoil humidity, especially in dry sandy soils. The chief problem is weed control. It may be desirable to weed the crop two or three times until the plants are well developed and their shade prevents the growth of weeds.

CLIMATE

Cassava is a typical tropical plant. The approximate boundaries for its culture may be accepted as from 30N to 30S latitudes; however, most cassava growing is located between 20N and 20S. In general, the crop requires a warm humid climate. Temperature is important, as all growth stops at about 10C. Typically' the crop is grown in areas that are frost free the year round. The highest root production can be expected in the tropical lowlands, below 150 m altitude, where temperatures average 25-27C, but some varieties grow at altitudes of up to 1 500 m.

The plant produces best when rainfall is fairly abundant, but it can be grown where annual rainfall is as low as 500 mm or where it is as high as 5 000 mm. The plant can stand prolonged periods of drought in which most other food crops would perish. This makes it valuable in regions where annual rainfall is low or where seasonal distribution is irregular. In tropical climates the dry season has about the same effect on Cassava as low temperature has on deciduous perennials in other parts of the world. The period of dormancy lasts two to three months and growth resumes when the rains begin again.

As a tropical crop, cassava is a short-day plant. Experiments conducted in hothouses show that the optimum light period is about 12 hours and that longer light periods inhibit starch storage.

SOIL

Cassava grows best on light sandy loams or on loamy sands which are moist, fertile and deep, but it also does well on soils ranging in texture from the sands to the clays and on soils of relatively low fertility. In practice, it is grown on a wide range of soils, provided the soil texture is friable enough to allow the development of the tubers.

Cassava can produce an economic crop on soils so depleted by repeated cultivation that they have become unsuitable for other crops. On very rich soils the plant may produce stems and leaves at the expense of roots. In some parts of Africa freshly cleared forest soils are regarded as highly suitable after they have borne a cereal crop.

FERTILIZATION

No fertilization is required when the land is freshly cleared or when there is enough land to enable the cultivator to substitute new land for old when yields fall. Like all rapidly growing plants yielding carbohydrates, cassava has high nutrient requirements and exhausts the soil very rapidly. When cassava is grown on the land for a number of years in succession or in rotation. the soil store of certain nutrients will be reduced and must therefore be returned to the soil by fertilization.

Various experiments in Brazil, India and many regions of Africa and the Far East showed significant increases in yield, of roots as well as starch content, obtained by the application of fertilizers. Potassium salts favour the formation of starch, and nitrogen and phosphorus are essential for growth. However, if the soil contains large quantities of assimilated nitrogen, the result will be heavy development of vegetative growth without a corresponding increase in root production.

Generally speaking, fertilization is practiced at present in most parts of Africa and South America only on commercial plantations. In Thailand, only a few farmers apply artificial fertilizers, as they are usually too costly for the small farmer. Most farmers use different kinds of organic manures, such as cattle or duck manure or garbage.

The kinds and quantities of fertilizers required by a cassava crop depend on the nature of the soil.

DISEASES AND PESTS

In many regions, the cassava plant is not normally affected by diseases or pests. However, in others it may be attacked by the following:

> (a) Virus diseases. Mosaic, the brown streak and leaf curl of tobacco may attack leaves, stems and branches. Many parts of Africa harbour these diseases and attempts are being made to select resistant varieties.

(b) Bacterial disease. Bacteria such as Phytomonas manihotis (in Brazil), Bacterium cassava (in Africa) and Bacterium solanacearum (in Indonesia) may attack roots, stems or leaves of cassava plants.

(c) Mycoses. There are kinds which attack roots, stems, or leaves of cassava plants and cause various diseases.

(d) Insects. Some insects affect the plant directly (locusts, beetles and ants); others affect the plant indirectly by the transfer of virus (aphids).

(e) Animals. Rats, goats and wild pigs are probably the most troublesome; they feed on the roots, especially in areas adjacent to forests.

TOXICITY

The toxic principle in cassava is hydrocyanic, or prussic, acid, found in the roots, branches and leaves of the plant in both free and chemically bound forms. The plant contains a cyanogenetic glucoside called phaseolunatin begins to break down upon harvest into hydrocyanic acid, acetone and glucose by the action of the enzyme linase. The presence of hydrocyanic acid is easily recognized by a bitter taste. At the harvest of cassava roots, the amount of the acid in the plant varies from harmless to lethal -

from a few milligrams to 250 milligrams or more per kilogram of fresh root. Investigations show that the glucoside content in the cassava plant is markedly increased by drought and by potassium defciency.

Hydrolysis of the glucoside by the enzyme can be accelerated by soaking the roots in water, by crushing or cutting them or by heating. It was found that the hydrocyanic acid content varied little in different tubers of one plant but varied considerably in tubers obtained from different locations. The distribution of the acid in roots varied in different varieties. In sweet varieties, the major part of the acid is located in the skin and in the exterior cortical layer, while in bitter varieties the acid is uniformly distributed in all parts of the roots.

In choosing a strain, the hydrocyanic acid content should be taken into account. Highly poisonous strains are preferred for plantings with the object of starch manufacture, thereby minimizing thefts by both animals and men.

VARIETIES

Although cassava is an established commercial crop in many tropical countries and hundreds of varieties are in existence, little is generally known of the nomenclature and identification of varieties. Various varieties are usually differentiated from one another by their morphological characteristics such as colour of stems, petioles, leaves and tubers. Moreover, in many instances the same variety is known in various places by a number of names.

The numerous varieties of cassava are usually grouped in two main categories: Manihot palmata and Manihot aipi, or bitter and sweet cassava. This grouping is a matter of economic convenience, as it is difficult to distinguish the two groups by botanical characteristics. However, the distinction between them rests upon the content of hydrocyanic acid, which causes toxicity in the roots. This toxicity is not a variety constant but varies from place to place; all cassavas are now regarded as varieties of Manihot utilissima, and in certain circumstances a "bitter" variety may become "sweet" and vice versa. Hydrocyanic acid content tends to be higher on poor soils and in dry conditions. According to the recognized classification, sweet. or nontoxic. roots contain less than 50 milligrams of hydrocyanic acid per kilogram of fresh matter.

At one time it was thought that the toxicity of a cassava root was associated with species or variety, but the hydrocyanic acid content was found to vary markedly with growing conditions, soil, moisture, temperature and age of the plant. Certain varieties in Africa, for instance, were found to be innocuous in Dahomey and poisonous when grown in forest soils in Nigeria; the so-called bitter type from Jamaica failed to produce the toxic substance when grown in Costa Rica.

The chemical composition of cassava roots differs considerably. Studies of 30 varieties in Mexico gave the following results: the dry-matter content of the roots varied between 24 and 52 percent, with a medium of 35 percent; protein content varied between I and 6 percent, with a medium of 3.5 percent.

Table 1 is based on an analysis made in Madagascar comparing the cassava root with the potato

For industrial development, many efforts are being made to organize research and experiments in various geographical regions for the selection of new varieties with high yields of roots and higher starch content. For purposes of nutritional improvement. strains with a high protein content are being sought.

TABLE 1. - AVERAGE COMPOSITION OF THE CASSAVA ROOT AND THE POTATO (COMMON VARIETIES AT HARVEST TIME)

	Cassava	**Potato**
	Percent	

Moisture	70.25	75.80
Starch	121.45	19.90
Sugars	5.13	0.40
Protein	1.12	2.80
Fats	0.41	0.20
Fibre	1.11	1.10
Ash	0.54	0.92

[1] Bitter varieties usually average about 30 percent starch content.

HARVESTING

Harvesting of cassava can be done throughout the year when the roots reach maturity. In regions with seasonal rains, like Madagascar, harvesting is usually done in the dry season, during the dormant period of the plant; where rain prevails all year round, as in Malaysia, cassava is harvested throughout the year.

Maturity differs from one variety to another, but for food the tubers can be harvested

at almost any age below 12 months.

From the standpoint of starch production, cassava should be considered ripe when the yield of starch per hectare is highest. An optimum age of 18-20 months was found in experiments with certain strains of the variety "So Pedro Preto" in a tropical climate (Java). The graph in Figure 7 shows the influence of the age at harvesting on the starch yield as the percentage loss of yield in relation to the yield at the optimum age as found in an experiment with a definite strain.

It is seen that both root and starch production increase rapidly to their maximum value, after which root production decreases slowly and starch production much more rapidly on account of the declining starch content of the tubers.

If the roots are left in the ground, starch content increases with age until, at a certain point, lignification takes place, causing the roots to become tough and woody, so that they are harder to prepare for consumption and other uses.

Once the roots are harvested, they begin to deteriorate within about 48 hours, initially owing to enzymatic changes in the roots and then to rot and decay. The roots may be kept refrigerated for up to a week. They may be stored in the ground for longer periods if they are not detached from the plant.

Harvesting is still generally a manual operation, although equipment to facilitate this operation is being considered. The day before harvest, the plants are "topped" - the stalks being cut off 40-60 cm above ground by hand, machete or machine and piled at the side of the field. This length of stalk is left as a handle for pulling. Material required for the next planting is selected and the rest is burned. In light soils the roots are slowly drawn from the soil simply by pulling the stems or with the help of a kind of crowbar and the tubers are cut off the stock. In heavier soils a hoe may be required to dig up the roots before the plant is pulled out. It must be noted that once the plants have been topped, lifting of the roots must not be delayed, as sprouting and a drastic fall in the starch content of the tubers will result.

FIGURE 7. Percentage loss in yield of whole tubers and starch relative to yield at optimum age. The solid line refers to whole tubers and the dotted line to starch.

YIELD

Cassava is not usually grown on soils where it would be most productive - that is, the light sandy loams, fertile and deep, which are reserved for other crops less tolerant of poor soils. When cassava is grown by traditional tropical methods, yields lie between 5 and 20 tons per hectare, varying with the region, the variety, the soil and other factors. However, when the crop is given more attention, yields of 30 40 tons per

hectare are obtained. It has been reported that it is normal for some varieties, under appropriate cultivation methods, to yield over 60 tons per hectare.

The high yields frequently achieved at agricultural experiment stations and occasionally by some active farmers show what might be accomplished with improved varieties and better cultural practices.

Nevertheless, cassava yields in total calories per hectare compare very favourably with those of other starchy staples, as shown in Table 2.

TABLE 2. - AVERAGE YIELDS OF TROPICAL STARCHY STAPLES, 1948-52

	Brazil	**Java**	**India**	**China (prov. Of Taiwan)**
	Millions of calories per hectare			
Maize	4.4	2.4	2.3	5.0
Rice	3.9	3.9	2.8	5.5
Yams and sweet potato	7.5	5.4	5.6	8.6

Cassava	14.2	7.1	5.8	11.6

SOURCE: FAO Yearbook of Food and Agricultural Statistics (1955).

Mechanization

In most of the tropical world cassava is grown on small plots; however, in some countries (e.g., Mexico. Brazil and Nigeria). large plantations have been started and interest in mechanization is growing. The degree of mechanization depends on the amount of land, available labour in the area and general policy regarding the use of manual labour.

The use of machinery for land preparation is preferable to manual labour to ensure the best possible seed bed for tuber development. Subsequent operations of planting. weeding, topping and harvesting can be done by hand as well as by machinery.

Labour input for the production of a hectare of cassava varies widely in different parts of the tropics. It has been estimated that in Zaire 778-830 manhours are required per hectare of cassava, including preparation of cuttings, planting, weeding and harvesting. as compared with 1 868-2206 man-hours in Uganda. In South America and the Caribbean a maximum of 494 man-hours has been estimated for the same

operations. A possible reason for the higher requirements in Africa is the growing of cassava as an intercrop, with more timeconsuming operations.

The peculiar nature of the cassava crop presents a number of problems as regards mechanization, hut it has been successfully mechanized to a degree in some countries.

The following is an outline of the present use of machinery in cassava cultivation:

(a) The hoe remains the principal implement for cultivating, weeding and harvesting.

(b) Basic operations. such as ploughing and harrowing, may be done by tractor.

(c) A mechanical planter made in Brazil is in use there and in Mexico. It is a tworow planter using a tractor driver and two men on the machine to feed cuttings from the reserve bins into the rotating planting turntable. In operation, the cuttings fall in succession through a hole into a furrow opened by a simple furrower. A pair of disks throw dirt into the furrow and floats pulled by chains pack the soil over the cuttings. The planter is able to cover about 5 hectares per day.

(d) A unit for ridging and planting has been developed by modifying a ridger to work as a ridger-cum-planter and a cultivator to work as a six-row planter after the area has been ridged.

(e) A simple machine used in Mexico is a gasoline-powered table saw to prepare the cuttings for planting. The machine has the advantage of speed and regularity of produced cuttings. As compared with manual work the time saving is 3:1.

(f) It has been found to be virtually impossible to carry out the first weeding operation between the ridges with a cultivator. Mechanical weeding of the top of the ridges presents a number of difficulties.

(g) A topping machine consisting of a heavy screen mounted on the front of a tractor has been developed to push down the tops: then a rotary mower on the back of the same tractor can cut the downed top to make harvesting by hand possible. The height at which the tops are cut back can be easily regulated with any rotary mower.

(h) Cassava is not a crop that lends itself readily to mechanical harvesting because of the way the tubers grow. They may spread over I m and

penetrate 50 60 cm. Careless use of machinery for harvesting can damage tubers, resulting in a darkening due to oxidation that will lower the value of the flour. However, in Mexico and Thailand, mould-board ploughs have been used to make hand harvesting less tedious. Stalks can be cut successfully by a mid-mounted mower or a topping machine, and the roots are lifted mechanically with a mid-mounted disk terracer. In Ghana, about 2000 m2 could be harvested in 21/2 hours by a tractor' whereas ordinarily 5 man-days were required A modified beet or potato harvester has been suggested for use behind the tractor, with a pulling mechanism in place of the digging shares to raise the tubers by pulling at the cut stems left after topping.

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2. Cassava flour and starch

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The separation of the starch granules from the tuber in as pure a form as possible is essential in the manufacture of cassava flour. The granules are locked in cells together with all the other constituents of the protoplasm (proteins, soluble carbohydrates, fats and so on), which can only be removed by a purification process in the watery phase. Processing the starch can therefore be divided into the following stages:

> **1. Preparation and extraction. Crushing of the cells and separation of the granules from other insoluble matter (i.e.' adhering dirt and cell-wall material) including the preparatory operations of washing and peeling the roots, rasping them and straining the pulp with the addition of water.**
>
> **2. Purification. Substitution of pure water for the aqueous solution surrounding the starch granules in the mash obtained in the first stage, as well as the operations of sedimentation and the washing of the starch in tanks and on flour tables, silting, centrifuging, etc.**
>
> **3. Removal of water by centrifuging and drying.**
>
> **4. Finishing. Grinding, bolting and other finishing operations.**

This method of processing is essential in the preparation of any kind of starch. For

cassava, however, because of the relatively small amount of secondary substances, the separation at each stage is performed with great ease. Whereas with maize and other cereals the grinding of the seed and the mechanical separation of the germ and the pericarp from the grain present special problems in stage 1, and the separation of protein and other constituents in stage 2 can only be accomplished with the aid of chemicals, these operations can be reduced to a minimum in cassava preparation. It is indeed possible to obtain a first-rate flour from the cassava root without special equipment by using only pure water. This makes the processing of cassava flour particularly suitable for rural industries.

Supply of cassava roots

Most starch factories buy cassava roots from growers in their neigh-borhood, directly or through agents. Some factories, however, own their cassava plantations. Modern processing plants usually contract various growers in the area to supply roots. In such situations the factory should furnish financial and technical assistance to the growers, and an agronomist should be assigned to help producers develop better production practices and to conduct control experiments for determining the proper varieties, fertilizers, and methods of insect and disease control for the area.

In many countries, prices are set on the basis of a certain starch content, with a discount or a premium for deviations from that level, which is determined according to the locality and the varieties. The starch content in the tubers is determined subjectively by the factory's representative or objectively by chemical analysis. Subjective evaluation is done by selecting a medium-size root and snapping it in two. If the tuber snaps with medium force, the crop is generally regarded as mature and the flesh will appear firm, white and dry. Such roots are considered to have the maximum starch content of 30 percent. Lowstarch flesh from immature tubers is usually slightly yellow and, although firm, has a translucent watery core. If considerable force is required to snap the tuber, it is considered to have become woody and the crop to have passed its prime.

Chemical analysis of the tubers is a truer method for the determination of starch content, but it requires a laboratory and qualified technicians.

In most cases' root weight is estimated at the farm by simple means which are not entirely accurate and consequently do not reflect the exact yield. It is therefore advisable to have special weighing bridges in the factories for recording the weights of the roots as well as of the final products.

Processing operations

IMPORTANCE OF QUICK PROCESSING

In the processing of cassava starch it is vital to complete the whole process within the shortest time possible, since as soon as the roots have been dug up, as well as during each of the subsequent stages of manufacture, enzymatic processes are apt to develop with a deteriorating effect on the quality of the end product. This calls for a well-organized supply of roots within relatively short distances of the processing plant and, furthermore, for an organization of the stages of processing that will minimize delays in manufacture. Thus, while simple in principle, the manufacture of a good cassava flour requires great care.

The roots are normally received from the field as soon as possible after harvest and cannot be stored for more than two days. Since the presence of woody matter or stones may seriously interfere with the rasping process by stoppage or by breaking the blades, the woody ends of the roots are chopped off with sharp knives before the subsequent processing operations.

PEELING AND WASHING

In small and medium-size mills the general practice is to remove the peel (skin and cortex) and to process only the central part of the root, which is of much softer

texture. With the relatively primitive apparatus available and limited power, the processing of the whole root would entail difficulties in rasping and in removing dirt, crude fibre and cork particles, whereas comparatively little extra starch would be gained.

The structure of the root permits peeling to proceed smoothly by hand (it is often done by women and children). Work starts in the morning as soon as the roots are brought in; as it must be finished as quickly as possible, numerous hands are needed. The roots are cut longitudinally and transversely to a depth corresponding to the thickness of the peel, which can then be easily removed. Any dirt remaining on the smooth surface of the core of the root can now be washed off without any trouble and the peeled roots deposited in cement basins where they remain immersed in river water until taken out for rasping (Fig. 9). Frequent treading by foot cleans any loosely adhering dirt from the roots.

In the larger factories, whole roots are generally processed. The washing here serves to remove the outer skin of the root as well as the adhering dirt. Provided the root is sufficiently ripe, skin removal may proceed without the use of brushes. Only the outer skin or corky layer is removed, as it is profitable to recover the starch from the cortex. The inner part of the peel represents about 815 percent of the weight of the whole root.

The mechanical washer (Fig. 10) is a perforated cylindrical tank which is immersed in water. A spiral brush propels the roots while they are subjected to vigorous scrubbing in order to remove all dirt. A centrifugal pump is fitted to one end of the machine and connected to a series of jets arranged along the carrying side of the brush. These jets produce a countercurrent to the flow of the roots, ensuring that they receive an efficient washing.

Another efficient washer is a rotary drum with an interior pipe which sprays water on the roots. The drum is either wooden or perforated metal, about 3 to 4 m long and 1 m in diameter, with horizontal openings; it is mounted inside a concrete tank. In some, rotating paddles are fitted along the axis. Washing is done by the action of water sprayed, assisted by the abrasion of the roots both against one another and against the sides of the cylinder or the paddles.

The roots are hand-fed from one end and when they come out at the other they are clean and partially peeled, the action being continuous. Dirty water and skin are periodically drained out through a small opening in the concrete tank.

Some trials in Brazil have attempted the complete peeling of roots for the production of a white starch, and also have used copper, brass or bronze equipment instead of iron, which in contact with wet starch may lead to the production of ferrocyanide (the

result of a reaction between iron and hydrocyanic acid), which gives the starch a bluish colour.

In modern factories the roots are pre-washed by soaking in water to separate the coarse dirt and then passed through a combined unit for washing and peeling as described above.

RASPING OR PULPING

It is necessary to rupture all cell walls in order to release the starch granules. This can be done by biochemical or mechanical action. The biochemical method, an old one, allows the roots to ferment to a certain stage; then they are pounded to a pulp and the starch is washed from the pulp with water. This method does not give complete yields and the quality of the resulting starch is inferior. Mechanical action is carried out by slicing the roots and then rasping, grating or crushing them, which tears the flesh into a fine pulp.

By pressing the roots against a swiftly moving surface provided with sharp protrusions, the cell walls are torn up and the whole of the root is turned into a mass in which the greater part, but not all, of the starch granules is released. The percentage of starch set free is called the rasping effect. Its value after one rasping may vary between 70

and 90 percent: the efficiency of the rasping operation therefore determines to a large extent the overall yield of starch in the processing. It is difficult to remove all the starch, even with efficient rasping devices, in a single operation. Therefore, the pulp is sometimes subjected to a second rasping process after screening. The rasping is carried out in different ways with varying efficiency.

Hand and mechanical rasping

On very small holdings in some cassava-growing regions the roots are still rasped by hand on bamboo mats. Where daily production amounts to several hundred kilograms of flour, simple mechanical implements are used.

A simple but effective grater is obtained by perforating a sheet of galvanized iron with a nail and then clamping it around a wheel with the sharp protruding rims of the nail openings turned outward. The wheel may be driven by hand, but it is often driven by foot like a tricycle, the worker pressing the roots from above onto the rasping surface: or the rasping surface is attached to one side of a rotating disk equipped with a crank transmission, which is driven by foot. The pulp is collected in baskets or wooden containers to be carried to the sieves.

Hydraulic raspers

Larger water-powered raspers can be used where running water is available. The waterwheel is rotated by a flywheel and driving belts to a pulley on the shaft of the rasping drum. The drum. 20-30 cm in diameter. is either attached to a primitive wooden construction or fitted into a "rasping table." The operator. seated at the table, presses the roots against the drum. The grated mass is forced through a narrow slit between the drum and the shelf before it drops into the trough, whence it is carried to the sieves.

The rasping devices described above are made of perforated inplate. Though inexpensive, they are relatively inefficient as the rasping plate must often be replaced on account of rapid wear.

Engine-driven raspers

Engine-driven raspers are more economical when production rises above a certain level - say, for the handling of 10 tons of fresh roots a day. The most current model is the Jahn rasper. The machine has a rotor of hardwood or drawn steel tube, 50 cm in diameter, with a number of grooves milled longitudinally to take the rasping blades or saws. The number of saw teeth on the blades varies from 10 to 12 per centimetre according to need. The blades are spaced 6-7 mm apart on the rotor.

In simpler versions, the rotor is fitted into a housing in such a way that the rasping surface forms part of the back wall of the receptacle for the roots. Facing the rasping surface, a block or board is inserted which is movable by a lever and turns on an axis near the upper rim of the compartment. By manipulating this buffer the roots are pressed onto the rasping surface, which moves downward in the hopper, and the mass is propelled through a slit in the bottom of the hopper. It is advisable to give the inner surface of the buffer the form of a circular segment corresponding to the section of the rotor exposed so that, at its extreme position inward, the distance between rotor and block is only a few millimetres. This, however, is generally possible only in the all-steel raspers to be described later.

In many medium-size factories, water is run into the hopper during rasping, in order to facilitate crushing and removal of pulp. The drawback of this practice, however, is that relatively large fragments of the roots escape crushing; hence it is not to be recommended from the point of view of effectiveness. It is never applied in well-equipped factories.

In a rasper of the type used in larger factories, the housing is equipped with adjustable breasts with sharp steel edges for the control of rasping fineness. More recent constructions provide for the return to the rasping surfaces of those pieces of the roots which were thrown out sideways. The pulp has to pass a screen-plate with

sharp-edged holes or slits, during which it is homogenized to a certain degree and, in fact, undergoes a secondary crushing.

Power consumption during rasping

To obtain the maximum rasping effect, the power supply should be accurately attuned to the constructional details of the rasper, i.e., to the distance between the surface of the rotor and the breasts in the housing.

The energy required to tear up the roots is derived from the momentum of the rotor, a certain minimum of kinetic energy being necessary to obtain any rasping effect. Above a certain rotor speed, however, it is to be expected that no considerable further increase in the rasping effect will be obtained. There is thus an optimum speed for the rasper in conformity with the need for a high rasping effect on the one hand and with the economy of power supply on the other. In this connection it should be remembered that only the linear velocity of the rasping surface counts. In practice it has been found that a rasper of the usual dimensions - a diameter of 40-50 cm and a length of 30-50 cm for the rotor - should be driven at 1000 rotations per minute, corresponding to a linear velocity of the rasping surface of about 25 m per second. The power of the engine required to drive a single rasper of this type is 20-30 hp. In most cases diesel engines are used.

Variations in resistance of the roots to rasping

At or near optimum speed of the rasper, both rasping effect and energy required per I 000 kg of fresh roots still depend a good deal on the kind of roots being treated. Comparative results obtained for six different varieties of cassava, peeled and unpeeled, with an electrically driven experimental rasper reproducing as far as possible the form and working conditions in medium-size factories are given in Table 3. As is to be expected, high rasping effects involve a lower use of energy. The influence of peeling the root is important in both respects.

Secondary rasping or grinding

In view of these results it is no wonder that the rasping effect differs widely in different factories. In modern factories, it may be estimated that an effect of about 85 percent is attained at the first rasping; at these production levels, however, it is economical to submit the pulp to a second crushing process, either in a second rasper or in special mills where the pulp is ground between stones. These mills, however, do not seem to have found much favour with cassava manufacturers.

In a secondary rasper, the indentation of the saw blades should be somewhat finer, about 10 per centimetre (25 to 27 teeth per inch) as compared with about 810 per

centimetre (19 to 26 teeth per inch) for the primary rasper. The overall rasping effect is raised to over 90 percent by the secondary rasper.

The differences in output under different rasping techniques are shown by the following figures: in one medium-size factory, using a single Jahn rasper, the capacity was at most three tons of roots per hour; a larger factory, working with primary and secondary raspers, achieved more than double this amount per hour per primary and secondary rasper unit.

TABLE 3. - RASPING EFFECT AND ENERGY REQUIRED FOR ROOTS OF DIFFERENT VARIETIES

	Rasping effect		Rasping energy[1]	
Variety	**Unpeeled**	**Peeled**	**Unpeeled**	**Peeled**
Mangi	62.7	80.4	6.76	6.62
Basic rao	67.2	79.4	7.15	6.31
Tapicuru	66.3	67.5	5.30	-
Sc Pedro Preto	67.4	68.7	5.21	3.44

Bogor	62.1	60.5	4.47	4.05

[1] In kWh per 1000 kg of free starch produced.

SCREENING

In separating the pulp from the free starch a liberal amount of water must be added to the pulp as it is delivered by the rasper, and the resulting suspension stirred vigorously before screening. Mixing with water can be carried out more or less separately from screening, but more often the two operations are combined in "wet screening" - that is' the mass is rinsed with the excess water on a screen which is in continuous motion.

Hand screening

In the smallest mills, screening is done by hand. The rasped root mass is put in batches on a cloth fastened on four poles and hanging like a bag above the drain leading directly to the sedimentation tanks. Spring water or purified river water is run in from a pipe above the bag, and the pulp is vigorously stirred with both hands. Sometimes bamboo basketwork is used to support the screening cloth. The pulp under processing still contains appreciable amounts of starch and therefore has a certain value (e.g., as a cattle fodder): in the small mills it is pressed out by hand, and the lumps obtained

are dried on racks in a well-ventilated place.

The rotating screen

A simple form of rotating screen consists of a conical frame of hardwood, fixed on a hollow, horizontal axis, at least 3 m long, covered with ordinary cloth or phosphor-bronze gauze. Phosphor-bronze is often preferred for its durability, but its use necessitates frequent brushing in order to remove clogging pulp particles. The crude pulp is fed into the cone at the narrow end and by the rotation of the screen, at approximately 50 revolutions per minute, slowly moves down to the other end, whence it is conveyed to the pulp tanks. In the meantime, water is sprayed on it under pressure (e.g., 6 atmospheres) from a number of openings in the hollow shaft. Thus, by the time the pulp reaches the lower end of the cone, it is more or less completely washed out. The rotation screen has the advantage of preventing the plugging of the meshes of the sieve with gummy materials (they tend to agglutinate with the fibre as the screen rotates). The flour milk is caught in a cemented basin stretching out below the screen over its whole length, and from there runs along channels into sedimentation tanks or flour tables.

The screen is mounted close to the rasper and at a somewhat lower level in order to ease the flow of the crude pulp. The washed-out pulp discharged at the lower end of

the screen is carried off by some form of conveyor to basins outside the factory. Since its dry matter still consists mostly of starch, this byproduct after drying and pulverizing is marketed as a fodder.

A more elaborate type of rotating screen is equipped with two sets of brushes, one set being arranged to convey the fibre along to the discharge, the other acting as beaters, which at the same time keep the screens clear to allow the starch milk to flow away readily. Both sets of brushes are adjustable, so that excessive wear on the bristles can be taken up and the maximum life obtained from them. The screens are carried in aluminium frames which are removable for changing covers. Up to now a single rotating screen is most generally used in factories of medium capacity. In larger factories, for economic reasons, the starch must be extracted from the whole root as thoroughly as possible with the minimum amount of water. This often implies a more intricate arrangement of the operation of rasping and screening as well as more efficient screening devices.

The shaking screen

In large factories the rotating screen is replaced by the shaking screen. It consists of a slightly inclined, horizontal frame, 4 m in length and covered with gauze, which is put into a lengthwise shaking motion in short strokes by means of an eccentric rod. The

fresh pulp, after being mixed with water in distribution tanks, is conducted by pipes to the higher end of the screen; during screening, the pulp remaining on top of the screen is slowly pushed downward by the shaking motion.

It is advantageous to let the suspensions pass a series of shaking screens of increasing fineness (80-, 150-, and 260-mesh), the first one retaining the coarse pulp, the others the fine particles. The pulp remaining on the first of these screens is often subjected to a second rasping or milling operation and then returned to the screening station.

Another means of increasing efficiency is to perform the combined operations of screening and washing the pulp in two stages. In the first stage' the pulp is vigorously stirred with water in a washer provided with coarse screens at the bottom and with paddles in order to obtain thorough mixing during the transport of the pulp toward the end of the trough. In the second stage, the crude flour milk from these washers is conducted to a shaking screen below, which retains the rest of the fine pulp. The operation is twice repeated with the pulp thus obtained in similar washer-and-screen units, which may be arranged in a battery.

The complete separation of free starch from pulp is achieved here by the countercurrent principle. In the third (lower) washer, the pulp from a first rasping is washed out with flour milk from the second washer-and-screen unit. The pulp from

this first treatment passes a secondary rasper, whence it is conveyed to the washer, where it is rinsed with starch milk from the first (upper) washer-and-screen unit. Finally, the pulp is conveyed to the upper washer where fresh water is run in.

Efficient rising of the pulp on the screens is promoted by inserting one or more shallow transverse channels in the surface of the screen, where the strong whirling movements caused by the shaking of the screen effectively loosen the starch granules from the pulp.

Jet extractors

An efficient machine for the separation of starch from cellulose fibre is the jet extractor, or the continuous perforated-basket centrifuge. The starch-pulp slurry is put in a conical basket and centrifugal action separates the starch dispersion from the fibrous pulp. Jets of water sprayed on the pulp as it travels the length of the cone assure complete recovery of the starch.

The Dorr-Olivier DSM screen

Another type of modern equipment used in the starch industry for the complete separation and washing of fibre is the Dorr-Oliver inclined DSM screen, which consists

of a stationary screen housing equipped with a con cave wedge bar-type screen (see Fig. 11). The suspension to be screened is fed tangentially either by gravity or under pressure into the screen-plate and flows in a direction perpendicular to the bars. Each bar of the screen surface slices off a layer of liquid of a thickness approximately one fourth the slot width. Different types of screens, with slot widths ranging from 50 up to 3 mm, are used in the starch industry.

After rasping, the starch-pulp slurry flows down the DSM screen by gravity and the pulp and starch are separated. As many as four screens are operated in series to assure that the starch dispersion is completely separated from the pulp. The pulp from one screen is discharged into a basin, redispersed with dilution water, and pumped to the succeeding screen.

SETTLING AND PURIFICATION OF STARCH

The term "settlings' as used here includes the whole series of operations for separating the pure starch from soluble contaminants. The quality of the flour produced depends to a great extent on the proper performance of these operations, which comprise settling in successive tanks, settling on flour tables, and the action of modern separators. Each operation can be used alone or carried out in different combinations. They all result in a more or less concentrated suspension of starch in

pure water.

Duration of settling process and quality of product

As has already been stated, the entire processing of cassava must be completed within as short a time as possible. This is particularly true of the separation of the free starch from its suspension in the so-called fruit-water - the watery part of crude starch milk - because of the very rapid chemical changes in this solution (the formation of very stable complexes between starch and proteins, fatty material and so on). As it is almost impossible to separate the pure starch from these complexes, the value of the flour for many purposes is seriously lowered by those processes.

At a later stage - the fruit-water being rather rich in sugars and other nutrients - microorganisms start to develop and eventually lead to a vigorous fermentation. Alcohols and organic acids are produced, among which butyric acid is particularly noticeable on account of its odour. These biochemical changes exert a negative influence on the quality of the flour similar to the foregoing physicochemical ones. It is all but impossible to prevent the formation of this acid in the processing of cassava; traces of it are discernible even in very good brands of the finished flour. Indeed small rural mills can often be located by the smell of butyric acid.

As a consequence of the necessity for speed, the technique of settling has developed rationally from the simple settling tank to the settling table, with a considerable reduction in the time of contact between starch and fruit water. In modern processing methods the whole period between rasping and drying is reduced to about one hour.

Before the different methods of settling are discussed in detail. a few of the fundamental facts on sedimentation should be discussed.

Settling and granule size

Besides this. however. other factors. such as the pH of the medium and its content of protein and other colloidal matter. through the corresponding changes in colloidal state. have some influence on the rate of sedimentation and especial on the consistency of the settled flour.

The diameter of cassava starch granules ranges between 4 and 24 microns: thus. a gradation according to granule size has to he expected in successively deposited layers of sediment. This gradation will sharpen with the length of the path of sedimentation from the initially mixed suspension. Therefore. during tank sedimentation the lower layers will contain granules of a wide range of sizes, settled during the first stages of filling the tanks with the crude starch milk. The gradation mentioned will only be

noticeable if the tanks are filled entirely. The size distribution found experimentally in a sediment of 30-cm thickness after 24 hours of settling hears out these expectations. as shown in Table 4.

It is seen that gradation by particle size sets in above one third the height of sediment. The standard deviation in the top layer is relatively large. It can be seen that this layer contains many granules of all sizes. which under the microscope have a corroded appearance. Moreover. one finds a certain proportion of fine cellulosic debris. precipitated proteinous and other organic matter.

In sedimentation on flour tables a corresponding gradation may he expected. in this case with respect to the distance from the head of the table.

TABLE 4. - SIZE DISTRIBUTION OF GRANULES IN SEDIMENT OF CASSAVA STARCH

Sediment layers	**Most frequent diameter**	**Average diameter**	**Standard deviation**
	Microns[1]		
Lower layer at bottom	14	14.5	3.7

At 1/3 height	16	14.5	3.9
At centre	12	11.7	4.1
At 2/3 height	12	10.9	4.3
At 0.3 cm from surface	8	9.6	4.5
Top layer (light flour)	6 9.	4	4.4

[1] Micron = 0.001 millimetre.

Centrifugal separators, however, will produce a uniform mixture of granules of all sizes which occur in the starting material.

Settling in tanks

This is the oldest method, and, indeed, tanks are the obvious means at low production levels in small rural mills. In very small mills, wooden barrels or troughs serve the purpose, but as soon as the production reaches several hundred kilograms of flour per day it is usual to construct tanks of cemented brickwork sunk into the ground. Rectangular and round tanks or basins are used in the Far East for the settling

of starch as well as for the washing and the purification of the settled starch, as shown in Figure 12. The dimensions and the number of tanks are determined by level of production and convenience of handling (e.g., 2 x 4 m in surface dimensions and 0.5 to I m in depth).

It is essential that the flour does not remain in contact with cement or masonry any longer than necessary, as this has a notably deteriorating influence on the quality of the flour. Therefore. the bottom of the tanks is covered with wood of a kind which is proof against the prolonged action of the slurry and does not react on the flour. A wooden skirting, moreover, is fitted on the walls to a height of, say, 10-15 cm so that the whole mass of flour contained in a tank full of starch milk will settle against a wooden surface. The lining may be of tiles rather than wood. Holes provided with stoppers are fitted into the walls, preferably at different heights, to let off the supernatant, or excess, liquid after settling, one hole just above the floor being used for the purpose of cleaning the tank between settlings.

During this process a number of tanks are usually filled in succession, the flow of starch milk being conducted to the next tank, after the previous one has been filled up, by means of checks placed in the channels. Settling takes at least six hours; thus, after rasping which is carried out early in the morning, the supernatant liquid is let off in the afternoon. However, rasping is often carried out late in the morning, and in that

case the flour is left to settle overnight, up to 20 hours or more. Though settling is more complete in this case, the action of enzymes and microorganisms may also have progressed.

The fruit-water is now let off by removing the stoppers from the holes, beginning with the upper ones, thus reducing turbulence as far as possible. Notwithstanding this, in drawing off the last of the supernatant liquid, appreciable amounts of the lighter starch fractions in the upper layers of the sediment go with it; as in general, the drain waters are not processed in these small mills' they constitute a loss, which together with the starch originally left in suspension may be estimated at 5-10 percent of the flour produced.

The upper layer of sedimented flour, which has a yellowish green tint, contains many impurities and is generally scraped off and rejected. The remaining moist flour is then stirred up with water and left to settle again. In most cases, two settlings suffice to obtain a reasonably clean flour. In larger factories producing flours for special purposes, settling may be repeated several times with or without the addition of chemicals.

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The pour table

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In large factories of medium size a great step forward in the settling operation has been taken through the replacement of the settling tanks by flour tables or basins. Because of the space it occupies, a table is generally practical only in medium-size and larger factories.

The flour table is a shallow channel, some 50 m long, about 30 cm deep and of a width varying with the amount of starch to be worked up daily. The bottom is covered with wood or tiles, as described in the previous section, and in principle should be horizontal, though it is sometimes given a slight inclination, say of 1 cm per metre.

The flour milk enters at one end, preferably from a compartment of the table itself, occupying over one half metre of its length and separated by a silt about 20 cm high, which ensures a uniform overflow over the whole width of the table. The liquid drawn

off at the end of the table should be substantially free of starch and is thus rejected.

In settling on a table, the sedimentation path of the starch granules, which is vertical in the case of settling in tanks, will be drawn out into oblique lines on account of the horizontal movement of the slurry. The longer the time needed by any particle to pass from its position in the suspension down to the bottom, the further its ultimate place in the sediment will be from the head of the table. The stratification obtained in settling tanks is therefore in the present case partly converted into a differentiation as to granule size over the length of the table. Hence, floating or very slowly deposited fibre and dirt particles, including protein, will be removed at the end of the table, and the flour settling on the higher parts will contain a larger proportion of the larger starch granules and very little of the protein and other contaminants. Thus, the sediment on these parts of the table constitutes, generally, a better grade of flour, the rest being worked up as a lower grade. As the time of settling for all particles is much shorter than in settling tanks, the contact of the starch with the fruit-water is likewise considerably reduced.

As settling is most copious at the upper end of the table and slowly falls off toward the far end, the sediment soon shows the effect of an inclination of the table itself. As the working proceeds, the movement of the slurry is therefore accelerated on the upper end, tending to accentuate the difference in quality.

The flour table acts most efficiently if filled to maximum capacity. Some factories which must work up different quantities from day to day have flour tables of varying width - say, 2, 3 and 4 m.

The advantages of the flour table over the settling tank may be summed up as follows:

1. The time of contact of the flour with the fruit-water is shortened.

2. The starch settled on different parts of the table is differentiated according to purity and granule size, thus enabling the manufacturer to produce simultaneously and without extra cost at least two brands of different quality.

3. Losses of fine starch are far less because the sedimentation path is much shorter and drainage proceeds at a minimum rate.

Influence of chemicals on settling and the proprieters of the product

It may therefore be surmised that' apart from the rate of settling, the right consistency of sediment is important in achieving an efficient separation of the starch from the fruit-water. The starch losses incurred with draining in settling tanks will decrease as

the starch settles to a firm cake, and even the efficiency of tabling will depend partly on the compactness of the sediment.

Pure starch settles in clean water to a compact mass of peculiar mechanical properties. If suddenly broken up (e.g., with a scoop). it crumbles like a brittle substance: but as soon as the forces causing deformation relax' it loses all form and spreads out like a thick syrup (melting. as it were, on the scoop). This phenomenon. termed dilatancy is explained by imagining the granules in the sediment, when at rest piled up on one another in the most space-saving manner' whereas any disturbance of this array by external forces results in an increase of the interstitial volume accompanied by a " drying up" of the cake. The same factors may give the dry flour its "crunchy" property.

The volume of the sediment and its compactness depend very much on the presence of impurities, such as fibre, which tend to result in a softer sediment. Apart from this, it has been found that the composition and the reaction of the ambient solution have an important influence on settling. An acid reaction promotes rapid settling and a compact sediment; an alkaline reaction has the opposite effect.

As in many medium-size factories chemicals are added for various purposes before settling, it seems worth while to review in some detail the effect of the substances most often applied, both on the consistency of the sediment and on the properties of

the product.

It should, however' be emphasized that there is little sense in adding chemical aids where the basic conditions for the production of a high-quality flour are not fulfilled. in particular if clean working is not put first and foremost. On this condition there is no doubt that a flour of prime quality can be produced without the use of any chemicals. Moreover. because of the danger of misapplication. these additions are not to be recommended without the expert supervision as a rule available only in large factories.

Sulfuric acid In many instances this acid, which is added as an aid to sedimentation. results in a product of enhanced whiteness. The effect on sedimentation is noticeable at concentrations above 0.001 ml of the concentrated acid (specific gravity 1.84) per litre of starch of 2" Brix. (Degrees Brix are about proportional to the grams of flour per litre.) Addition of ten times the quantity causes very rapid sedimentation, but a rather soft sediment is obtained. The effect of this chemical in lowering the viscosity of the product is already appreciable at very small concentrations. Up to about 0.001 ml per litre of starch milk there is a slight increase in viscosity; at higher concentrations a marked decrease. The latter effect is a disadvantage in most applications of the flour; however, it is less so in the manufacture of baked products as whiteness is all-important.

Great care should be taken in adding this chemical, which should only be used in diluted form, prepared beforehand, and thereafter removed by one or more subsequent settlings in pure water.

Alum (aluminium sulfate). The presence of alum in the starch milk may be the consequence of the addition of a surplus of this chemical in the purifcation of the water used. It has a favourable effect on sedimentation, and also enhances the viscosity of the flour, an addition of 0.1 g per lire of starch milk of 2" Brix resulting in an increase of about 50 percent in viscosity.

Sulfur dioxide (sulfurous acid). The addition of sulfur dioxide is a common practice in the manufacture of most grain starches (e.g.' maize starch). It probably helps to separate the starch from the other substances to which it is more or less firmly bound in its protoplasmic state. Furthermore, it keeps bacterial and enzymatic action within bounds. Sulfur dioxide also acts as a bleaching agent, although the white colour thus obtained soon deteriorates. The acid produces a lowering of the viscosity of the product, especially after prolonged action, but e single settling from water containing the usual concentration of 0.3 to 0.4 g per litre followed by settling in pure water has no serious effect.

It is questionable whether the use of sulfur dioxide is advantageous in the processing

of root starches and in particular of cassava. In any case, the acid should be applied with great caution and thereafter carefully washed out by subsequent settlings in pure water.

Chlorine. The addition of active chlorine in its different forms (the element itself, chloride of lime or one of the various commercial hypochlorites) considerably augments the viscosity of the product' provided the concentration is kept low - about I mg per hire of starch milk. At that concentration it acts favourably on sedimentation, while its disinfecting and bleaching properties are also very marked, the sediment obtained being compact and white. Higher concentrations of about 50 mg per litre result in a very soft and discoloured sediment and a product of very low viscosity. These properties of active chlorine preparations make them the very best means of obtaining an end product of better quality.

Sedimentation processes

Up to the Second World War, the sedimentation processes used in large cassava factories usually consisted of refinement in tanks and on tables. Separation by centrifuging, though practiced in the starch industries using potato and maize as raw material, does not seem to have found wide application with cassava during this period. Since then, more efficient centrifugal processes for the separation and cleaning

of starch in general have been devised. Although originally designed for the processing of potato and maize starch, both machines and centrifuges of a more conventional type are now beginning to be applied in the cassava industry, and it may be expected that at the higher production levels they will soon supersede other methods.

Sedimentation on one flour table is not usually sufficient to effect a complete separation of pure starch from slurry. One obvious defect of both tables and sedimentation tanks is that they do not separate contaminating particles heavier than starch (sand, clay). In the large factories, when producing a high-grade flour the product is collected, after a first tabling, in containers with conical bottoms, where it is stirred moderately with fresh water. Heavy particles settle in the lower part of these stirring tanks and can be discharged from time to time from a tap in the bottom. The flour milk obtained is then pumped to a second table or set of parallel tables, where settling takes place. To prevent any reaction between the flour milk and the wall material, these channels may be coated with a resistant material such as aluminium.

The action of this second tabling operation is different when the table is inclined. Apart from settling in the channels, the more rapid motion of the liquid subjects the underlying sediment of flour to silting - that is, the starch granules and other particles, even after settling, are carried along with the stream to be deposited farther on.

The drag exerted by the stream on a body at the bottom increases with its dimensions. Therefore, the more voluminous fibre particles, which on account of their specific gravity might settle on the higher parts of a table, will be swept down to the lower end by silting. Silting thus supplements the purification obtained by the flour table; in addition' it tends to homogenize the settled starch mass.

Concentration of flour milk in all sedimentation processes has definite limits. In particular, during tabling the suspension should contain no more than 25-30 g of starch per litre. Higher concentrations will result in an undesirable lengthening of the sedimentation time. In silting. higher concentrations, up to 250 g per litre, are allowed.

The supervision of the concentration is best carried out by measuring the density of the slurry with hydrometers. It is usually expressed in degrees Brix, a standard taken over from the sugar industry (grams of sucrose per litre at 17C The relation between the latter quantity. specific gravity, and hydrometer readings according to Brix and Baum for different starch suspensions at room temperature is presented in Table 5.

TABLE 5. - DENSITY OF STARCH SLURRIES OK VARIOUS CONCENTRATIONS AT ROOM TEMPERATURE (20C)

Air-dry starch	Dry starch	Specific	Degrees Brix	Degrees Baum

(15 % moisture)		**gravity**		**(B)**
Grams/litre				
5.0	4.2	1 000	0.4	
10.0	8.5	1 001	0.8	0.2
15.0	12.7	1 003	1.1	0.4
20.0	17.0	1 004	1.5	0.6
25.0	21.2	1 006	1.9	0.8
30.0	25.5	1 007	2.2	1.0
35.0	29.7	1 008	2.6	1.2
40.0	34.0	1 010	3.0	1.4
45.0	38.2	1 011	3.4	1.6

Lamellators

The principle of cutting down the settling distance of the starch granules, as achieved by the use of a flour table. is followed also in the construction of lamellators: oblique plates (lamellae) of glass or metal (for cassava only copper can he utilized) are fitted

radially into the upper part of conical tanks, the lower part being provided with a stirring device and a tap. The flour milk enters the centre of the upper part and from there flows radially and at low velocity through the spaces between the lamellae and over the outer rim of the cone.

The path of free sedimentation of the starch granules is limited here to the vertical distance between two adjacent plates, which amounts to a few centimetres only, after which they roll down more rapidly along the surface of the plates into the lower part of the cone. The larger granules will thus sink in the central part of the apparatus and will collect at the bottom of the cone; the finer grains will settle at the periphery and collect on the conical wall. As small granules slip along an inclined surface faster than large ones, clogging on the walls is minimized. Clogging of the flour in the spaces between the lamellae is prevented by their radial arrangement, each interspace widening in the direction of flow of the suspension.

Centrifugal methods

A rapid separation of starch grains from fruit liquor and the elimination of the impurities in colloidal suspension are attained by centrifuging, with consequent improvement in quality of the finished product. Centrifuging cannot, however, replace entirely the gravity settling operation: after centrifuging? the starch still has to be

freed from any remaining solid impurities by settling in tanks or on tables.

One of the current conventional types of centrifugal separator consists mainly of a horizontal imperforate drum or bowl (Figs. 13, 14) with a continuous spiral-ribbon starch remover or scraping device inside (A, D). The drum rotates in a frame with bearings at both ends. Over a gearbox, the drum and the scraper are driven at slightly different speeds by a direct-coupled motor. The starch milk enters the slightly conical drum at the narrow end (B) and passes to the other end. where the liquid outlet (E) is located. On its way through the howl. the milk throws off starch grains and other solid matter' which concentrate at the periphery. Here the concentrate is taken up by the scraper and brought counter-current to the narrow end. where it is discarged (c) with the addition of fresh watter The purest starch is made by using liberal amounts of soft water. Hard water (high in lime content) has been known to leave calcium oxalate in the finished product.

FIGURE 14. Longitudinal section of a centrifugal separator

The rapid displacement of fruit liquor by fresh water has been brought to a certain degree of perfection in machines known as concentrators.

The current type of concentrator illustrated in Figures 15 and 16 consists of a

separator bow with a double wall which turns on a hollow spindle (i). The starch slurry is fed through the inlet (a and b) into the inner howl (C) where it is pressed by centrifugal force onto the inner wall. which is fitted with a number of nozzles of special design. At the same time. water is pumped by a centrifugal pump (K) along the hollow spindle into the water chamber between the inner shell anti the outer howl wall. This wall is provided with similar nozzles located just opposite those in the inner shell. The fresh water from the water chamber enters the nozzles in the inner shell. thus intensively washing the starch coming out of these openings. and the diluted truit-water leaves the apparatus through .1 after passing a set of separating disks and a paring device serving to quench excessive frothing.

FIGURE 15. Cross section of a starch concentrator

The starch' together with fresh water, is pressed through the outer nozzles and leaves the apparatus through e as a concentrated suspension in substantially clean water.

The capacity of the separator depends primarily on the size of the starch granules: the throughput capacity will be lower for fine-grained starches. In fact' some loss of starch with the separated fruit-water is inevitable' because very small starch granules will escape sedimentation under any circumstances. It is claimed that such losses are smaller than in other centrifugal processes. Moreover. the separator consumes less

power and its operation is less sensitive to variations in the starch concentration of the treated starch milk' which otherwise often results in clogging. Separators of this type are easy to install and do not need foundations: in operation' however. they require expert supervision.

The action of the separators (concentrators) is completed by rapid batchwise settlings in bowl centrifuges or in purifiers where the purest starch is the first to settle in a thick layer on the bowl wall' followed by strata of starch mixed with FINE fibre ("grey starch"), the fruit-water forming the inner layer. In the older types of centrifuges the operation is discontinued after a few minutes' the water is let off, and the grey starch is removed by washing. The purified starch is then stirred up with fresh water and either drawn off for dewatering or subjected to a second centrifuging.

The newest purifiers have the advantage of performing the above operations while the bowl is in motion. As shown in Figure 17, the bowl or drum turns on a rigid axis and is furnished with a winged feeding chamber. The bowl is fed through a tube (1) The pivot arm (2) carries an agitator (3) and a knife (4) which skims off the fruit-water and scrapes off the grey starch, both of which are discharged through an opening in the bottom of the bowl. The skimmer (5) for purified starch milk is mounted on another pivot. These tools are operated hydraulically and make about a quarter turn from one extreme position to the other.

The operation of a purifier is usually linked directly with that of the above concentrators, the crude starch milk being first washed and concentrated to 16-18B by two concentrators in series.

The starch dispersion is washed with large quantities of water in a series of wooden tubs, settling tanks or basins as described before or in refiners and separators. The crude starch is transferred by hand or in baskets from the settling tanks into the washing tubs or basins, where the starch is agitated vigorously with clear water and then allowed to settle for 6-12 hours. This process is repeated several times until the starch is thoroughly purified. During settling, the starch sediment is sometimes covered with cloth to absorb the excessive moisture. However, in modern factories, two types of equipment are used for the purification of starch:

1. The Merco centrifugal separator, which is based on the well-known cream-separation principle. The separator features an integral re turn-flow principle which ensures a continuous and uniform output of solid products by recycling a portion of the underflow back into the rotor. This creates a flushing action and permits the use of a rotor nozzle size sufficiently large to prevent clogging.

FIGURE 17 Horizontal section of a current type of purifier

2. The Starcosa channel separator, which involves the nonturbulent flow of starch dispersion over dividing plates for the purpose of separating the heavier fine fibres from the lighter starch water dispersion.

Preliminary drying by centrifugation

At higher production levels in larger factories, technical and economic reasons have led to the adoption of a system in which concentrated slurries of pure starch are concentrated or thickened by mechanical means to a moisture content of 35 40 percent before drying by evaporation. Mechanical dewatering is generally performed in dewatering centrifuges. although continuously working vacuum filters are also used. especially in combination with modern tunnel driers.

The centrifuges for this purpose are of the basket type, as shown in Figure 18, equipped with a perforated bowl lined with a filter of cloth, small-mesh wire netting or the like. The starch is fed by batches as a slurry of 23B; during centrifuging, the water is removed through the filter and the starch settles on the bowl wall in the form of a cylindrical cake. Some fine fibre and dirt always cover the inner surface of the cake and are scraped off before discharging the batch. Cassava starch, like other fine-grained starches, has properties allowing it to form a very firm sediment in the bowl, which is difficult to clear by hand or even with a mechanical clearing device. The most

useful form of centrifuge is thus equipped with an exchangeable set-in which permits removal of the whole batch of starch after centrifuging. Vertical positions on the ground plate of the set-in facilitate the discharge.

In general, centrifugal drying, which brings down the moisture content to about 40 percent, is linked up with some form of evaporation drying in a continuous process. While a great variety of such driers are available in commerce only a few which are especially suited to the drying of starch will be described here.

DRYING

The removal of free water from the starch sediment obtained in settling tanks and on flour tables or from the concentrated slurries produced by separators and purifiers can be partly accomplished by mechanical means (e.g., centrifugation). The final drying. however. must always be performed by evaporation, either in the open air (sun drying) or in ovens. In modern factories, oven drying is always combined with mechanical drying, the whole operation, as in all other phases of the process, being conducted so as to take the least possible time.

Sun drying

As the sun is the cheapest source of heat, all small mills and many medium-size factories resort to this kind of drying despite the problems and the risk of contamination involved. The flour cake left after draining in the sedimentation tank or on the flour table is scooped up and after crumbling (sometimes with the aid of coarse matting or a wire screen) is spread out on basketwork trays about I m in diameter. Each tray is covered with as much of the wet product as contains some 0.5 kg of dry starch. The trays may be placed on the ground itself, but preferably should be laid on racks 1 m above the ground (Fig. 19). In this way, besides direct radiation, the heat reflected from the ground aids drying while the circulation of air is ensured on both sides of the layer of flour.

It is preferable to begin the drying process soon after sunrise so that in fair weather and a dry atmosphere it can be completed in one day. Often, however, this does not suffice, and before sundown the trays are stacked up on the factory premises. During the night, evaporation continues slowly, aided by the retained sun warmth, and is completed the next day in the open air. In the course of drying, a number of workers continually crumble the lumps of starch on the trays to speed up the drying. The crude flour is considered sufficiently dry when the remaining lumps are too hard to be crumbled by hand. The moisture content is then between 15 and 20 percent.

An important advantage of sun drying is the bleaching action of the ultraviolet rays. At

the same time, however, a certain chemical degradation sets in, ultimately having an unfavourable influence on the quality of the product. Besides, contamination by dust cannot be entirely avoided during sun drying, especially on windy days; a lowered whiteness and the occurrence of "specks" will result. Finally, the baskets have to be cleansed regularly with a solution of bleaching powder, in order to prevent contamination by microorganisms. Even then, the baskets are subject to rapid wear and have to be replaced frequently.

Given sufficient space and the necessary number of baskets (about 5 000), a daily output of 2 tons of dry flour may be realized with sun drying. Of course, in cases like this, the manufacture would gain very much in efficiency and stability if drying were accelerated and concentrated in a smaller space by the use of ovens. At medium production levels ovens are rarely used, however, because both the installation and use of ovens, apart from the initial expense and the cost of fuel, require some engineering knowledge. Until now a completely satisfactory solution of the drying problem for medium-size factories has not been found. Rather primitive oven driers are used here and there, whereas factories with a somewhat higher daily output employ chamber and drum driers. The latter two types, applied in the manufacture of baked tapioca products, are described below.

Drying ovens

The simplest type of oven consists of a firing tunnel of brickwork covered with galvanized iron or copper plates on which the moist flour is spread in a thin layer. Firing should be moderate, so as to keep the temperature of the plates well below the gelatinization point of the starch, and the flour should be frequently raked up. The space above the oven should be vigorously ventilated. In Malaysia and other parts of the Far East, ovens called "drying yards," about 30-40 m long and 3-5 m wide are used for the drying of cassava starch. Enough wood is burned in the tunnel to heat the cement surface to the required temperature (see Fig. 20). The number of drying yards ranges from two to five, depending on the size of the factory and the kinds of products.

FIGURE 21. Sectional view of a chamber drier

Chamber drier

The chamber drier consists of a number of adjoining compartments with insulated walls, each one equipped with heating, ventilating and control devices. The wet material is placed on the trays. which are either directly introduced into the chamber drier or loaded on a trolley that is pushed into the drier. The process can be rendered more economic in this kind of drier by a system of air circulation. In a model drier, the air current produced by the screw fan is warmed by a heating element and moves

across the material to be dried, giving off heat while taking up water vapour from the moist flour (Fig. 21). Through the adjustable slot a small part of the circulated air is discharged from the chamber, and at the same time a corresponding quantity of fresh air is drawn in from the outside, whereas the main air current recommences the cycle as described above. A considerable reduction of the drying time can be obtained by the insertion of air-guiding surfaces which effect an equalization of the air speed over all the trays.

Although drying in this apparatus takes relatively much time and labour, it is easy to handle and for that reason suitable for medium-size factories producing limited quantities of flour.

Drum driers

Probably the simplest arrangement for the continuous drying of flour is a horizontal or inclined revolving drum, heated from the outside, into which the moist flour is fed at one end. During transport inside the drum, which may be accomplished by various mechanical means, the product gives off its moisture to a stream of ventilating air (Fig. 22). In applying direct fire or steam the usual precautions against overheating have to be taken.

Bell driers

These represent an efficient form of continuous drier, combining a high capacity with a simple construction, which does not necessitate supervision by skilled workers. Here the starch is carried along on a series of conveyor belts, one on top of the other, in a stream of hot air. Moist starch is shed onto the top belt and conveyed over the whole length of the construction; at the end it drops on to the belt below, which is driven in the opposite direction, and so on. With each drop from a belt to the one below, the starch is turned over and ventilated. Heaters such as steam pipes are fixed between the belts and effect a rapid evaporation, the water vapour being removed by the upward draft.

Tunnel driers

The manufacture of a uniform product of definite moisture content is best ensured with modern tunnel driers in which the moist starch is carried on a conveyor belt through a tunnel divided into compartments forming drying zones. The circulating air is kept at a definite temperature, and moisture content in each zone is automatically controlled by conditioning devices. The flour is sucked up by vacuum from a concentrated slurry on a revolving cloth sieve with a cake-scoring device and a spring discharge. The starch cake, containing 40 percent water on the wet basis, is discharged

in small broken strips directly to the travelling bed of the drier, where it encounters gradually changing drying conditions. The flour is discharged at the other end of the tunnel with a moisture content of about 17 percent, in the form of very loose agglomerations which are easily crumbled and bolted. The drier, 2.5 m wide and 10 m long and divided into four zones, has a capacity of 15 tons of dry flour per 24 hours.

Pneumatic driers

Another type of drier is the pneumatic flash drier. The starch cake is led from the basket centrifuge by a warm conveyor to a pneumatic drier, where the final moisture content is reduced to 10-13 percent. Drying is effected by hot air produced by a set of oil burners working on the atomized burning principle and compressed air. The required quantities of fresh air are sucked into the hot air generator through an air filter and heated to about 150C. During the drying process the starch is pneumatically conveyed from the bottom to the top of the drier and then deflected downward.

Starch particles which are not quite dry are returned to the drying unit located at the bottom, while the dry starch is separated in the cyclone from the conveying air and led through a rotary pocket seal into a starch powder sifter.

FINISHING AND PACKAGING

Bolting

Crude dry cassava flour consists for the greater part of hard lumps of starch. As it is useless for most purposes in this form, it has to be subjected to a pulverizing process followed by dry-screening. The latter operations are often referred to as bolting.

As a bolting installation is remunerative only where production is relatively high, smaller enterprises do not as a rule install their own equipment for the purpose. Often, however, a number of small mills deliver their crude flour to a central bolting factory, which at the same time may function as a trading concern for the finished product. In these central installations bolting is carried out as in medium-size and larger cassava factories, while at the same time definite "brands" are composed by mixing.

At the medium production levels it pays to have simple bolting machines, in which the flour is crushed between rolls. The apparatus, if necessary, can be driven by hand.

Roller bolting The crude flour is shed into a hopper placed above a pair of rollers turning in opposite directions at the same speed. The agglomerations of starch are broken up by the action of the rollers, but fibre and other tough particles are left intact. The crushed flour is subsequently received in a conical rotary screen of the

same construction used for wet-screening and described previously. Here the small lumps which have escaped crushing, fibre and other foreign particles are separated from the starch by a screening gauze 100 to 200 mesh/inch. The dry pulp discharged is fed back into the hopper once more. The rolls and the revolving screen are coupled to the same motor, which in an emergency may be replaced by a hand-driven crank.

Roller bolting is a relatively slow process and has therefore been superseded by disintegrator bolting. Recently, however, the particular advantage of the roller process - its relatively mild crushing action - has been combined with a greater speed of working in new machinery with a system of grooved rollers.

Bolting by disintegrators At present. most medium and all larger factories are equipped with beater disintegrators for the bolting process. In the disintegration action not only the starch lumps hut also here and other foreign material are pulverized and forced through screen plates of 100 mesh/inch or finer. as desired. If the starting material was of questionable purity. the resulting flour may contain appreciable amounts of nonstarch material. which cannot be separated easily. The power consumption of these disintegrators is between 10 and 20 hp depending on the amount of flour that needs to be disintegrated per hour: the working speed is some 1 200 rev/mint

The arrangement of the equipment is similar to that for roller bolting. As much starch is strewn during the operation. the disintegrator and rotating screen are housed in wooden chambers provided with windows for the discharge of the bolted flour which can be closed by shutters or a thick cloth when in operation.

Storing and packaging

The finished starch should he stored in a dry place. preferably on a board floor or in bins. where it can he mixed in order to obtain a uniform lot.

Before storing, the starch is sifted to assure lump-free uniform particles. It is usually packaged in gunny sacks for shipment, but multiwall paper bags are becoming more popular. A modern sifting and bagging machine is shown in Figure 23.

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Extraction of starch from dried cassava roots

A limited quantity of the cassava imported into Europe in the form of chips and dried sliced roots is manufactured into starch. The dried roots are cleaned, washed and grated and the starch is separated by cylindrical sieves; however, this practice is costly and the starch produced is of inferior quality for the following reasons:

(a) The brown skin, which contains chlorophyll and coagulated proteinous substances, adheres strongly to the ligneous tissues. While it is easy to remove this skin from the fresh roots, it is very difficult to remove it from the dried roots and, therefore, the starch of dried roots is always dark.

(b) The nitrogenous substances are found in a colloidal state enveloping the starch granules in the pulp slurry of the fresh roots. It is easier to separate these nitrogenous particles in the pulp slurry of fresh roots than in dried roots.

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3. Baked tapioca products

The baked products for which cassava flour is the basic ingredient are known commercially as tapiocas or tapioca fancies. In Malaysia and some other areas these

products are commonly known in the industry as sago products. The term probably originated with the Chinese production of sago-palm starch products. The manufacture of tapioca fancies is a logical follow-up of the production of the flour itself in the countries of origin. Separation of the processing of the flour and of the derivatives would be illogical. Many medium-size and larger factories are also equipped for the manufacture of such baked products as flakes, seeds, pearls, and grist.

These products are made from partly gelatinized cassava starch obtained by heat treatment of the moist flour in shallow pans. When heated, the wet granules gelatinize, burst, and stick together. The mass is stirred to prevent scorching. They are manufactured in the form of irregular lumps called flakes or of perfectly round beads 16 mm in diameter known as seeds and pearls (Figs. 24-26). The grist is a finer-grained product obtained by milling gelatinized lumps, and siftings and dust are residual products of the manufacture of seeds and pearls.

Preparation of wet flour

The raw material for baked products is the flour scooped up from sedimentation tanks or tables after the supernatant, or excess water, has been drained and the "yellow"

flour scraped off. Clearly the use of moist starch, an intermediate stage in the processing of the Dour, is economically advantageous.

Only very white first-quality flour can be used in the manufacture. To obtain this, sulfurous acid is often added in the first sedimentation. This chemical should, however, be washed out as completely as possible by a second sedimentation in clean water; any traces of the acid left in the flour tend to spoil the quality of the end product. It is strongly advised not to use active chlorine preparations in this case, as they influence the agglomeration of the starch into pearls and other forms in an unfavourable way.

The cake of moist flour, containing about 45 percent water, is broken up by a small mill, spades or pressing it through frames strung with steel wire spaced about 10-20 cm apart, after which the lumps are rubbed through a screen of about 20 mesh/inch to produce a coarse-grained moist flour.

At this stage the flour is ready only for gelatinization and the production of flakes; to prepare pearls and seeds, the small aggregates of moist starch should be subjected to a process of building up and consolidation. which gives them the size and cohesive strength desired for the further treatment. The operation is known by the Indonesian name as the gangsor method. A portion of the moist starch is put into a long

cylindrical bag of twill cloth which is held at each end by one man. Together. with a rhythmical strong jerking movement, they throw the mass of starch lumps from one end of the hag to the other (Fig. 27). After a few minutes of this treatment the irregular lumps have grown into beads of varying size and have gained in firmness. Another portion of the moist flour is added and the gangsoring is continued. the operation being repeated until the heads have grown more or less to the desired size. Depending on the skill of the worker. the size of the starch balls is fairly uniform. Curiously enough, the knack of gangsoring is achieved only by a fraction of all workers, so the operation should be classified as skilled labour.

In Malaysia the flour is fed into open, cylindrical rotating pans about 0.9 m in diameter and 1.2 m deep (Figs. 28, 29). During rotation the starch grains are forced to adhere together in the form of small particles or beads. The resulting product depends on the speed and the length of time of rotation.

After gangsoring, beads of the right size are sorted out by screening between plates with circular holes corresponding to the required dimensions (Fig. 30).

Gelatinization

In gelatinizing, starch undergoes a radical alteration in molecular arrangement, with a concomitant change in properties. From a practically insoluble product of semicrystalline structure it becomes an amorphous substance, miscible with water in any proportions at sufficiently high temperatures, giving viscous solutions which after cooling set to a semisolid elastic mass: a jelly, or gel.

This process may be brought about by the action of chemicals or by heating in an aqueous medium; only the latter case is of interest here. The onset of gelatinization is characterized by a loss of granular, structure which also promotes swelling; both processes can easily be followed under a microscope. With cassava starch, gelatinization sets in at about 60C, and the process is completed at about 80C. The point of gelatinization depends to a certain extent on granule size, the smaller granules being more resistant to swelling.

In the manufacture of baked products, the treatment is kept at a moderate temperature so as to cause gelatinization only in the surface layer of the lumps of moist starch. The product obtained therefore consists of agglomerations of practically raw starch enclosed by a thin layer of the tough and coherent gelatinized form.

For flakes, gelatinization is performed in shallow pans about 60-90 cm in diameter and 20-25 cm deep, having the profile of spherical segments, which are placed in holes on

a brick oven and heated on a moderate fire. In order to prevent burning the starch, and perhaps also as an aid in achieving an end product of the desired lustre, the pans are wiped beforehand with a towel soaked in an edible oil or fat. Shorea (tenkawang fat) or Bassia (illipe fat), having properties approaching those of cocoa butter, seem to be preferable for the purpose, but groundout oil is used as well. Furthermore, it is necessary to rake the mass continuously with large forks, both to prevent burning and to ensure uniform gelatinization. From time to time a sample of the flakes is tested for toughness until proper consistency is attained.

The hand-baking process can also be applied in the manufacture of pearls and seeds, but rather irregularly shaped beads are obtained, inferior in colour and in other qualities.

Better mechanical methods for obtaining a first-rate product have long been known. In one of these, gelatinization is performed with the direct application of steam. The starch beads are poured onto plates in a rather thick layer, the plates forming a conveyor belt which is slowly drawn through a tunnel charged with steam. In this way, uniform gelatinization is ensured.

A device widely used in Indonesia (Java), which combines the advantages of several other methods, consists of a hollow cylinder revolving on rollers and driven by motor

via a suitable transmission, all resting on a foundation which at the same time serves as a hearth with fire-holes. Flanges on the rollers hold the revolving drum, which is inclined at an angle of about 10. The raw beads are poured into a gutter at the higher end of the drum at such a rate that they spread into a single layer by the time they reach the hotter parts of the inner surface of the drum. The width of this flow of beads need not exceed 15 cm if the drum has a diameter of 80 cm and revolves at 8-10 rotations per minute. A suitable length for the drum is 4 m. In rolling down, each bead covers the same long, screw-shaped path across the inner drum surface, and in the hotter regions a gradual gelatinization sets in, the rotation of the drum preventing overheating. By the rolling movement, moreover, the surface of each bead is uniformly gelatinized and at the same time becomes perfectly spherical in form.

Drying

The gelatinization process in the hand-worked flakes changes the moisture content of the product by no more than a few percent, and the same applies to the steam-treated pearls and seeds. In the drum described above, drying sets in parallel with the gelatinization and may be promoted by ventilating the drum, but the removal of water here is also incomplete.

Thus, in general, a final drying after gelatinization is necessary in order to bring down the moisture content to the desired level of about 12 percent. Drying in this case is best accomplished in chamber driers of the circulating type. For instance, in a chamber drier for pearls and seeds the initial temperature should not exceed 40"C lest further gelatinization and bursting of the beads set in. Toward the end of the treatment the temperature may be raised to 60-70C. With efficient exhausters, drying may be completed in 1 1/2-2 hours. Normally, from 16 tons of moist starch, 10 tons of the dried product are obtained.

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4. Cassava products for animal feeding

Cassava products have long been used for animal feeding. Large quantities of cassava roots and cassava waste are utilized in the cassava-producing countries for this purpose. Imports of dried cassava roots and meal into European markets for the supply of the compound feed industry are also increasing.

Chips

This is the most common form in which dried cassava roots are marketed and most

exporting countries produce them. The chips are dried irregular slices of roots which vary in size but should not exceed 5 cm in length, so that they can be stored in silos. They are produced extensively in Thailand, Malaysia, Indonesia and some parts of Africa.

PROCESSING CASSAVA C HIPS

The present method of processing chips in Thailand, Malaysia and some other countries is very simple, consisting in mechanically slicing the cassava roots and then sun drying the slices. The recovery rate of chips from roots is about 20-40 percent. However, the products are considered inferior in quality by some quality-conscious feedstuff manufacturers, although many others consider them satisfactory.

Preparation of the roots

When the roots are not sorted, peeled and washed, the chips are usually brown in colour and have a high content of fibre sand and foreign objects as well as hydrocyanic acid. Trimming, peeling and washing the roots in a similar manner as for the processing of cassava flour are recommended in order to produce white chips of superior quality.

Slicing or shredding

The roots are shredded in a special machine, which is usually made locally. The machine consists of a rotating notched cutting disk or knife blades mounted on a wooden frame equipped with a hopper as shown in Figure 31. The cassava roots are cut into thin slices and pieces as they pass through the machine.

Drying

Sun drying is used mostly where the sliced roots are spread out on drying areas, or concrete floors of various dimensions. Experiments in Madagascar showed that the concentration of chips during drying should not exceed 10-15 kg/m2, the required drying area space being about 250 m2 for each ton per day of dried roots produced.

To produce good quality chips the roots must be sliced and dried as quickly as possible after harvest. The chips should be turned periodically in the drying period, usually two or three sunny days, until the moisture content reaches 1315 percent. The chips are considered dry when they are easily broken but too hard to be crumbled by hand. The thickness of the slices also has an effect on the quality of chips. Thick slices may appear dry on the surface when their internal moisture content is still high.

When rain threatens during the drying process, the chips are collected by hand or by a tractor into piles under a small roof. Interrupted sun drying affects the quality of the finished chips and pellets. When the semidried chips are wet again by rain, they become soggy and upon completion of drying lose their firm texture. In rainy regions, where continuous sun drying is difficult, some form of artificial heat drying is required.

Broken roots

Similar to chips in appearance, but generally thicker and longer, they are often 12-15 cm long and can jam the mechanism of handling equipment. They are produced mainly in Africa where local processors prefer to produce longer roots because of the domestic demand mainly for products suitable for human consumption, as cassava is part of the staple diet. Once processed into chips the product becomes inedible, and the producer wants to conserve the local market.

Pellets

The pellets are obtained from dried and broken roots by grinding and hardening into a cylindrical shape. The cylinders are about 2-3 cm long and about 0.4-0.8 cm in diameter and are uniform in appearance and texture.

The production of pelleted chips has recently been increasing as they meet a ready demand on the European markets. They have the following advantages over chips: quality is more uniform; they occupy 25-30 percent less space than chips, thus reducing the cost of transport and storage; handling charges for loading and unloading are also cheaper; they usually reach their destination sound and undamaged, while a great part of a cargo of sliced chips is damaged in long-distance shipment because of sweating and heating.

Pellets are produced by feeding dried chips into the pelleting machine, after which they are screened and bagged for export. The powdered chips which fall down during pelleting are re-pressed into pellets and the process is repeated. There is usually about 2-3 percent loss of weight during the process.

Meal

This product is the powdered residue of the chips and roots after processing to extract edible starch. It is generally inferior in quality to chips, pellets and broken roots, has a lower starch content and usually contains more sand. The use of cassava meal in the European Economic Community has declined with a shift to the other cassava products during the last few years. However, there will remain some demand for this

product, especially by smallscale farmers who produce their own feedstuffs. since it does not require grinding and thus can be readily mixed with other ingredients.

Residual pulp

During the processing of cassava flour, the residual pulp which is separated from the starch in the screening process is used as an animal feed. It is usually utilized wet (75-80 percent moisture content) in the neighbourhood of the processing factory but is sometimes sun dried before it is sold. This product is considered a by-product of the cassava starch industry and represents about 10 percent by weight of the cassava roots.

The approximate analysis of this product (dry matter) is as follows:

	Percent
Protein	5.3
Starch	56.0
Fat	0.1
Ash	2.7

Fibre	35.9
TOTAL	100.0

5. Cassava starch factories

The profitability of any cassava factory depends primarily on the following conditions:

(a) year-round availability of cassava roots of the desired quality in sufficient quantity;
(b) presence of abundant water with the needed qualities;
(c) reliable power supply;
(d) transportation facilities both for the roots and the end products;
(e) availability of capital and labour.

Small and medium-size factories are more frequently found in rural regions with a rather dense agrarian population, numerous streams, and at least one highway to a not too distant commercial centre.

Power

In the small and medium-size factories the only processes consuming a considerable amount of energy are rasping of the roots and, where a bolting installation is present, crushing of the crude dry flour. At the lowest production levels the manufacture can, therefore, be effected entirely by hand; the larger rural mills, however, have recourse to running water as the chief source of power

A rasper and eventually a rotating screen can be driven by a simple waterwheel about I m in diameter, constructed of hardwood and revolving on an iron shaft. The mill is set up preferably near a riverside or brook. At some point upstream, water is led off into a channel of suitable size. The amount of water running in the channel before reaching the waterwheel is regulated by the operation of lock gates.

Above a certain production level, depending on various factors, the energy consumed by the rasper, rotating screen, disintegrators (in bolting installations) and accessory equipment (such as pumps) is such that it is more advantageous to employ a diesel engine or an electric motor. In modern factories located near cities, power for industrial purposes can usually be purchased from the local power station at reduced rates. In the factory, a small stand-by engine generator is recommended for use in the event of power failure.

Water

Apart from its use as a source of power, the availability of ample pure water is of the utmost importance in processing cassava flour. During the greater part of the process, the starch granules are in contact with water which, besides the soluble constituents of the roots, contains all the substances originating from the water added in wet-screening of the pulp and in sedimentation. The deleterious effect of crude suspended matter in the water used (turbidity from clay, etc.) will be obvious. Moreover, starch in its natural state acts as a moderately strong absorbent of electrolytes and colloidal matter in solution. As a result, any ions in the water, even if present in small concentrations, are apt to be accumulated in the granules, thus influencing the outward appearance and the physicochemical properties of the flour.

Iron ions have a particularly bad effect in this respect because, apart from being strongly adsorbed, they tend to fix hydrocyanic acid, a normal component of cassava, in the form of dark-coloured compounds. In larger factories specializing in the production of first-rate flours, therefore, even the use of iron in piping and other equipment should be avoided where contact with the flour milk is possible.

Smaller factories, as a rule, will resort to spring water for processing, on account of its greater purity as compared with river water. Not infrequently, pure water is obtained from springs in the neighbourhood of rivers or artesian wells, so that both kinds of water can be used together. River water, crude or cleared in a sedimentation tank, is

used for washing the peeled roots; and spring water or artesian water, which needs little filtration, is used in contact with the flour in processing. If only river water is available, it may be used after sufficient purification.

The daily consumption of water for processing required by small rural mills is no more than a few cubic metres. A simple pit in which river water is left standing may suffice to obtain pure water.

An improved system of water purification is illustrated in Figures 32 and 33. River water enters one of the two cement cisterns communicating at the base. The water in the second tank rises slowly through a bed of filtering material - for instance, some sprigs covered with a layer of pebbles. A very efficient filtering bed is obtained from a material available in most tropical regions - the fibre from the leaf-sheath of the sugar palm (Arenga saccharifera), in Java called injuk or indjuk. On account of its peculiar texture this material is not easily clogged and retains most suspended matter. However, in filtering, ordinary sand may serve equally well.

WATER PURIFICATION INSTALLATION FOR CASSAVA PROCESSING (Plan)

WATER PURIFICATION INSTALLATION FOR CASSAVA PROCESSING Vertical cross section.

A small-scale factory using sedimentation tanks for its flour milk consumes about 1.5 m3 of water for 100 kg of fresh roots; hence, the tank should be able to provide the necessary water for a production level of about 2 tons of dry flour per day.

Purification may be aided by chemical means - for example, by the addition of a little aluminium sulfate (alum) - but this is not a widespread practice. A particularly useful and economical aid for cleansing the process water is the cultivation of certain floating water-plants in the purification tanks, principally the following tropical species: Eichornia crassipes, Utricularia spp., Salvinia auriculata and S. cacculata. Suspended clay and other material collect on the hairy roots of these plants. Application is not restricted to small-scale factories; large factories often have their vast purification tanks covered with this kind of vegetation. The ion exchange process is applied in some modern factories to reduce the mineral content of water used for the purification of starch as well as for steam boilers.

A suitable outlet must exist also for the resulting waste water of the factory. Very often this waste water is not allowed to drain off into the public sewage system without purification.

Types of factories

Cassava processing can perhaps best be outlined in the form of the layouts of or other data on existing factories belonging to each of the three production levels (small, medium, and large) which have been taken as a basis for classification.

LAYOUT OF A SMALL MILL

In such mills the work is performed entirely with simple hand-driven tools or at the most a waterwheel as a source of power. These factories, as a rule, do not produce more than 200 kg of crude, unbolted flour a day; if run by a family, the daily production is generally not more than 100-120 kg.

A small factory with a daily output of about 200 kg of dry flour functions as follows. Water is drawn off from a brook, dammed up for the purpose, by the channel leading to a waterwheel. The rotation of the wheel is transmitted via the flywheel and a belt to the rasper which is mounted in the rasping table with seating bench. The roots are peeled and dumped into the basin, where they are washed with clean water from a feed pipe, after which they are transferred to the rasper. The pulp obtained by rasping is transferred to the washing basins, where it is washed thoroughly with spring water or purified river water. The flour milk runs into the settling tanks.

After settling, the fruit liquor is let off through a drain, joining the wash water from

the roots and the water from the channel on its way to the river. The moist flour is conveniently dried near the factory on racks in the open, and the packing of the crude dry flour and other related work are performed in a small shed. The waste pulp is worked up in factories like this one; it is dried in the sun and sold to a bolting factory together with the crude flour.

LAYOUT OF A MEDIUM-SIZE FACTORY

In these factories the installation of an electromotor or diesel engine of about 20 hp raises the production capacity to a level of about 5 tons a day, principally on account of more efficient rasping. The other operations also change somewhat in character as compared with the small-milL methods, but they are the same in principle and little skilled labour is needed. The power supply mentioned above is sufficient to drive one mechanical rasper. In many instances, however, the factory includes a bolting installation, which, in general, is driven alternately with the rasper, and the factory produces an assortment of finished flours: in this case a somewhat larger power supply (at least 25 hp) is necessary. Factories of this kind are very suitable for rural areas where unskilled labour is comparatively cheap but technical equipment and skill are difficult to procure.

Both small mills and medium-size factories. in general, have to buy their roots from

landowners in their neighbourhood. On account of many economic and social factors the supply often lacks stability and continuity. Consequently, the possibility of production planning is slight, and this is perhaps the most important factor limiting the size and output of such factories. In areas where farmers or farmer organizations have more advanced ideas, where they are commercially minded and combine in rural industrial enterprises to process their own agricultural product, the supply of roots can be organized to the great economic benefit of all concerned.

Figures 34 and 35 show the main elements of a typical medium-size factory with a capacity of 2-3 tons of dry flour per day. The arrangement and dimensions, given m centImetres, are those recommended by an expert with long practical experience. Figure 34 shows vertical sections of the arrangement through the axis of the rotating screen (above) and perpendicular to this axis (below). The peeled roots are stored in basin A, washed in basin B, and transferred from the latter basin to the rasper (C), mounted on a rasping table (L in Fig. 35). A 20-hp diesel engine (H) coupled to the pump (G), which supplies water from the well (F), drives both the rasper (at 800 rev/min) and the rotating screen (at 120 rev/min) via the transmission gear (1). The flour milk passes from the rotating screen (D) to the flour table (E), which has a slope of about I percent.

FIGURE 34. MAIN ELEMENTS OF A TYPICAL MEDIUM-SIZE CASSAVA-PROCESSING

FACTORY(Vertical sections).

FIGURE 35. MAIN ELEMENTS OF A TYPICAL MEDIUM-SIZE CASSAVA-PROCESSING FACTORY (Horizontal sections).

LARGE OR ESTATE FACTORIES

By starting with a sufficiently large investment of capital, it is possible to overcome the limitations mentioned above and reach at once production of the order of 40 tons of dry flour a day. Manufacture at this level presupposes that a continuous sale is secured with the dextrin industry, one of the industries using cassava starch. Supplying cassava for specific industrial purposes, however, in turn places definite demands on the flour mills, which can be summed up as the demand for a regular supply of an assortment of flour of specific and constant quality. Clearly, this demand will be met only when the factory can rely on adequate raw material - roots - from its own extensive plantations where a selected strain of cassava is grown. On this level only, appropriate machinery for purification and more elaborate techniques are coming into their own, to save labour, minimize losses, and so process more economically.

Division into three classes of factories is, of course, arbitrary: medium-size factories may have fairly modern machinery, such as centrifuges for the preliminary drying of

the flour, whereas a much larger factory may be limited to rather out-of-date methods of drying. Still, as a rule, each operation in processing the flour is carried out in a form characteristic of the particular class in the above classification of factories.

The processing operations in different types of factories are illustrated in the following flow sheets and diagrams. Figure 36 shows an example of the operations used in a small to medium-size cassava starch factory in Malaysia. The equipment and methods of manufacture are mostly old-fashioned. Figure 37 shows an example of the processing operations in a medium- to large-size factory in Thailand. Most of the equipment is modern and the production is mostly prepared for export. Figure 38 shows a diagram of the operations of a large factory with modern equipment proposed for Nigeria.

FIGURE 36. Flow diagram of operations in an old-fashioned small to medium-size processing factory.

FIGURE 37. Flow diagram of operations in a modern medium to farce processing factory.

FlGURE 38. Flow diagram of operations proposed for a large modern processing factory.

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Establishment of a cassava starch factory

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The following economic study is for the establishment of a modern cassava starch factory with a capacity of 24 tons of dry starch per day. The study includes the estimated required investment and working capital for the establishment and the operation of the factory as well as the estimated operating costs and the expected profitability of the project (see Tables 6-9).

The factory is supposed to be established in a tropical region where all basic industrial requirements such as water, power, transportation facilities and raw materials are available.

The total investment in such a factory is estimated at $736 340 and the working capital

is estimated at $142 000 for the operation of the factory for a period of three months. The project is expected to give annual profits of $108970, which is equivalent to 14.8 percent of the estimated invested capital.

TABLE 6. - ESTIMATED TOTAL CAPITAL INVESTMENT FOR THE ESTABLISHMENT OF A CASSAVA STARCH FACTORY (24 TONS PER DAY)

	U.S. dollars
Land (5 acres; 2 ha)	1000
Buildings	
Site preparation	5 000
Buildings for processing, storage, office, laboratory, garage, repair shop	90 000
Corrugated steel sheet construction for gates and fence around plant	5 000
	100 000
Process equipment	
Cost of equipment (see Appendix 5)	410 000

Installation (20 percent of cost of equipment)	84000
Engineering and design (10 percent of total cost)	59400
Start-up expenses	15 000
	568 400
Contingency (10 percent of total cost)	66940
Total plant investment	736 340

The factory is supposed to be supplied with modern equipment known to have the highest production efficiency. Together with the use of suitable cassava varieties, the industrial yield of starch extraction exceeds 24 percent. In this study, however, a moderate rate of extraction of 23 percent is used.

The cost estimates for equipment and other materials are based on previous studies (e.g.: Grace, Wabby & Eriksen, 1970; Little, 1964) and on quotes from some equipment suppliers. The cost of fresh cassava roots at $9.35 per ton represents the average price in Malaysia in 1969. The estimated wages are based on the highest levels paid in some tropical countries and include all prerequisites, such as annual leave, and medical and social contingencies.

	U.S. dollars per year
Unskilled labour	400
Semiskilled labour	500
Skilled labour	1000
Foremen	1500

TABLE 7. - ESTIMATED REQUIREMENTS OF LABOUR, SALARIES AND WAGES[1] FOR A CASSAVA STARCH FACTORY (24 TONS PER DAY)

	Cost per year	Total
	Dollars	
Management		
1 Manager	12 000	
1 Assistant manager	8 000	
1 Mechanical superintendent	6 000	
1 Technical supervisor	6 000	

4		32 000
Indirect labour		
1 Agent for roots supply	2400	
4 Office clerks	4000	
3 Guards (semiskilled labour)	1800	
2 Unskilled workers for grounds	800	
10		9 000
Direct labour		
1 Processing technician	4 800	
1 Quality-control technician	4 800	
3 Foremen for processing shifts	4500	
2 Foremen for maintenance and transport	3 000	
21 Skilled workers for processing operations	21000	
11 Skilled workers (drivers, mechanical and electrical maintenance)	11000	

13 Unskilled workers for processing	5 200	
11 Unskilled workers for maintenance and transportation	4 400	
63		58 700
Total		99 700

[1]Includes fringe benefits.

TABLE 8. - ESTIMATED OPERATING COST AND WORKING CAPITAL FOR THE PRODUCTION OF CASSAVA STARCH (24 TONS PER DAY)

	U.S. dollars	
Raw materials		
Fresh cassava roots @ $9.35 per ton (31 300 tons per year)		292 650
Operating supplies and utilities		
Fuel and diesel oils	20000	
Power at $3/kWh	25 000	

Packaging materials at $40/100-kg bags	28 800	
Maintenance supplies (3 percent of equipment cost)	12 300	
General supplies		
		89 100
Operating labour		
Salaries and wages including all benefits		99 700
Sales expense ($2 per ton)		14400
Local taxes and insurance (1 percent of plant investment)		7 400
Depreciation (10 percent on equipment and 2 percent on buildings)		64 600
Total cost per year		567 850
Estimated working capital (3 months' operating cost at full capacity)		142 000

TABLE 9. - ESTIMATED PROFITABILITY OF A CASSAVA STARCH FACTORY (24 TONS PER DAY)

	U.S. dollars

Total estimated sales of products		
Cassava starch @ $78 per ton (7 200 tons per year)	561600	
Waste or refuse (local markets) at $35 per ton . .	115 500	
Total estimated operating cost		677 100
		-567 850
		109 250
	Percent	
Net estimated annual profits		
Profits per invested capital	14.8	
Profits per operating cost	19.2	
Profits per working capital	76.8	

The sales price of cassava starch and refuse is estimated at $78 per ton for starch (f.o.b. price for export) and $35 per ton for refuse, as was reported in 1967 in Thailand. Refuse is extensively used, in the dry or wet state, as animal feed.

OPERATIONAL FIGURES

The factory is designed to operate continuously, three shifts per 24 hours, for 300 days per year. The total capacity is 24 tons per day or 7 200 tons per year of high-grade cassava starch with a moisture content of 10-12 percent.

Total fresh roofs required per year	31 300 tons
Total area required for cassava cultivation	3 100 acres (1 255 ha)
Power consumption per year	838 800 kWh (116.5 kWh per ton of starch)
Waler consumption per year	496 800 m3 (69 m3 per ton of starch)
Diesel oil for the trucks	approx. 110 m3 (24 000 gal)
Fuel oil for steam generator	approx. 320 m3 (70 000 gal)

6. Utilization of cassava products

Cassava in the human diet

Cassava is sometimes classified as a crop for developing countries and for consumption only by rural people, whereas the large crop of cassava grown annually in the tropics is actually consumed in all its forms at nearly all income levels. Originally the cassava tuber was a main food crop only in South America. Nowadays, however, it is grown as a substitute for rice or alternately with rice on extensive acreages in regions where, for centuries, rice has been the sole food crop.

In many tropical countries cassava as the principal source of carbohydrates occupies much the same position in the diet as potatoes in parts of the temperate zones. The cassava tuber is not a balanced food, consisting as it does largely of starch (Table 10); nonetheless, it is the most remunerative of crop plants in the hot climates, yielding perhaps more starch per hectare than any other cultivated crop with a minimum of labour.

During the Second World War, cassava assumed tremendous importance as a famine crop in many parts of the world, especially when rice supplies were cut off. Leaves and lender shoots are used in many tropical areas as a cooked vegetable or in sauces, as they are rich in vitamins and have a high protein count.

MAIN CONSTITUENTS AND NUTRITIONAL VALUE

A comparison of the chemical composition of cassava tubers and some products derived from it (gaplek and tapioca flour) with that of potatoes and rice, as presented in Table 10, may convey an impression of the relative nutritional value of cassava. (It should be borne in mind that only the peeled root is edible.)

As cassava is inferior in protein and fat content to both rice and potatoes, animal protein or products such as soybeans are often used to balance the diet in cassava-consuming lands.

TABLE 10. - NUTRIENTS IN CASSAVA ROOTS COMPARED WITH OTHER FOOD PRODUCTS

	Calories per 100g	Protein	Fat	Carbohydrate	Ash	Moisture	Fibre
	Percent						
Cassava tubers (peeled)	127	0.8-1.0	0.2-0.5	32	0.3-0.5	65	0.8

Gaplek	355	1.5	1.0	85	0.8	15	
Tapioca flour	307	0.5-0.7	0.2	85	0.3	15	0.5
Potatoes	89	2.1	0.1	20	1.0	77	0.7
Potato flour	331		0.3	82	0.3	15	0.4
Husked rice	347	8.0	2.5	73	1.5	15	0.7- 1.0

Cassava also compares rather unfavourably in vitamin content with other food products, as is shown in Table 11.

Besides starch, the cassava tuber contains some soluble carbohydrates, i.e., glucose and sugar, which can be inverted. These convey a pleasant sweet taste to the tubers of the nonpoisonous strains. The amount in the peeled root is 1-3 percent of total dry matter only, but it rises notably at the age of 16-18 months when the starch content is beginning to decline. The soluble carbohydrate content of the peel is larger - 5-10 percent of the dry matter - and it eventually makes up one fifth of the total carbohydrate content.

TABLE 11. - VITAMINS IN CASSAVA ROOTS COMPARED WITH OTHER FOOD PRODUCTS

	Vitamin A	Vitamin B	Vitamin C
	I.U./100 g		mg/100 g
Cassava tubers (peeled)		10	20
Gaplek		10	
Tapioca flour			
Potatoes	40	30-80	13- 15
Potato flour			
Husked rice		100-150	

These soluble carbohydrates naturally are lost in processing the tubers for starch; they may play an important role, however, in the preparation of fermented food products from cassava.

The nutritive deficiencies of cassava need not be a cause for concern when it is consumed with other supplementary foods. However, the so-called "cassava problem" as related to the "kwashiokor disease" means that persons with low incomes are prone to consume it in excessive quantities because it supplies sufficient calories and

gives a feeling of satiety in their diet; therefore, many suffer from a deficiency of protein and/or of vitamins.

Although the cassava tuber may be consumed in the raw state, it usually needs preparing in order to become palatable and digestible and, above all, to eliminate the poisonous prussic acid. This may be accomplished in several ways, thus obtaining various products which are traditional food items in the areas where cassava has long been well known. Some of these have to be consumed immediately; others may be kept for a considerable time and constitute a valuable food reserve.

RAW AND COOKED CASSAVA FOR IMMEDIATE CONSUMPTION

In the raw state the roots of the sweet varieties are used as a forage without being peeled. In the Philippines their suitability in hog feeding has been amply demonstrated in experiments.

The fresh, peeled root of the same varieties is suitable for human consumption, provided it is no more than a few months old, but it is seldom used as such. It cannot be kept for more than a day. The roots of the sweetest varieties are sometimes eaten raw as a between-meals snack or thirst quencher.

With simple cooking the root becomes equivalent to potatoes, though its taste is considered "heavier." Prussic acid in the fresh root is destroyed by slowly cooking the sliced roots, starting with ample cold water so that gradual heating ensures hydrolysis of the toxic principle. If the roots are submitted to fierce heat, thereby destroying enzyme action, a possibility of the retention of bound prussic acid exists, which in the bitter varieties may be dangerous. With the same reservation, steaming and especially frying in oil are recommended, as both these methods produce palatable foods.

In Indonesia, roots are often wrapped in leaves after covering them with a yeast preparation; fermentation for 24 hours suffices to produce a soft and slightly alcoholic side-dish.

Many food dishes using cassava, boiled or baked, as the basic ingredient to which is added meat, fish, soybean cake, shrimps or other protein source are prepared in various countries (e.g.: Krubub, Ketela and fish or prawn crackers in the Far East; Sancochado, Escabeche, Seco de Carnero, Sebiche and Pachananca in South America).

CONSERVED CASSAVA PRODUCTS

Gaplek

The simplest method of conservation consists of drying the sliced root in the sun; in the tropics this takes two or three days. Once dry, gaplek is sufficiently durable; during drying, however, it is particularly liable to mould, making it unsuitable for human consumption. Before the Second World War, the milled product (gaplek meal) was an important export from Indonesia to Europe for animal fodder.

Gaplek meal finds some application in those starch-using industries where the high content of moulds, fibre, and other constituents of the whole root can raise no serious objection, as in textile finishing and the manufacture of alcohol. As it is easy to maintain a large stock of gaplek, there would therefore be obvious advantages in using it as a basic material for the production of pure cassava starch. In Indonesia this use has presented no serious technical difficulties; however, it has never been applied on an important scale.

Farinha and cassava bread (couac)

A somewhat more elaborate treatment of the root than is needed for the production of gaplek leads to conservable food products which seem to be known only in Latin America and play an important role in nutrition there. It is interesting that this mode of preparation is usually combined with the traditional manufacture of crude cassava flour at the domestic level.

The roots, cleaned superficially, are first peeled with a knife and then grated. The most primitive grater, used by South American Indians, consists of a board upon which a number of little flints are embedded in a thin layer of wax. Graters consisting of a wooden board with wooden teeth are also in use. In somewhat more developed areas this work is done with a rotating rasp, usually hand-driven, which does not differ very much from the raspers in rural mills elsewhere.

When a sufficient amount of the rasped material has been collected, it is packed in leaves and pressed under a heavy stone, sometimes with the aid of pole leverage, or in a wooden screw-press. The traditional instrument in

Latin America for this purpose, however, is a basketwork cylinder known as the tipiti, which is specially woven so that it can take both a long and thin as well as a short and bulky form. In the latter form the basket is packed with fresh cassava pulp and hung from the bough of a tree, the "sock" being pulled until it is long and thin. This operation subjects the pulp to considerable pressure, thus extracting the greater part of the possibly poisonous juice.

The pulp obtained may be worked in two ways. In the preparation of farinha it is mixed for better quality with a little pulp which has been left to ferment for three days. The whole is then pounded and rubbed through a sieve, producing a slightly

damp meal.

It is then heated, in the open air, in a pan on a flat oven with a top consisting of granite slabs which guarantee even heat without burning. The pulp is turned continuously with a wooden rake during 3 to 4 hours of baking, which produces a granular, only slightly roasted product. If dry, farinha will keep indefinitely. It is an excellent cereal, usually eaten like rice in combination with other foods, especially meat and gravy, but it is also very useful as an emergency ration for travellers. It is known as farinha de mandioca or farinha de mesa.

By heating the pulp more intensively, without stirring, until the mass is slightly brown on one side, it sets into a solid slab. After baking on both sides, the cakes are further dried in the sun, and in this state will keep indefinitely. This cassava bread, or couac, is very hard, but it has an excellent flavour: it is usually eaten after being dipped in gravy.

In rural factories producing farinha or couac, generally only part of the pressed cake of cassava pulp is worked up to produce these products. The rest, in portions, is washed out in a cloth above a wooden bowl, each portion being stirred with successive amounts of water until most of the starch has been extracted. The bowl containing the starch milk is put aside for settling. After some time the water is decanted, and the

starch spread in the sun on reed matting. In two days it is dry. The flour obtained, of low to medium grade, is commonly used in Brazil for making cakes.

In Brazil also, the peeled roots are cut into large chunks and dried. The dried product is ground, sifted and the flour, known as farinha de raspa, is mixed with wheat flour in the making of bread, macaroni, crackers, etc.

Gari

A popular food among the low-income groups in west Africa and Nigeria, it is made by fermenting grated cassava tubers, semidextrinizing the mash by heat and finally drying the product to a type of meal. In rural areas, the roots are peeled and grated, and the pulp is put into a large cloth bag and set in the sun to drain and to ferment. When the pulp is sufficiently dry, it is removed from the sack for final drying on a low fire. Fermentation liberates the hydrocyanic acid at low pH and develops the characteristic flavour of gari. It is carried out first by cassava bacteria (Corynebacrerium manihot) that attack the starch with the production of lactic and formic acids, and then by a fungus (Geotricium candida) that acts when the pH has fallen to about 4.2, increasing the acidification and producing the characteristic aroma. Hydrogen cyanide is liberated during fermentation through the spontaneous hydrolysis of the cyanogenic glucoside of cassava at a low pH value. Many attempts are being made in Nigeria to mechanize

gari production under hygienic conditions as well as to fortify this low-nutrition food with a protein additive.

Cassava rice (landang)

Similar in properties to these products is landang, or cassava rice, a popular food in the Philippines. Landang retains much of the protein of the cassava root. It is used in the Philippines as a substitute for rice or maize. It may be kept for six months before being attacked by moulds.

This product is prepared by shredding the tubers and pressing the grated mass in a cloth until most of the juice is squeezed out. By whirling the mass in a winnowing basket, pellets are formed, their size determined by the speed of the motion and the moisture content. Pellets of more or less uniform size are isolated by sifting, steamed and then dried in the sun for some days. Alternatively, the tubers are soaked in water in earthenware jars (contact with metal should be avoided) until after five to seven days they begin to soften. Then they are macerated, the fibre is removed by hand and the mass is air dried before being made into pellets in the way just mentioned.

In India the production of a synthetic rice based on cassava has recently been started.

Cassaripo or tucupay

Nowadays the squeezed juice obtained during the preparations mentioned above is mostly thrown away. In South America, however, there is an ancient belief that the juice contains many valuable nutrients.

The method used is to concentrate the juice by means of evaporation, and then add various spices, including chilliest The resulting sauce, which is very similar to a soybean sauce, is called cassaripo or caslup in the West Indies and tucupay in Brazil. If sufficiently concentrated, it may be kept indefinitely. In the cooking process any content of prussic acid is destroyed; in fact, the bitter varieties of cassava give the best cassaripo. In the West Indies, cassaripo (West Indian pepper pot) is used in the conservation of fish or meat, in which case, however, it should be reboiled daily. It is to be regretted that this preparation is out of use now and even totally unknown in countries which are in great need of nutritional condiments.

Pastes

Various forms of heavy cassava pastes are made by pounding the fresh or boiled roots into a very smooth mass which is eaten as a vegetable loaf with an oily sauce. Examples of these products are the fufu of Ghana, the dumbot of Liberia, the atiek of

Ivory Coast, the bami of other areas.

New vegetable cheese product

The relative absence in cassava of essential food components, particularly protein, which makes it a cause of malnutrition, has led to the investigation of various methods of adding protein and other nutrients to this basic food. The Tropical Products Institute in London has undertaken studies of yeast culture on cassava and a vegetable cheese is made by the nutritional enrichment of cassava through fermentation. The process consists of fermentation of a cake of extruded cassava dough to which mineral salts are added with a spore inoculum of a selected strain of Rhizopus stolonifer. Crude protein levels have been raised from 0.1 to 4.0 percent, and the vegetable cheese product is acceptable for direct use in cooking.

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Cassava starch and its uses

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The flour produced from the cassava plant, which on account of its low content of noncarbohydrate constituents might well be called a starch, is known in world trade as tapioca flour. It is used directly, made into a group of baked or gelatinized products or manufactured into glucose, dextrins and other products.

Starchy foods have always been one of the staples of the human diet. They are mostly consumed in starch-bearing plants or in foods to which commercial starch or its derivatives have been added. The first starch was probably obtained from wheat by the Egyptians for food and for binding fibres to make papyrus paper as early as 4000-3500 B.C.

Starches are now made in many countries from many different starchy raw materials, such as wheat, barley, maize, rice, white or sweet potatoes, cassava, sago palm and waxy xaize. Althbugh they have similar chemical reactions and are usually interchangeable, starches from different sources have different granular structures which affect their physical properties.

Starch and starch products are used in many food and nonfood industries and as chemical raw materials for many other purposes, as in plastics and the tanning of

leather. Nonfood use of starches - such as coating, sizings and adhesives - accounts for about 75 percent of the output of the commercial starch industry.

In many industrial applications, there is competition not only among starches from various sources but also between starches and many other products. Resin glue has largely replaced starch in plywood because of its greater resistance to moisture; resin finishes are used in the textile industry and natural gums compete with starches in paper making. Nevertheless, the continuous development of new products has enabled the starch industry to continue its expansion. The growth of the starch industry in the future appears to be very promising, providing the quality of products and the development of new products permit them to compete with the various substitutes.

FOOD INDUSTRIES

The food industries are one of the largest consumers of starch and starch products. In addition, large quantities of starch are sold in the form of products sold in small packages for household cooking. Cassava, sago and other tropical starches were extensively used for food prior to the Second World War, but their volume declined owing to the disruption of world trade caused by the war. Attempts were made to develop waxy maize as a replacement for normal noncereal starches; but the

production of cassava starch has increased considerably in recent years.

Unmodified starch, modified starch and glucose are used in the food industry for one or more of the following purposes:

(a) directly as cooked starch food, custard and other forms;

(b) thickener using the paste properties of starch (soups, baby foods, sauces and gravies, etc.);

(c) filler contributing to the solid content of soups, pills and tablets and other pharmaceutical products, fee cream, etc.;

(d) binder, to consolidate the mass and prevent it from drying out during cooking (sausages and processed meats);

(e) stabilizer, owing to the high water-holding capacity of starch (e.g., in fee cream).

Bakery products

Although starch is the major constituent of flours, the art of' bread baking depends to

a large extent on the selection of flour with the proper gluten characteristics. Starch is used in biscuit making, to increase volume and crispness. In Malaysia, cassava starch is used in sweetened and unsweetened biscuits and in cream sandwiches at the rate of 5-10 percent in order to soften zyestexture. add taste and render the biscuit nonstickv. The use of dextrose in some kinds of yeast-raised bread and bakery products has certain advantages as it is readily available lo the yeast and the resulting fermentation is quick and complete. It also imparts a golden brown colour to the crust and permits longer conservation.

Confectioneries

In addition to the widespread use of dextrose and glucose syrup as sweetening agents in confectioneries. starch and modified starches are also used in the manufacture of many types of candies such as jellybeans. toffee. hard and soft gums, boiled sweets (hard candy). fondants and Turkish delight. In confectioneries. starch is used principally in the manufacture of gums. pastes and other types of sweets as an ingredient, in the making of moulds or for dusting sweets to prevent them from sticking together. Dextrose prevents crystallization in boiled sweets and reduces hvdroscopicity in the finished product.

Canned fruits, jams and prederves

Recent advances in these industries include the partial replacement of sucrose by dextrose or sulfur-dioxide-free glucose syrup. This helps to maintain the desired percentage of solids in the products without giving excessive sweetness, thereby emphasizing the natural flavour of the fruit. The tendency toward crystallization of sugars is also decreased.

Monosodium glutamate (MSG)

This product is used extensively in many parts of the world in powder or crystal form as a flavouring agent in foods such as meats, vegetables, sauces and gravies. Cassava starch and molasses are the major raw materials used in the manufacture of MSG in the Far East and Latin American countries. The starch is usually hydrolyzed into glucose by boiling with hydrochloric or sulfuric acid solutions in closed converters under pressure. The glucose is filtered and converted into glutamic acid by bacterial fermentation. The resulting glutamic acid is refined, filtered and treated with caustic soda to produce monosodium glutamate, which is then centrifuged and dried in drum driers. The finished product is usually at least 99 percent pure.

The production of commercial caramel

Caramel as a colouring agent for food, confectionery and liquor is extensively made of

glucose rather than sucrose because of its lower cost. If invert sugar, dextrose or glucose is heated alone, a material is formed that is used for flavouring purposes; but if heated in the presence of certain catalysts, the coloration is greatly heightened, and the darker brown products formed can be used to colour many foodstuffs and beverages.

Uniform and controlled heating with uniform agitation is necessary to carry the caramellization to the point where all the sugar has been destroyed without liberating the carbon.

THE GLUCOSE INDUSTRY

According to Whistler and Paschell, Abu Mansur, an Arabian teacher and pharmacologist, about 975 A.D. described the conversion of starch with saliva into an artificial honey. In 1811 Kirchoff discovered that sugar could be produced by the acid hydrolysis of starch. Glucose, or dextrose sugar, is found in nature in sweet fruits such as grapes and in honey. It is less sweet than sucrose (cane or beet sugar) and also less soluble in water; however, when used in combination with sucrose, the resulting sweetness is often greater than expected.

The commercial manufacture of glucose sugars from starch began during the

Napoleonic Wars with England, when suppliers of sucrose sugar were cut off from France by sea blockade. Rapid progress was made in its production in the United States about the middle of the nineteenth century.

At present, glucose is usually produced as a syrup or as a solid. The physical properties of the syrup vary with the dextrose equivalent (DE) and the method of manufacture. Dextrose equivalent is the total reducing sugars expressed as dextrose and calculated as a percentage of the total dry substance. Glucose is the common name for the syrup and dextrose for the solid sugar. Dextrose, sometimes called grape sugar, is the D-glucose produced by the complete hydrolysis of starch.

Starch hydrolysis

Two methods for starch hydrolysis are used today for the commercial production of glucose: acid hydrolysis and partial acid hydrolysis followed by an enzyme conversion.

Acidification is the conversion of starch into glucose sugar by acid hydrolysis. This operation is carried out in batches or a continuous process. In the first process, the starch slurry, 20-21Be, is mixed with hydrochloric acid (sulfuric acid is sometimes used) to bring the pH to around 1.8-2.0 in a steam converter and heated to about 160C until the desired DE is reached. The continuous process, which is replacing the batch

process, involves feeding the mixture of starch slurry and hydrochloric acid into a tubular heat-exchanger. The time and temperature of the process are adjusted to the desired DE in the end product.

In the next step, neutralization, the acidified mixture is neutralized with sodium carbonate or soda ash to remove the free acid and bring the pH value to 5.0 7.0. Sodium chloride is formed in the syrup in small quantities as a result of the neutralization of the hydrochloric acid by the sodium carbonate and remains in solution.

Refining follows. Some solids - impurities, precipitated protein and coagulated fat - can be removed by centrifugal separation. Impurities will depend largely on the starch used and its purity. The solution is then passed through filters (filter presses or candle-type ceramic filters).

The clear brown filtrate is decolourized by passing it through tanks of activated carbon, which removes colours and other impurities from the solution by surface adsorption but has no effect on the sugar.

Refining can be done by ion-change resins instead of activated carbon or combined with it. A recent development is to refine the converted liquor by electrodialysis, and

the final glucose syrup is very superior.

Concentration is the final step. The refined syrup is concentrated under vacuum in batch converters or continuous heat exchangers until the concentrated syrup reaches 80-85 percent solids or 43 45B. Commercial glucose syrups are sold according to the Beaum standard, which is a measure of the dry substance content and specific gravity.

Glucose syrup is transported in drums or in bulk road or rail tanks. It should not be stored in large quantities for long periods of time because its colour may deteriorate.

In the acid-enzyme process the starch slurry is treated by acidification, neutralization and filtration as in the acid hydrolysis process and then is fed into the enzyme converter. The temperature and pH are adjusted to the optimum conditions and the enzyme is added with slow agitation. The time of conversion depends on the initial dextrose equivalent obtained by acid hydrolysis, the type and strength of the enzyme and the final DE required. After the conversion has been completed, the enzyme is rendered inactive by raising the temperature and adjusting the pH, and the converted syrup is then refeed and concentrated in the same manner as in the acid-converted glucose syrup.

The use of certain enzymes results in DE values as high as 98-99 which means a higher

yield of dextrose from starch, or nearly complete conversion of starch into dextrose. When acid is used as the hydrolyzing agent, the DE of the conversion liquor, however, reaches only about 92 because a certain degree of polycondensation takes place and some of the yield of dextrose is lost owing to the acidity and high temperatures required for the conversion.

The production of dextrose

At present most of the dextrose in commerce is prepared in the form of pure dextrose monohydrate by a combined acid-enzyme process. The hot, thick glucose syrup with a concentration of 70-80 percent dextrose is run from the evaporator into crystallizing pans. Crystal formation is largely controlled by the quantity of dextrins left with the glucose. The separation of crystals from the syrup is carried out in centrifugal separators and the impurities are left in the mother liquor. Crystalline dextrose is then dried in rotary hot-air driers under vacuum and bagged in moisture-proof materials.

Recrystallization of dextrose will yield practically 100 percent pure dextrose crystals which are used as a pharmaceutical-grade sugar.

The starch used in the manufacture of glucose syrup must be as pure as possible with a low protein content (particularly soluble protein). In this respect, cassava starch can

be preferable to other starches.

There is an increasing interest in manufacturing glucose syrup directly from starchy roots or grains rather than from the separated starch in order to save on capital investments for the production and purification of starch from such raw materials.

The starch conversion industry (glucose and dextrose) is the largest single consumer of starch, utilizing about 60 percent of total starch production. Glucose syrup and crystalline dextrose compete with sucrose sugar and are used in large quantities in fruit canning, confectioneries, jams, jellies, preserves, ice cream, bakery products, pharmaceuticals, beverages and alcoholic fermentation.

The functional purpose of glucose and dextrose in the confectionery industry is to prevent crystallization of the sucrose; in the bakery products industry it is to supply fermentable carbohydrates; and in the ice-cream, fruit-preserves and similar industries it is to increase the solids without causing an undue increase in the total sweetness, thus emphasizing the natural flavour of the fruit, and also to prevent the formation of large ice crystals which mar the smooth texture.

In general, glucose and dextrose are used in the food industry as a partial or complete substitute for sucrose. The use of dextrose has increased in recent years in the food-

processing industries.

Cassava in composite flours

In many developing countries bread consumption is continually expanding and there is increasing dependence on imported wheat. Most of these countries, however, grow staples other than wheat that can be used for bread. Some grow various starchy tubers such as cassava, yam or sweet potatoes and some others grow cereals such as maize, millet or sorghum. It would therefore be economically advantageous for those countries if imports of wheat could be reduced or even eliminated and the demand for bread could be met by the use of domestically grown products instead of wheat.

The Composite Flour Programme initiated by the Food and Agriculture Organization of the United Nations in 1964 was conceived primarily to develop bakery products from locally available raw materials, particularly in those countries which could not meet their wheat requirements. Although the bakery products obtained were of good quality, similar in some of their main characteristics to wheat-flour bread, the texture and palatability of the composite-flour bakery products were different from those made from wheat flour. Bread made of nonglutenous flour has the crust and crumb structure of cake rather than bread and may not be considered acceptable by people

who are accustomed to conventional bread.

The light, evenly structured bread made of wheat flour and the characteristic soft crumb are due to the swelling properties of wheat-flour gluten in water. If pure starch from another cereal or tuber is used, the product is considerably more rigid and its texture is irregular because gases are insufficiently retained in the dough. Therefore, when starches that do not contain gluten-forming proteins are used, a swelling or binding agent must be added during the preparation of the dough to bind the starch granules (i.e., egg white, gums, glyceryl monostearate).

Efforts have been made in many countries to produce bread by conventional methods from wheat flour to which other flours such as cassava flour were added. It was generally found that the upper limit of such an addition was about 10 percent as the quality of the resultant bread was rapidly impaired beyond this limit of nonwheat flour content. However, recent experiments have shown that it is possible to increase the level of the nonwheat flour considerably without too great a change in the bread characteristics, provided certain bread improvers such as calcium stearyl lactylate are added or a relatively high percentage of fat and sugar is used. Bread of acceptable quality was obtained by the use of 30 percent of either cassava or corn (maize) starch and 70 percent wheat noun

Experiments made by the Institute of Food Technology in Rio de Janeiro show that 10 percent flour and 5 percent cassava or corn (maize) starch can be added to wheat flour of only medium strength (9-11 percent gluten) and made into a dough containing only I percent shortening which can be baked into loaves of as good quality and appearance as those of the respective wheat-flour samples.

Other experiments in some countries have been undertaken to make bread from nonwheat flours alone or mixed with wheat flour. Flours included cassava flour and cassava starch and sources of proteins included full-fat and defatted oilseed flours such as cottonseed, soybean and groundnut, as well as fish meal. In addition, binding agents, water, salt and sugar were used. The proportion of the protein source to starch was varied so as to ensure a protein content of 1820 percent in the composite flour. Results of using nonwheat flours alone suggested that the combination of cassava flour and cassava starch could be used in bread-making and that bread made from cassava flour and defatted soybean flour was of good quality. From the nutritional point of view, the protein quality of both the cassava-soya and the cassava-groundnut breads was higher than that of common wheat bread. In general, as in normal bread-making, the results depend on different factors operating in the bread-making procedure and the quality of the raw materials.

In India, a new product called tapioca macaroni was developed by adding a small

percentage of specially prepared groundnut meal and wheat semolina to cassava flour. The mixture is processed, cooked and consumed in the same way as foodgrains. The protein content is comparable to that of wheat (about 10 percent) and the macaroni is nearly twice as nutritious as rice.

The Food and Agriculture Organization has lately considered it desirable to investigate the possibility of making bread and similar bakery products of raw materials derived from starchy tubers and defatted oilseeds. An agreement was made between the Organization and some well-known research institutions to study this possibility. The following experiments have been realized:

> **(a) Development of a bread made from nonwheat materials at the Institute of Grain, Flour and Bread (TNO), Wageningen, the Netherlands.**
>
> **(b) Development of a bread with partial replacement of wheat flour at the Tropical Products Institute, London.**

MECHANICAL LEAVENING

Mechanical leavening of bread doughs is fast replacing conventional fermentation systems. This process offers the advantages of simplification, elimination of bulk

fermentation and better uniformity of dough consistency besides the possibility of utilizing weaker flours and starches with wheat flour. The Chorleywood Bread Process, adopted in 1961, is used to produce the highest proportion of all the bread consumed in the United Kingdom.

Experiments carried out by the British Arkady Co. Ltd., using mechanical leavening rather than bulk fermentation for the ripening of the dough and a blend of 60 percent wheat flour, 30 percent cassava starch and 10 percent soybean flour, produced a bread of good quality almost equal to the normal wheat-flour bread in volume, appearance and eating quality.

Several FAO-operated UNDP/SF projects concerned with the use of composite flours in bread-making have been realized. Bakery products made from composite flours of wheat (at least 75 percent) and potato, maize and cassava have been developed by an experimental bakery in Campinas, State of So Paulo, Brazil. (Other projects involving the use of flours other than cassava flour in bakery products have been carried out in Niger, Senegal and Sudan.) The report of a joint FAO/UNDP mission in Colombia recommended the establishment of an experimental bakery to determine the suitability of locally available raw materials for the production of bakery products from composite flours (e.g., cassava/soybean). The project was executed with FAO participation under a bilateral agreement between Colombia and the Netherlands.

NUTRITIONAL VALUE OF COMPOSITE FLOURS

The nutritional value of bakery products made from composite flours was assessed in 1965 by the Central Institute for Nutrition and Food Research, (Utrecht, Zeist), where the nutritional value of cassava/soya bread and cassava/groundnut bread was compared with the protein quality of common wheat bread. It was concluded that the protein quality of both breads was higher than that of common wheat bread. The cassava/soya bread topped the other two breads in protein quality, while the cassava/groundnut bread was slightly superior to common wheat bread.

In 1969 at the Queen Elizabeth College, London, breads produced at the British Arkady Co. Ltd. were assessed. They were made from various composite flour mixtures consisting of wheat flour, cassava starch, soya flour, millet and sorghum flour and fish-protein concentrate in various proportions with mechanical leavening. Results indicated that the protein value of the original bread had not been impaired by supplementation, but showed improvement.

Prospects for commercial production and widespread consumption of bread made of composite flours in different countries will depend upon local acceptance (taste and characteristics of the bread) and the price at which the bread will be available to the public.

Food habits are primarily based on socioeconomic and other conditions rather than on scientific considerations. Changes in established habits can take place gradually through public education and the spread of knowledge.

Cassava in animal feed

Cassava is widely used in most tropical areas for feeding pigs, cattle, sheep and poultry. Dried peels of cassava roots are fed to sheep and goats, and raw or boiled roots are mixed into a mash with protein concentrates such as maize, sorghum, groundnut or oil-palm kernel meals and mineral salts for livestock feeding.

In many tropical regions, the leaves and stems of the cassava plant are considered a waste product. However, analytical tests have proved that the leaves have a protein content equivalent to that of alfalfa (about 17-20 percent). Feeding experiments also showed that dehydrated cassava leaves are equivalent in feed value to alfalfa. Imports of dehydrated alfalfa in the Far East, mainly in Japan, have reached about 240 000 tons a year. Therefore, a large potential exists for the exportation of dehydrated stems and leaves of cassava.

In Brazil and many parts of southeast Asia, large quantities of cassava roots, stems and

leaves are chopped and mixed into a silage for the feeding of cattle and pigs. This use of cassava is increasing.

Cassava, similar to feedgrains, consists almost entirely of starch and is easy to digest. The roots are, therefore, especially suited to feeding young animals and fattening pigs. Many feeding experiments have shown that cassava provides a good quality carbohydrate which may be substituted for maize or barley and that cassava rations are especially suitable for swine, dairy cattle and poultry. However, cassava cannot be used as the sole feedstuff because of its deficiency in protein and vitamins, but must be supplemented by other feeds that are rich in these elements.

The amount of cassava and its products fed to animals as scraps in the tropical regions must be fairly large, but there is no way of estimating it. Barnyard fowls, goats and pigs probably consume cassava roots and leaves regularly in many parts of the tropics, but a true livestock feeding industry based on cassava has been developed only in very few areas.

In the European Economic Community the highly developed compound animal-feed industry uses dried cassava roots as an ingredient, and large quantities of cassava chips, pellets and meal are imported into these countries for this purpose. The composition of a compound animal feed varies according to the animal (cattle, pigs or

poultry) as well as to the kind of production (dairy, meat or eggs).

There are many constituents which can be used to supply the main elements in compound feed, such as starch, protein, fat, minerals and vitamins. In general, oil cakes are the main ingredients in the feedstuffs for cattle, while feedgrains are the most important for pigs and poultry. Cassava products were long used as a raw material for compound feedstuffs until their use declined after the Second World War, when grains became cheaper than cassava products in Europe. When grain prices rose again, cassava products were once more used extensively. The maximum content of cassava products in compound feedstuffs is officially set in many countries. In the Federal Republic of Germany, it varies according to the type, but is generally as follows: 10-40 percent for pigs, 20-25 percent for cattle and 10-20 percent for poultry; in the Netherlands and Belgium, however, the figures are much lower.

At present many large manufacturers are equipped with electronic computers to determine the composition of compounds in terms of feed values and price.

Nonfood uses

Starch makes a good natural adhesive. There are two types of adhesives made of

starches, modified starches and dextrins: roll-dried adhesives and liquid adhesives.

The application of cassava in adhesives continues to be one of the most important end uses of the product. In the manufacture of glue the starch is simply gelatinized in hot water or with the help of chemicals. For conversion into dextrin it is subjected separately or simultaneously to the disintegrative action of chemicals, heat and enzymes.

In gelatinized starch adhesives, quality requirements are such that the medium-quality flours can be used. In dextrin manufacture, the demands are much more exacting: only the purest flours with a low acid factor are acceptable. Cassava dextrin is preferred in remoistening gums for stamps, envelope flaps and so on because of its adhesive properties and its agreeable taste and odour.

Dextrins were accidentally discovered in 1821 when during a fire in a Dublin (Ireland) textile mill one of the workmen noticed that some of the starch had turned brown with the heat and dissolved easily in water to form a thick adhesive paste.

Three primary groups of dextrins are now known: British gums, white dextrins and yellow dextrins.

British gums are formed by heating the starch alone or in the presence of small amounts of alkaline buffer salts to a temperature range of about 180220C. The final products range in colour from light to very dark brown. They give aqueous solutions with lower viscosities than starch.

White dextrins are prepared by mild heating of the starch with a relatively large amount of added catalyst, such as hydrochloric acid, at a low temperature of 80-120C for short periods of time. The final product is almost white, has very limited solubility in water and retains to varying degrees the set-back tendency of the original starch paste.

Yellow dextrins are formed when lower acid or catalyst levels are used with higher temperatures of conversion (150-220C) for longer conversion times. They are soluble in water, form solutions of low viscosity and are light yellow to brown in colour.

The following are some of the major uses of dextrins in nonfood industries.

Corrugated cardboard manufacture. **One of the large users of dextrins is the corrugated cardboard industry for the manufacture of cartons. boxes and other packing materials. The layers of board are glued together with a suspension of raw starch in a solution of the gelatinized form. The board is pressed between hot rollers,**

which effects a gelatinization of the raw starch and results in a very strong bonding. Medium-quality flours are suitable for this purpose provided the pulp content is not too high.

***Remoistening gums*. These adhesives are coated and dried on surfaces, such as postage stamps and envelope flaps, for moistening by the user before application to another surface. Cassava dextrins in aqueous solution are well suited for this purpose as they give a high solids solution with clean machining properties.**

***Wallpaper and other home uses*. Various types of starch-based products are used as adhesives for wallpaper and other domestic uses.**

***Foundry.* Starch is used as an adhesive for coating the sand grains and binding them together in making cores which are placed in moulds in the manufacture of castings for metals.**

***Well drilling*. Starches and modified starches mixed with clay are used to give the correct viscosity and water-holding capacity in bores for the exploratory drilling of oil wells or water wells. These starch products are replacing other commercial products for making the muddy materials which are indispensable for drilling wells. For this purpose a coldwater-soluble pregelatinized starch which can be made up to a paste of**

the required concentration on the spot is desired.

***Paper industry*. In the paper and board industries, starch is used in large quantities at three points during the process:**

> **(i) at the end of the wet treatment, when the basic cellulose fibre is beaten to the desired pulp in order to increase the strength of the finished paper and to impart body and resistance to scuffing and folding;**
>
> **(ii) at the size press, when the paper sheet or board has been formed and partially dried, starch (generally oxidized or modified) is usually added to one or both sides of the paper sheet or board to improve the finish, appearance, strength and printing properties;**
>
> **(iii) in the coating operation, when a pigment coating is required for the paper, starch acts as a coating agent and as an adhesive.**

Cassava starch has been widely used as a tub size and beater size in the manufacture of paper, in the past mainly on account of its low price. A high colour (whiteness), low dirt and fibre content, and, above all, uniformity of lots are needed in this instance.

An important new application of starch is in the machine-coating of magazine paper, formerly done exclusively with caseins. There are indications that cassava is particularly well suited to the purpose; however, definite specifications for the starch still have to be worked out.

***Textile industry*. In the textile industry, starches occupy an important place in such operations as warp sizing, cloth finishing and printing. Warp sizing is the application of a protective coating to prevent the single yarns from disintegrating during weaving. The size consists of an adhesive and a lubricant and is generally removed after weaving. Cloth finishing alters the "feel" of the fabric by making it firmer, stiffer and heavier. Cassava starch is also used for cloth printing or producing certain designs in various colours on the smooth surface of a finished fabric. While cassava accounted for about 20 percent of all starch for these purposes in 1937, it has been largely replaced by other starches after the Second World War.**

An exception is the manufacture of felt, where cassava continues to be used exclusively in the finishing process.

***Wood furniture*. Before the Second World War the manufacture of plywood and veneer relied mainly on cassava as a glue. The basic material in this case is gelatinized at room temperature with about double the amount of a solution of sodium**

hydroxide. After prolonged kneading of the very stiff paste in order to give it the required stringy consistency, the glue is applied to the wood with rollers. As the presence of a certain amount of the pulp is useful, medium- to low-quality flours are acceptable or even preferable, although the presence of sand is objectionable.

Since 1945, however, the use of cassava as a glue has declined to second place owing to the increasing success of water-resistant plastics.

Particle board from cassava stalks

As cassava cultivation increases, more stalks will become available for disposal. The Tropical Products Institute, London, has been working on the utilization of the cassava plant. Particle boards could be made from cassava stalks by cutting them into small sections and mixing them with certain resins. The strength of the board can be varied by altering the resin content or the density.

Fermented products

CASSAVA ALCOHOL

Cassava is one of the richest fermentable substances for the production of alcohol. The fresh roots contain about 30 percent starch and 5 percent sugars, and the dried roots contain about 80 percent fermentable substances which are equivalent to rice as a source of alcohol.

Ethyl alcohol is produced from many carbohydrate materials. In Malaysia and some other countries, many factories are equipped to use cassava roots, starch or molasses (by-product of the sugar industry), the type of product depending on the costs of the raw materials. When cassava is used, the roots are washed, crushed into a thin pulp and then screened. Saccharification is carried out by adding sulfuric acid to the pulp in pressure cookers until total sugars reach 15-17 percent of the contents. The pH value is adjusted by using sodium carbonate, and then yeast fermentation is allowed for three to four days at a suitable temperature for the production of alcohol, carbon dioxide and small amounts of other substances from sugar. Alcohol is then separated by heat distillation. The yield of conversion is about 70-110 litres of absolute alcohol per ton of cassava roots depending on the variety and method of manufacture. The crude alcohol of cassava is described as average in quality. It has a disagreeable odour, but can be improved if the first and last fractions in the distillation process are discarded. It is usually utilized for industrial purposes, as in cosmetics, solvents and pharmaceutical products. If the production is required for human consumption, special care should be taken in handling the roots to rid them of hydrocyanic acid.

DRIED YEAST

Microbial protein is attracting growing interest owing to the enormous protein requirements of the world. Among the microorganisms which are considered possible food sources, yeast has perhaps stirred the greatest interest. Candida and saccharomyces yeasts have had a well-established place for many years as feed, and the technology of production, the composition and the nutritive value of yeast are well known.

Most of the production of yeast is based on such low-cost raw materials as waste liquids, wood hydrolyzates and molasses. Starch-rich plant materials from wastes or surplus production are also utilized as substrata for yeast production. Cassava starch and cassava roots are being used in Malaysia and some other countries for the production of yeasts for animal feed' the human diet and for bakery yeast. The starch is hydrolyzed into simple sugars (predominantly glucose) by means of mineral acid or by enzymes. Certain yeasts are then propagated which assimilate the simple sugars and produce microbial cellular substances. The dry, inactive yeast contains about 7 percent moisture and the raw protein content can vary between 40 and 50 percent depending on the raw material.

The yield of yeast production also depends on the raw material. In some applications

of cassava starch conversion into substances obtained from yeasts, a 38-42 percent yield of yeast product containing 50 percent raw protein has been obtained.

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Competitive position of cassava

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Looking back on the many uses of cassava, it may be asked: what are the reasons for its rapid introduction and permanent use in some starch-using industries, while in others it has not gained a place of importance? One explanation is found in the unique properties of this kind of starch.

While full treatment of the colloidal behaviour of cassava is outside the scope of the present paper, the more essential of these properties may be summarized as follows. The product is readily gelatinized by cooking with water, and the solution after cooling

remains comparatively fluid; jellies or puddings cannot be prepared with it. The solutions, moreover, are relatively stable in that they do not readily separate again into an insoluble form, as is the case with corn (maize) starch and potato starch ("retrogradation").

Various factors of lesser importance have also influenced the position of cassava on the market, mainly in a negative sense. Being produced mostly in developing regions with an unstable economic position, it is not available with the same regularity and predictability as, for instance, corn (maize) starch; it is available in many grades and qualities, which are highly variable, and its price, especially in recent years, fluctuates considerably.

It is possible to distinguish three sectors of the starch-using industries, in each of which cassava occupies a fundamentally different position:

(a) Where irreplaceable by other starches.

In the manufacture of remoistening gums cassava has no competitors for the time being. Attention should be called, however, to the continuous efforts to adapt other starches to the special demands of these industries, both by chemical means as well as by the selection of starch-bearing plants. Mention should be made of the so-called

waxy-maize starch, which approaches cassava in many respects.

(b) Where other starches are preferable despite the cost factor.

Some of the more desirable characteristics of other starches may be the result of further processing, as, for instance, in the corn (maize) starch industry. Examples are the thin-boiling, chlorinated and other special starches. Cassava furnishes only a crude starch with a wide range of quality and characteristics.

(c) Where interchangeable with other starches.

In this case, price and marketing conditions are the only controlling factors. Because of severe competition from other kinds of starch, in this field cassava has lost much ground of late.

It can safely be concluded that a market for cassava of all grades will be found for many years to come; however, the possibility of an expansion of its use will depend to a great extent on improved techniques in processing as well as on more efficient methods of marketing the flour.

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7. Quality control of cassava products

In the processing of cassava, questions naturally arise regarding efficiency and output; moreover, in selling the product the determination of quality becomes important. These problems can only be resolved by qualitative and quantitative study of the composition of the raw materials and the properties of the finished products. The financial return, especially in large factories, will depend to a certain degree on such control analyses, which in a way are actually part of the processing itself.

Analysis of basic materials

The two important basic materials requiring analysis are the cassava roots and the water used in processing. The best practical qualitative test of these materials consists in reproducing the whole process on a small scale and judging the resulting flour by comparing it with a standard sample or by analysing it according to the methods described farther on. In fact, for judging the suitability of the water available, small-scale processing is the only test of practical value.

Apart from this, since starch is the substance to be isolated, a determination of the starch content in both the fresh roots and the pulp remaining after rasping and wet-

screening is necessary for control of the efficiency of the process and in particular for determination of the rasping effect.

Finally, tests for the presence of hydrocyanic acid are necessary owing to the important food uses of cassava.

TEST PROCESSING ON A SMALL SCALE

A random sample of, say, 10 kg of cassava is thoroughly washed to remove the cork layer; then either the whole or the peeled roots are grated or ground. The pulp is washed out over 50-mesh bronze gauze and the flour milk obtained over 260-mesh gauze. When the suspension reaches 3 Brix

(approximately 35 g of dry starch per litre), it is left to settle for four hours. The top liquid is then decanted, and water is added to the settled starch to make a slurry of 10 Brix, which is strained over 260-mesh gauze and left to settle for the second time. After decanting, the starch is mixed with water to a thick suspension (45 Brix) and filtered on a Buchner funnel under vacuum. The moist starch is dried in an oven, preferably in circulating air, commencing at a temperature of 50C, and concluding at 60C. The dried starch is sieved through silk before examination.

DETERMINATION OF STARCH CONTENT IN FRESH ROOTS AND WASTE PULP

This analysis is best carried out with oven-dried pulp, a separate sample of fresh, moist pulp being used to determine moisture or water content, or with a sample of the fresh root material.

1. Quantitative determination of starch content is based on hydrolysis with acid and measurement of the resulting glucose. The weighed sample representing about 2.5 g of dried materials is ground and stirred with 250 ml of water for an hour, after which the insoluble residue is transferred to a vessel along with an additional 250 ml of water. After adding 200 ml of 0.5 NHCI, the solution is boiled under reflux and cooled; then the acidity is adjusted to pH 5 with NaOH, and when the solution reaches 250 ml, it is filtered. The glucose equivalent is determined by an aliquot according to the Munson and Walker method or any other suitable method (as described, for instance, in Methods of analysis of the Association of Official Agricultural Chemists, 1956). The amount of glucose multiplied by 0.93 is taken to equal the amount of starch which was in the aliquot.

2. A short-cut in the analysis of fresh roots is possible by determining the water content rather than the starch content. The method is practical especially where the variety of cassava and the growing conditions may be considered practically constant.

The following empirical relation has been established as the result of a series of analyses of roots of four different strains of cassava, all grown on the same soil and during the same period.

Whole root:

Percent starch = percent total dry matter -7.3 = 92.7 - percent water

Peeled root:

Percent starch = percent total dry matter - 6.8 = 93.2 - percent water

Although the constants occurring in the above equations will have to be redetermined for each new set of circumstances, the application of these rules may be of great help in factories lacking chemical personnel and equipment.

3. A simple and inexpensive method for the quantitative determination of starch in cassava roots has been described by Krochmal and Kilbride. During peak seasons cassava tubers are kept in polyethylene bags and stored in a deep-freeze. The frozen samples are sliced and blended with 500 ml of water for five minutes in a blender. The pulp is washed on a sieve with an additional 500 ml of water, and the fibrous material

retained on the sieve is thrown away. The washed material is poured into aluminium pans and dried at about 85C for 6-12 hours until a constant weight is attained. The weight of the residue represents the percentage of starch calculated from the weight of the sample.

Rasping effect

The fraction of the starch in the roots which is set free by rasping may be evaluated directly by washing out a weighed sample of the pulp, as obtained from the factory rasper, on a 260-mesh sieve, collecting the starch on a filter, and weighing it after thorough drying. The percentage of free starch thus obtained divided by the total starch content of the pulp gives the rasping effect (R).

The following method for the determination of R may be preferable in certain respects as it obviates the rather difficult direct determination of the free starch by using only the analysis for starch and fibre content of the roots and the waste pulp produced in processing them.

The roots are analysed for starch using one of the methods described previously and for fibre (cellulose). A sample of the waste pulp obtained in processing the roots is dried in an oven, milled and analysed for the same components. Since the waste pulp

consists substantially of water, cellulose and starch, the percentage of starch can be deduced from the moisture and fibre content. The same holds for the roots, provided the freshly ground mass is washed out in a filter before analysing it.

If the starch contents of the roots and the waste pulp are s_r and s_W respectively and the corresponding fibre contents are f_r and f_W. it is readily seen that the fraction of the starch which remains bound to the fibre (i.e., occluded in cells which have escaped crushing by the rasper) amounts to

$(s_W/f_W)/(s_r/f_r)$

and thus the rasping effect is

$R = (1- (s_f\, f_r \,/\, s_r f_W))$ X 100 percent

PRUSSIC (HYDROCYANIC) ACID ANALYSIS

Qualitative test (Quignard's test)

Prepare sodium picrate paper by dipping strips into I percent picric acid solution and then, after drying, dipping them into 10 percent sodium carbonate solution, thereafter

drying them again. Preserve these strips of paper in a stoppered bottle. Chop finely a small amount of the roots to be tested and put the choppings into a test tube. Insert a piece of moist sodium picrate paper, taking care that it does not come into contact with the root pulp. Add a few drops of chloroform and stopper the tube tightly. The sodium picrate paper gradually turns orange if the root material releases hydrocyanic acid. The test is a delicate one, and the rapidity of the colour change depends on the quantity of free hydrocyanic acid present.

Quantitative determination (alkaline titration method)

Put 10 to 20 g of the crushed root material in a distillation flask, add about 200 ml of water and allow to stand two to four hours, in order to set free all the bound hydrocyanic acid, meanwhile keeping the flask connected with an apparatus for distillation. Distil with steam and collect 150-200 ml of distillate in a solution of 0.5 g of sodium hydroxide in 20 ml of water. To 100 ml of distillate (it is preferable to dilute to a volume of 250 ml and titrate an aliquot of 100 ml) add 8 ml of 5 percent potassium iodide solution and titrate with 0.02 N silver nitrate (I ml of 0.02 N silver nitrate corresponds to 1.08 mg of hydrocyanic acid) using a microburet. The end point is indicated by a faint but permanent turbidity which may be easily recognized, especially against a black background.

Criteria for quality of flour and starch

For a product like starch, which is used as a basic material in many quite different branches of industry, the value of a certain brand greatly depends on the purpose for which it is intended. Quality in cassava can therefore only be defined with reference to the end use. In each industry using the starch, the starting material will be subjected to certain tests in order to determine whether it is suitable for the process concerned. In some cases, a mere superficial test of purity will suffice (when, for instance, it is used as a filler); in others, more elaborate determinations will be necessary. The value of the product in question will thus vary from case to case, and quality as well as price will emerge as a result of these investigations.

In general it can be said that the more careful and clean the manufacture of cassava flour, the higher will be its value for most purposes and thus its quality. There are, however, some exceptions to this rule, as where a flour of medium purity is preferred to one of prime quality. The medium- and off-quality flours have a market comparable in volume to that of the prime-quality flours.

The analysis of cassava flour consists of a group of selected tests, which together provide the best possible general insight into the usefulness of the material. The analysis comprises chemical determinations, such as those of water, pulp and ash, as well as physiochemical tests for the measurement of viscosity and acidity. On the basis of the results of these tests, quality is usually designated in the form of a grade, that is, a cipher expressing the quality in general or, more specifically, in relation to a certain property. The letters A, B and C thus often denote first, medium and poor quality, each classification being bound to specified limits of the properties investigated.

Cassava producers and industrial users have long understood that a universally accepted system of specifications with concomitant grading based on the results of a number of accurately defined tests would do much to stabilize marketing. The first attempt to draw up such a system of specifications was made in Indonesia between 1930 and 1940; it was based upon a series of qualitative and semiquantitative tests which had long been used in commercial circles. Certificates stating the results of analysis of the flour according to this system, notwithstanding its shortcomings, gave buyers in most countries an adequate idea of the quality of the product.

Technical developments in the countries where most of the end-use industries are centred, particularly the United States, led to much more specific and stringent demands regarding certain properties of the flour. Existing specifications soon ceased to cover satisfactorily the relevant features of the various brands of flour. To correct the situation and to adapt the grading of the product more closely to its various

applications, a new system of specifications and grading was drawn up in 1943 by the Tapioca Institute of America (TIA) in close cooperation with most end-use industries. This widely adopted system is given in full in Appendix 1.

The tests to determine the quality of cassava starch include those for mesh size, colour, odour, cleanliness, pulp or fibre content, moisture content, ash, acidity and viscosity of cold flour slurry as well as cooked starch paste. All these tests help establish the grade and therefore the commercial value of the product. The discussion of these quality features will bring out more clearly the significance of the properties involved. For several of these properties alternative methods of determination sometimes give valuable complementary information on the quality of the flour.

MESH SIZE

This test measures efficiency of bolting. Fine pulp, however, obtained from bolting with disintegrators will pass the screens. In judging the purity of a flour, neither this test nor the determination of pulp under the TIA system is sufficiently precise; it is supplemented in a way by the cleanliness test, and an additional determination of pulp content by hydrolysis would seem advisable.

DRY APPEARANCE

In this test the brightness or whiteness of the flour is visually compared with that of a "standard," which is a prime-grade flour produced by certain firstclass factories. The result cannot be clearly expressed by enumeration. Besides, the difficulty of procuring flour of standard whiteness which will keep for a sufficiently long time is an important drawback.

With the many excellent modern types of spectrophotometric apparatus available, however, it would not be hard to devise an objective and accurate quantitative expression for the whiteness of the flour as measured by its reflectivity relative to that of a sufficiently durable standard of whiteness (e.g., barium sulfate). In fact, this method has been adopted in Indonesia. Remarkably enough, comparative experiments in which the same flours were judged by the direct visual method and by the objective reflectivity method have shown that the former test is about as accurate as the latter, provided the observer has enough experience with the visual method and has accustomed himself to the standard of whiteness adopted.

As an independent measure of the purity of the flour, dry appearance has lost much of its significance, but it is still a commercial criterion. It is customary in commerce to estimate the number of specks occurring on a flattened surface of the dry flour as an indication of clean processing.

CLEANLINESS

The following is a somewhat elaborate form of the test for specks which indicates the total amount of foreign particles in a sample. Five millilitres of distilled water are added to I g of dried starch. The mixture is stirred, and then 5 ml of 0.7 N sodium hydroxide solution are added and the uniform gelatinized mixture is examined for impurities. The degree of whiteness and clearness depends on the quantity of pigment, dirt and protein present in the starch.

PULP

The amount of pulp, or fibre, present in the finished product is of foremost importance in deciding the usefulness of a flour in various applications. The presence of insoluble cellulose is a serious hindrance in almost any industry where solutions of gelatinized starch are needed. Exceptions are the manufacture of corrugated cardboard and of plywood where the fibre is useful to a certain extent as a binder.

In the form given in the specification system under consideration, the test makes possible the determination of small amounts of fibre with comparative ease. The sediment volume measured is somewhat dependent on the fineness of the fibre. The presence of a slight trace of fibre, pulp or other impurity can be detected by

microscopic examination of the size and shape of the starch granules.

The actual amount of cellulosic fibre in the flour and of foreign insoluble material can be determined by weighing the residue after a mild acid hydrolysis of the sample. Two to three grams of flour are boiled with 100 mm of 0.4 percent hydrochloric acid for one hour. The liquid is filtered through a weighed filter crucible fitted with filter paper or through a Jena glass filter, G 3. After washing with hot water the crucible is dried at 105" to 110C to a constant weight. One hundred times the gain in weight of the crucible divided by the weight of the test portion is the percentage of fibre and impurities.

It has been found that the determination of fibre content with these two methods runs parallel to a certain extent - that is, a 0.6 percent fibre content by the hydrolysis method corresponds to 10 ml of pulp per 50 g of flour by wet-screening.

A rough estimate of the amount of pulp may be based on the "crunch" of the flour - that is, the sound emitted when a sample, packed tightly in a small bag, is pinched between the fingers. "Crunch" is strong in pure flours, but above a certain pulp content it is lost.

VISCOSITY

Raw starch suspended in water gives rise to more or less viscous slurries. While in some applications the viscosity of these suspensions may be of some technical importance, the term "viscosity of flour" is generally used for the viscosity of a solution of flour after gelatinization, because it is in that form that flour is used in most industries.

Numerous methods are used to determine this property. They differ in the instrument applied in the actual measurement of the rate of flow of starch solutions, and in the method of preparing the starch solutions to be tested. As the comparative test in the present specification system is rather subjective, a few quantitative determinations which have found wide application in the starch industry (particularly cassava) are described below.

Hot-paste viscosity

This is the viscosity measured after the gelatinization of a sample in hot water. The instrument used is an Engler viscometer, which must be operated accurately, for variations in the preliminary treatment of the paste have an appreciable effect on the result. The Engler viscometer consists of two concentric cylindrical copper vessels. The outer vessel (A) filled with water serves as a heating bath. The inner vessel (C) is gilded inside and marked with three indications (a) on a plane perpendicular to the axis of

the instrument. By adjusting screws on the legs of the instrument, the surface of a liquid in the inner vessel can be made to touch these marks at the same time, in this way ensuring an exactly vertical position of the instrument and a controlled level of liquid in the vessel. The outer bath is heated by a ring burner. The vessel (C) can be closed by a lid (D) in which a thermometer (Kl) can be fitted; another thermometer (K2) is placed in the bath. Before measurement the peg (h) is placed in the upper opening of the orifice (b), the actual measuring capillary of very precise dimensions. The liquid to be measured is then poured into the interior vessel to the level indicated by the marks; the lid is put in place, and after a few minutes needed for equalization of the temperature with that of the bath, the peg is removed, and at the same time a stopwatch is started. The flask placed below the orifice is calibrated at 100 and 200 ml; the measurement may be stopped at one of these marks.

FIGURE 39. The Engler viscometer

To determine the viscosity of starch, gelatinization is performed by heating a slurry containing a definite amount of the flour (usually 6 g) in 300 ml of distilled water at a definite rate with constant and not too vigorous stirring. The temperature should reach 100C in six to seven minutes. The solution is then transferred immediately into the inner vessel of the viscometer in the way described above. the water in the outer vessel being kept boiling during the whole determination. The flow of the solution

into the flask is started when the temperature has reached 94C during the measurement it usually rises to 96C, a mean temperature of about 95C prevailing during this period. The time needed for 200 ml (or another definite quantity of the solution) to flow out divided by the time needed for the same amount of water at 20C gives the hot-paste viscosity in degrees Engler. In comparing different samples, the same amount of flour (dry weight) must be

Alkaline viscosity

This is the viscosity of a solution of the flour in a dilute solution of alkali. As a practical test it has the great advantage of being carried out at room temperature.

Detailed instructions are as follows. A sample of dry flour weighing 3 g is suspended in 30 ml of water placed in a beaker 600 ml in volume and 7.5 cm in diameter. The suspension is agitated with a mechanically operated stirrer made from a glass rod which is bent into a zigzag at the lower end, giving a stirring surface of approximately 4.5 cm breadth and 7 cm height. The temperature is adjusted to 27.5C and 270 ml of a I percent sodium hydroxide solution is added. Stirring at 200 revolutions per minute is continued for three minutes from the moment the sodium hydroxide is poured in; the mixture is then left to stand in a bath of 27.5C for 27 minutes; toward the end of this time it is carefully poured into the Engler viscometer, and the flow of the solution is

started after the 27 minutes have elapsed. Thus, the sodium hydroxide is allowed to act upon the flour for exactly 30 minutes before the measurement of viscosity is started. The quotient of the time of flow of the solution (at 27.5C) and that of water (at 20C) is the viscosity (with sodium hydroxide) of the flour in degrees Engler. The results of alkaline and hot-paste viscosity generally run parallel.

The disadvantage of both the quantitative methods described above is that they assess the viscosity of the paste only at a certain point, whereas for many applications it is important to know the variation in viscosity under specific circumstances over a definite period of time. This objection is overcome with the modern recording viscometers, which allow the viscosity values to be followed during a process using hot paste from room temperature up to about 100C at a rate of heating which is automatically controlled; the viscosity can also be recorded at any desired temperature for any additional length of time.

Recording viscomerers

Most models are built on the same principle and some of them are available commercially. They generally consist of a noncorrosive metal cup fitted on an axis coupled to a strong electric motor, giving the cup a slow rotation at a constant speed. The actual measuring instrument, in the form of a rod with side arms, is fixed on a

shaft aligned with the axis of the cup and is suspended in the liquid to be tested. Heating is furnished by the radiation from coils placed in the housing around the cup.

For the measurement of viscosity the cup is filled with a slurry of definite composition at room temperature (25C), and the heating and rotation are switched on simultaneously. The rate of heating is generally controlled at 1.5C per minute. The drag exerted by the contents of the cup on the measuring rod is balanced by a calibrated spring or a counterweight, and the deviation of the rod from its free position is transmitted to a lever with pencil affixed which records the flow resistance on a chart on a revolving drum. After reaching 90C the heating is automatically switched over to constant temperature. The possibility of recording viscosity at falling temperatures is provided by water-fed cooling coils.

The form of the viscogram obtained is more or less characteristic for the starch investigated; in general, the viscosity attains a peak value and then slowly falls off. The maximum value and the other features of the curve serve as a basis for grading. Since the dimensions of the curve depend on the construction details of the apparatus, the viscometer has to be calibrated with standard flours of known quality.

ASH

The amount of inorganic constituents present, as measured by the ash content, can be considered an indication of clean processing and, in conjunction with the acid factor (see below), conveys an impression of the quantity of metal ions bound to the raw starch. The colour of the ash is also of interest, as an off-colour indicates the presence of objectionable elements (e.g., brown-red from iron).

MOISTURE

Determination of moisture by the oven method, though simple to perform, requires many weighings and is otherwise rather lengthy. Moreover, the results tend to be low in a highly humid surrounding atmosphere such as is likely to occur in tropical regions.

A more rapid method, free from these objections, consists in boiling a sample with xylene (boiling point 135C) and collecting the water driven out in the form of vapour, which separates from the xylene after condensation in a graduated tube.

In the oven method, the starch sample is placed at a depth of less than 2 mm from the bottom in a receptacle with a tight-fitting cover and weighed. With the cover removed' it is heated in a vacuum oven at 105C under a pressure of about 25 mm until a constant weight is obtained. The loss in weight during the heating period is considered equal to the moisture content.

The moisture contents specified for the A, B and C grades in the present system are difficult to obtain in most of the producing areas. The starch leaves the medium-size factories and the bolting installations with a moisture content generally over IS percent, but during shipping moisture declines a few percent. If the moisture content is high, there is a likelihood of mould growth.

ACIDITY

This test is of considerable interest to manufacturers of dextrin from cassava. The titration required in the determination of the acid factor is a measure of the acid-binding capacity of the flour. As most dextrins are prepared with the addition of acid, it is understandable that the acid factor should be of prime importance in the conversion of starch to dextrin. It has been found that a smooth course of dextrinization requires an acid factor of between 2.0 and 2.5.

The initial pH, apart from its role as a starting point in the determination of the acid factor' may be used as an indication of the presence of moulds or other impurities in the flour: low pH values indicate deterioration. The amount of acid present is often determined by separate titration of a sample suspended in alcohol with dilute alkali solutions.

NITROGEN

Nitrogenous bodies are usually determined by the Kjeldahl method. A sample of about 3-5 g is digested in a Kjeldahl flask by boiling it in 25 ml of concentrated sulfuric acid and about 0.2 g of copper sulfate as catalyst. Boiling is continued for 30 minutes after clarification of the reaction. The flask is cooled, and the contents are diluted in 200 ml of water, with a few pieces of granulated zinc and 25 ml of 4 percent sodium sulfide solution added. About 50 ml of 45 percent sodium hydroxide solution is cautiously run down the side of the flask, which is then connected to a condenser. The outlet of the condenser should extend into a vessel containing a measured quantity of standard acid solution. The flask is gently shaken to mix the contents and heat is applied to distil the ammonia from the reaction flask into the acid solution.

The excess acid in the receiver is titrated with standard sodium hydroxide solution, using methyl red as an indicator. After a determination of the amount of ammonia distilled and calculation of the results as nitrogen, it is common practice to report values as percent protein by multiplying the percentage of nitrogen by the factor 6.25.

Analysis of baked products

These partly gelatinized products are always consumed in cooked form - in soups, puddings and so on. Consequently, their behaviour in contact with cold water and during gelatinization in boiling water is the best criterion of quality. The tests and specifications given below are the result of long experience in the trade of these commodities. They are particularly directed to the swelling capacity and stability of the structure of the pearls in cold water and during cooking. A determination of the titratable acidity is added as a test of durability.

COLD SWELLING TEST

Ten grams of the material are placed in a graduated 100-ml cylinder and the bulk volume is noted. The cylinder is then filled with water, and after standing 24 hours the volume of the swollen beads is determined. A high swelling power is preferable, though definite values are not given.

COOKING TEST FOR PEARLS AND SEEDS

Three and a half grams of the material are added to 200 ml of boiling water, and boiling is continued for two minutes. After cooling for 30 minutes, the contents of the beaker are heated again to boiling point, with a low flame, and boiling is continued for another 30 seconds. Then the liquid is left to cool for half an hour and transferred

to a graduated cylinder. After settling, the total volume of the swollen product is read. Generally, part of the original beads will have disintegrated; the volume of these fragments which form a layer of "slime" on top of the swollen whole beads is noted separately. The market demands rapid swelling with a minimum of disintegration during cooking, and a large volume after the second cooking. Normally' the volume of the whole beads is more than 8 ml per gram of starting material and the slime layer less than 4 ml per gram.

TITRATABLE ACIDITY

Five grams of the material, obtained by grinding the product in a disintegrator with a 150-mesh sieve, are mixed with 100 ml of alcohol which has been neutralized, using phenolphthalein as an indicator. The mixture is left to stand, with occasional stirring, for 24 hours. It is then poured on a dry filter and 50 ml of filtrate are titrated with N/10 sodium hydroxide, I ml of the reagent corresponding to an acidity of 0.24 percent calculated as acetic acid. Normally, less than 0.05 percent is found.

Specifications for particular uses

Specifications of starch are being developed rapidly and analysis of commercial

starches is becoming more and more necessary for both the producer and the consumer. The general specification system just reviewed does not cover all the properties which may be of interest for particular end uses. An instructive example is to be found in the specifications for dextrin from cassava as used in remoistening gum (Appendix 2). Though much depends on the performance of the dextrinization, it may be assumed that only certain varieties of the basic material will meet these requirements. Cassava dextrin is preferred in remoistening gums for stamps, envelope flaps and so on because of its adhesive properties and its agreeable taste and odour.

Requirements surpassing by far the specifications system of the Tapioca Institute of America are found also in the food industry.

Standards, grades and methods of analysis for starch and starch products have been established during the last two decades by the International Organization for Standardization. Some leading food corporations in the United States have also developed their own specifications in order to bring about some uniformity of quality in cassava products (Appendix 3).

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8. World production and trade of cassava products

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Cassava is grown in many tropical countries of Africa, Asia and Latin America. Most statistics do not usually distinguish between sweet and bitter varieties; in some, sweet varieties are not included as they are commonly grown as a secondary crop for home consumption. The world production of cassava roots in 1973 (excluding China) is shown in Table 12. Brazil is the largest producer, but most of the crop is consumed locally and exports are only a small portion of the total output. The same pattern applies to other important producers, such as Nigeria, Indonesia, Zaire, India and Colombia. Cassava does not form an important part of the staple diet in Thailand, and that country is now the world's largest exporter of cassava products. In the last few years most of the important producers have greatly increased their production.

Surplus production of cassava products enters international trade in different forms, such as chips, broken dried roots, meal, flour and tapioca starch. Dried cassava roots and meal are used as raw material for compound animal feed, while cassava starch is

used for industrial purposes; grocery tapioca is used solely for human consumption.

Exports

The principal markets for cassava products are in Europe - the European Economic Community being the most important for dried roots - and for cassava starch the United States, the United Kingdom and Japan. Although complete statistics of world trade in cassava products are not available, thus making it difficult to estimate the total quantity entering international trade, the import statistics of the EEC and the United States show a substantial increase in recent years, particularly for dried cassava roots.

Table 13 shows exports of cassava products in 1973 in comparison with the production of cassava roots in some of the major exporting countries, except Indonesia, for which figures were not available.

TABLE 12. - WORLD PRODUCTION OF CASSAVA ROOTS IN 1973 (IN THOUSAND TONS)

South America		***Africa***	
Argentina	177	Angola	1630

Bolivia	245	Benin	700
Brazil	26 559	Cameroon	719
Colombia	1320	Central African Empire	1100
Ecuador	400	Congo	590
Paraguay	1108	Ghana	1660
Peru	482	Guinea	420
Venezuela	272	Ivory Coast	625
		Liberia	250
		Madagascar	1175
Asia		Malawi	150
China (Province of Taiwan)	328	Mali	120
India	6 371	Mozambique	2 500
Indonesia	11 185	Niger	156
Malaysia	239	Nigeria	9 600

Philippines	480	Senegal	122
Sri Lanka	616	Tanzania	3 350
Thailand	6 416	Togo	517
Viet Nam	380	Zaire	8 595
		Total	90 457

SOURCE: FAO, Production Yearbook 1974. Revised Series, Rome, 1975.

Dried cassava roots, however, are supplied to the European Economic Community countries mainly by a few exporting countries (see Table 14).

Imports

The following are the largest importers of cassava products:

1. United States. The present annual consumption of all starch products in the United States is about 3 million metric tons. Cassava starch comprises about 1.5 percent of all commercial starch consumed and is imported from many countries, but mainly Thailand and Brazil. The rest of the consumption is, however, almost all corn (maize)

starch. The rising utilization of starches is the result of population growth' new applications of the starch and the growth of certain industries which use starch, particularly the paper industry.

TABLE 13. - EXPORTS OF CASSAVA PRODUCTS AND PRODUCTION OF ROOTS, 197'

	Exports	**Production of roots**
	Thousand tons	
Brazil	21	26 559
Thailand	1834	6 416
Madagascar	4	1175
Togo	5	517
Angola	2	1 630
Malaysia (West)	29	239

TABLE 14. - MAJOR EXPORTERS OF CASSAVA ROOTS TO SOME MEMBERS OF THE EUROPEAN ECONOMIC COMMUNITY, 1973

	Importing countries	Germany F.R.	The Netherlands	Belgium
Exporting countries		Percent of imports of dried roots		
Thailand		70.0	95.0	60.0
Indonesia		3.1	3.8	21.0
Tanzania		1.5	_	
China		20.0	_	
Mozambique		1.3	_	
Malawi		3.3		
Total		99.2	98.8	81.0

Cassava starch enters free of duty and its importance on the U.S. market is dependent on its price relative to that of corn (maize) starch and potato starch.

TABLE 15. - IMPORTS OF CASSAVA STARCH BY SELECTED COUNTRTES, 1973

Importing countries	United States	United Kingdom	Canada	France	Japan	Total

Exporting countries	Metric tons					
Thailand	42778		17	3085		45880
Brazil	5331		2407			7738
Malaysia (West)	164	2470	472	527		3633
India	36					36
Nigeria	18					18
Dominican Republic	14					14
Colombia	8					8
Canada[1]	774					774
Hong Kong[1]			17			17
The Netherlands[1]			135			135

United States'			1033		3	1036
Togo				3 502		3502
Madagascar				3 329		3329
Others				128		128
Total	49123	2470	4081	10571	3	66248

1 Re-exporters,
SOURCE: National trade statistics.

TABLE 16. - IMPORTS OF CASSAVA CHIPS AND MEAL OF SOME EEC COUNTRIES

	1965	**1970**	**1971**	**1972**	**1973**
	Thousand tons				
Germany, F.R	520	591	529	487	410
The Netherlands	76	502	514	681	771

Belgium	100	268	204	330	420
France	17	35	40	141	163
Italy	1	14	_	_	_
Total	714	1410	1287	1639	1764

SOURCE: National trade statistics.

2. United Kingdom. The United Kingdom's imports of cassava and sageo starches amount to about 2 500 tons per year and are used in food preparation rather than for industrial purposes.

3. Japan. Japan is potentially an important market for cassava starch because the price of locally produced starch is high and the traditional production of sweet potato and white potato starch is decreasing. The local production is about 800 000 tons a year of a national consumption of 1.3 million tons of starch. However, imports of cassava starch (56 000 tons in 1967) are now nonexistent owing to the competition of corn (maize) starch.

Japan is fast becoming an important new market for cassava chips and meal, as there has been an increasing, demand for raw material for the compound feedstuff industry. However, the general policy in the country is to import raw materials rather than

finished products in order to encourage local industries. In addition, the Government imposes a quota system on imports and an import duty of 25 percent on all cassava products.

4. European Economic Community. The international demand for cassava products for animal feed is concentrated in western Europe and the European Economic Community, especially the Federal Republic of Germany. As these countries have the most developed compound animal feed industries, and as prices of feedgrains have been increasing, they are considered the major outlet for exporting countries of cassava products (Table 16).

Total consumption of animal feed is based on the number of livestock and the consumption per head of the livestock. Between 1965 and 1970 the number of livestock did not increase significantly in the major EEC countries, as shown in Table 17; however, the consumption per head has been continually increasing asa result of changes in feeding methods. The figures in Table 18 represent the rates of increase of compound feed consumption per animal between 1965 and 1970.

The figures in Table 18 reflect exactly the stages of development in the use of compound animal feedstuff. In the Netherlands, the most advanced country in this field, the rates of increase of compound feedstuff consumption per head are small and

there is even a decline in some uses (pigs and poultry); however, in the Federal Republic of Germany, France and Italy the rates of increase are very high and will continue to be so until the consumption per head reaches the present level of consumption in the Netherlands.

TABLE 17. - ANNUAL RATE OF INCREASE IN NUMBER OF LIVESTOCK IN SOME EEC COUNTRIES, 1965 - 70

	Germany F.R.	The Netherlands	Belgium-Luxembourg	France	Italy
	Percent				
Cattle	1.6	2.5	1.4	1.6	1.6
Pigs	2.7	12.5	14.5	3.2	14.0
Poultry	7.2	4.3	7.0	-2.3	2.3

SOURCE: FAO, Production Yearbook, Rome, 1973.

TABLE 18. - ANNUAL RATE OF INCREASE OF COMPOUND FEED CONSUMPTION PER HEAD IN SOME EEC COUNTRIES, 1965 - 70

	Germany, F R.	The Netherlands	Belgium-Luxembourg	France	Italy
	Percent				
All cattle	8.0	5.8	3.1	8.2	24.0
Pigs	8.8	-1.0	2.5	6.0	-4.5
Poultry	2.0	-3.5	3.6	4.4	10.0

SOURCE: FAO, Production Yearbook, Rome, 1973.

Distribution and transport

Trade in cassava products is handled by shippers, importers and agents. Some importers are also agents who act on behalf of foreign suppliers and conduct their business on a commission basis in order to lessen the risks.

Freight rates for bulk pellets are much lower than those for chips in bulk and other products. During transport, especially on long voyages, deterioration caused by moulding, heating and sweating may be a problem.

Recommendations

The compound feedstuff industries require large quantities of cassava products. Because of the increasing competition in the production and marketing of these products, producing countries are advised to take the following recommendations into consideration:

1. As the economics of international trade require minimum quantities per shipment, exporters should ensure that regular quantities are available for year-round export.

2. Each importing country has a minimum quality standard for each product. It is therefore important that an exporting country establish a quality-control system to maintain the quality of its exported products. Once an abovestandard quality is maintained, the exporter will gain a good reputation and even receive a premium for his products.

3. Export prices must be based on world market prices. Exporters must always remain informed of price fluctuations and trends in the international market.

4. Bulk shipment is preferable to transport in bags. It is therefore advisable to have bulk-loading facilities in the ports of the exporting countries. These facilities can also be used for other agricultural or mineral products.

5. Exporters must have enough experience in international trade to deal with experienced and established importers. They can use the experience of suitable firms or agents in the importing countries to establish good trade relationships until they acquire the necessary knowledge.

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9. Development of the cassava-processing industry and its future

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Particularly in countries where the science of agriculture is not yet developed,

continuous guidance under some type of development scheme is necessary in order to make the best use of cassava for local consumption and for export. Such a scheme may be operated through a government organization or through a private organization advised and in some cases supervised by the government.

The method chosen will depend on local conditions' and it must be realized that changing existing methods of production and processing will take time in most areas because of the retarding influence of local customs and beliefs as well as economic conditions. The scheme outlined below is only a suggestion and obviously must be adapted to the existing organizational pattern of the government, its extension services and the extent to which the industry itself is organized.

Production

The initial approach to farmers and merchants should be through practical field demonstrations at the lowest levels of village production.

In many producing countries, the cassava industry suffers from such disadvantages as an insufficient and irregular supply of roots to the factories in addition to the high cost of roots. These countries should encourage research work with the object of obtaining

a maximum yield of roots per hectare and a maximum starch content in the roots. Experiments should be conducted in various regions for the improvement of agricultural practices and the breeding of new varieties with continuous testing and selection for high yields and suitability to local conditions.

The formation of an organization of cassava growers in each region will encourage production, make possible financial and technical assistance, and help coordinate the supply of roots to the factories.

Processing and marketing

During the initial stages a competition sponsored by local officials or merchants with a prize for the best will foster interest in the scheme.

The most propitious occasion on which to inaugurate such a competition would be one of the many marketing and festival days celebrated in the villages. It may continue for several months and be open to participants from a number of villages in cassava-producing areas.

The next step could be the setting up of small cooperative processing units in areas which are ready for such development, whereby improved machinery and accessories

could be brought into use to obtain a better product. A pilot plant may be established in each cassava-growing region as a centre for research and development of the industry, for demonstration of modern processing equipment and for the training of personnel.

Obviously, under such a development scheme a certain number of officers will be necessary to guide the programme - at least some instructors and an inspection officer stationed in the cassava-processing areas.

The instructors should be patient and tactful, as they must remain on good terms with the workers, and must be capable of good systematic instruction by practical demonstration.

The duties of an inspector call for an agricultural engineer specialized in processing with a good general education and practical background and with administrative experience. He should be senior to and supervisor of the district instructors.

As cassava is generally grown in rural areas and processed in small factories, the promotion and guidance of village farmers' cooperatives, not only for processing but also for grading and marketing, is an important part of the duties of the officers. Such cooperative societies should be able, in later stages, to deal with products for export.

Once a start has been made, the establishment of a cassava board composed of government officers, representatives of farmers' cooperatives and individual factory owners as well as representatives of merchants and related industries should be considered. The board should meet regularly to ensure a continuation of useful contacts and act in an advisory capacity to the government. It can handle problems of production and marketing of cassava products, open new markets and regulate prices of various products, provide financial assistance to processors and traders, maintain quality standards, promote research and the development of new products and so on.

Future of the cassava industry

FOOD AND NONFOOD USES

Because starch-derived products are used in almost every industry, the starch industry itself is vulnerable to competition from more specialized synthetic products.

In the textile, foundry and paper-coating industries, synthetic polymers present a serious threat to starch products, but they are still expensive. Much work is therefore being carried out to form products combining starch and synthetic polymers with the best qualities of both materials. The future of starch utilization in such industries may

be promising if technical efforts continue to make use of the new synthetic materials rather than compete with them or oppose them. There is no doubt, however, about the secure future of starch-based products in the food industry.

The new improved methods of producing glucose syrup and dextrose by enzymes and by direct conversion from raw materials are going to give sucrose stiff competition. Furthermore, it has recently been claimed that sucrose consumption has certain injurious effects on health while starch, starch products and glucose do not. The utilization of glucose syrup and dextrose is rapidly increasing in the food industry, and consequently their production from various starches is continuously expanding.

At present yellow maize is the most important raw material used for starch production. New waxy maizes have been developed with higher amylose content than and different properties from normal maize. The market position of cassava starch is believed to depend on the possibility of world industry, particularly in the United States, developing domestic substitutes from the waxy varieties of grains (maize and sorghum) and from roots and tubers such as sweet potatoes and white potatoes at lower cost than that of imported cassava starches.

Growing populations in the cassava-producing countries will continue to provide a home market for cassava roots and products. Many countries are entering production,

and the international market for many products has become more competitive. Thus it seems unlikely that European markets will attract a large volume of exports. However, eassava could make a much more important contribution to national economies and provide a more stable base for food industries, both for local consumption and for export, if cassava starch could compete with other starches by improving the quality of its products and lowering the cost of production.

BREAD-MAKING

Bread consumption is constantly increasing in many developing countries, which still depend mostly on imported wheat or wheat flour while they grow various staples such as starchy tubers like cassava or cereals other than wheat. Recent experiments show the possibility of partial replacement of wheat flour in bread-making by other flours (e.g., cassava and soya).

It seems quite logical that the utilization of cassava flour in bread-making will increase considerably in most developing countries.

ANIMAL FEED

As the standard of living rises. the demand for meat and dairy products is also

increasing, especially for quality products. Livestock breeding is progressing rapidly and significant increases in meat production are foreseen in many countries as shown in Table 19.

The use of well-balanced compound feedstuffs has proved to be the most efficient way to meet the shortage of home-grown natural fodder and to increase efficiency in the raising of milk cows, beef cattle, broilers and laying hens, and pigs. Many feeding experiments show that cassava provides a goodquality carbohydrate which may be substituted for maize or barley; however, cassava must be supplemented by other feeds that are rich in protein and vitamins.

TABLE 1 9. - M EAT PRODUCTION IN SELECTED COUNTRIES

Country	**Base year 1969-71**	**Projection 1975**
	Thousand tons	
France	1 640	2 071
Germany, F.R	1296	1502
The Netherlands	302	335
United Kingdom	818	1185

Japan	270	305
Total	4 326	5 398

SOURCE: FAO, Agricultural commodities projections 1970-1980, revised 1975.

The consumption of cassava products such as dried roots, chips and pellets by the compound feedstuff industry is expected to increase considerably in the future: therefore, it is vitally important that producing countries encourage belter processing and quality control. Furthermore, it is hoped that more attractive markets for animal feed containing cassava will open up in the producing countries.

Appendixes

Methods and specifications for determining the quality of cassava flours

(Tapioca Institute of America, October 1943)

1. MESH

Apparatus

United States standard sieves, 140, 80 and 60 mesh.

Method

Fifty grams of flour are screened through the appropriate sieve acnording to grade. While more accurate results can be obtained by making the test with a Ro-tap machine (a mechanical shaker of special design) or other type of mechanical shaker, satisfactory results can be obtained by hand shaking.

Specifications

Grade	***Percent required to pass***	***Mesh sieve to be passed***
A	99	140
B	99	80
C	95	60

2. DRY APPEARANCE

Method

A sufficient sample of flour is taken to make a rectangle approximately 2.55 cm (I to 2 inches) on a side and 1.6-3.5 mm (1/16 to 1/8 inch) high. The flour is placed on a white paper pad, laid out to these measurements with a spatula and one side evened off. Adjoining this side, a similar pile is made with a standard flour. A clean smooth piece of paper is laid over both piles and pressed gently with the spatula to make a smooth upper surface. The two piles are compared by eye in a neutral light (i.e., by daylight) free from shadows and direct glare.

Specifications

Grade	***Colour***	***Black specks***
A	Near standard	None
B	Near standard	Very few
C	Near standard	Few

3. CLEANLINESS

Apparatus

Crystallizing dish 100 mm in diameter and 50 mm deep.

Method

Twenty-five grams of the sample are thoroughly dispersed in 150 ml of distilled water in the crystallizing dish and allowed to settle for two hours. The sample is compared against a standard sample for dirt and foreign particles seen from the underside of the dish and in the floating liquid.

Specifications

Grade	***Colour***	***Dirt, foreign particles***
A	Near standard	None
B	Near standard	Very few
C	Near standard	Few

4. PULP

Apparatus

United States standard sieve, 140 mesh

Graduated cylinder, 100 ml

Method

Fifty grams of sample are put on the sieve and washed with water until the washings show substantially no starch particles. The residue is transferred to a 100-ml graduated cylinder and water added to the 100 ml mark. The pulp is allowed to settle for two hours. The pulp is measured as the number of millilitres of residue.

Specifications

Grade	*Pulp (max. in ml)*
A	0.5
B	2.5
C	12.0

5. VISCOSITY

Apparatus

Boiling water bath

Short-form pyrex beakers, 250-ml capacity

Glass rods 1 cm (3/8 inch) in diameter and 20 cm (8 inches) long Thermometers

Method

By the proper amount of flour is meant the following:

As a standard for comparison, the standard for grade A is always cooked with 10 g of flour per 150 g of distilled water. If the sample which is to be graded is thought to be approximately grade A, then it should be cooked with 11 g of starch per 150 g of water. If the unknown flour is thought to be grade B. then 17 g should be used. If the flour is supposed to be grade C, then 20 g should be used. In this way, if the unknown flour has a higher viscosity than the standard when cooked with 10 g of flour to 150 g of water, then the unknown flour would be grade A, B or C, according to the amount of flour used in the viscosity test.

If a more accurate measure of the viscosity is desired, then additional "cookups" should be made in the same manner as above, with the exception that one should endeavour to find out how much flour is required when cooked with 150 g of water, in order to obtain the same viscosity as the standard grade A flour when cooked with 10 g of flour per 150 g of water.

This amount of flour required by the unknown flour would be the measure for viscosity. For example, if the unknown flour required 13 g per 150 g of water to give the same viscosity as grade A when cooked with 10 g per 150 g of water, then the flour in question would be grade B. having a viscosity of 13.

The proper amount of flour is mixed with 150 g of distilled water in a 250 ml beaker. A rod and a glass thermometer are inserted and the tare is taken. The beaker is placed in a boiling water bath and the contents stirred with the rod and thermometer until the temperature reaches 80C. The beaker is covered with a watch glass and is left in the bath for ten minutes without further stirring. At the end of this time the beaker and contents are removed from the bath and the loss in moisture by evaporation is adjusted with hot distilled water. It is then cooled in running water with a minimum of stirring until the starch solution reaches 25C. The thermometer is then removed and viscosity comparisons are made by stirring by hand at the rate of approximately two turns per second, with a roughly circular motion. By observing the resistance offered

to the rod by the starch solution and comparing that resistance to the standard "cook-up," one can estimate the viscosity of a given sample.

Specifications

Grade	***Max- g/ml water***
A	11/150
B	17/150
C	20/ 150

6. ASH

Apparatus

Shallow, relatively broad ashing dish

Muffle furnace

Method

Approximately 5 g of flour are weighed into the ashing dish, which has previously been ignited, cooled and weighed. A sample is inserted in the furnace at about 500C (dull red) until a light gray ash results, or to constant weight. The sample is then cooled in a desiccator and weighed.

Specifications

Grade	***Max. ash (percent)***
A	0.15
B	0.25
C	0.50

7. MOISTURE

Apparatus

Metal dish, 55 ml in diameter, 15 ml in height, provided with inverted slipin cover fitting tightly on the inside.

Ventilated oven regulated to 130C 5C.

Method

Approximately 5 g of flour are weighed into a dish which has previously been dried in the oven, cooled, and weighed. The dish is uncovered, and dish, cover and contents are dried in the oven at 130C 5C for four hours. The dish is covered while still in the oven and then transferred to the desiccator and weighed when cool. The moisture is calculated and the loss of weight expressed as a percentage of the original sample.

Specifications

Grade	***Max. moisture (percent, factory packed)***
A	12.5
B	12.5
C	14.0

8. ACIDITY

Apparatus

Electrometric pH meter

Method

Twenty-five g of flour are dispersed in 50 ml of distilled water. The initial pH is determined. N/ 10 hydrochloric acid or sulfuric acid is then added to the suspension until pH 3.0 is reached. The titration is run at room temperature.

Specifications

Grade	*Initial pH*	*Max. ml N/10 acid to reach pH 3.0*
A	4.5-6.5	2.5
B	4.5-6.5	6.0
C	4.5-6.5	No titration required

Specifications for dextrin

(issued by the United States Government Printing Office)

The dextrin shall have been converted from starch derived from the cassava root. It shall be a high-quality dextrin adapted for use in gumming operations, free from grit or other foreign matter.

Detailed specifications

	Percent
Dextrin by polarization	83.0
Reducing substance, as dextrose	3.0
Volatile at 105C	6.5
Ash content	0.2
Material insoluble in cold water	0.3
Fat content	0.4
Polariscope reading, Ventzke, 10 g of dextrin in 100 ml of	90.6

solution	
Refractive index at 25C, 250 g of dextrin plus 125 g of water	1.4555

Physical properties

The dextrin shall be in powdered form. After being applied to and dried on the paper, it must be light in colour, flexible, transparent, and of superior adhesive qualities. The dextrin must be neutral or have only a slightly acid reaction. It must have an unobjectionable odour and taste.

The viscosity Engler at 20C of a solution made by dissolving 120 g of dextrin (including moisture) in 250 g of water shall fall within the range 200250 seconds when measured after standing for 3, 24 and 48 hours.

General requirements

The dextrin shall be packed in tight paper-lined bags containing approximately 200 lb [about 90 kg].

Specifications for starch

(developed by a large food corporation)

1. *Appearance and uniformity*: Samples of about one teaspoonful from each bag are examined under a glass plate and compared for colour and specks. The colour should be uniform, white and free from pigments. The lot is considered nonuniform if over 10 percent of the samples are darker or have more specks than the rest.

2. *Mesh size*: 99 percent of the starch granules must pass through a 100-mesh screen or 95 percent pass through a 140-mesh screen.

3. *Odour*: The cooked flour must have a fresh odour, free from any musty or rancid odour.

4. *Moisture content*: Not more than 10-13 percent. Moisture content of less than 10 percent indicates severe drying conditions and a possible explosion hazard during storage. More than 13 percent indicates danger of mould contamination.

5. *Ash content*: Not more than 0.2 percent.

6. *Protein content*: Not more than 0.4 percent.

7. *pH value*: 4.5-5.5.

8. *Viscosity*: Must be suitable for both cold flour slurry and cooked starch paste.

Standards for cassava chips and manioc meal in thailand

(Notifications of the Ministry of Economic Affairs)

Re: Dried tapioca standards

By virtue of the power conferred in Section 4 of the Export Standards Act B.E. 2503, the Minister of Economic Affairs gives notice as follows:

1. Dried tapioca is declared standard goods.

2. Standards for dried tapioca shall be as specified in the annex hereto.

3. Persons taking or exporting dried tapioca from the Kingdom through the Bangkok Customs Station, Tah Chalaeb Customs Station, Changvad Chandaburi or the Klong Yai Customs Station, Changvad Trad, shall produce a good standard certificate.

4. Standards verification service charges for dried tapioca are prescribed as follows:

(1) for not more than 50 metric tons, not more than 250 baht;
(2) for amounts in excess of 50 metric tons, not more than 4 baht per metric ton.

In the event a sample is analysed, there shall be an additional charge of not more than 300 baht for verification of its standard.

5. Service charges for the issuance of standard certificates are prescribed as follows:

(1) for not more than 50 metric tons, not more than 20 baht;
(2) for amounts in excess of 50 metric tons, not more than 0.40 baht per metric ton.

Effective from the 1st of September 2506.

Notice given the 30th May 2506 (1962)

KASEM SRIPHAYAK
Minister of Economic Affairs

Dried tapioca standards

1. Definitions:

> **(1) "Dried tapioca" means tapioca root (Manihot utilissima Pohl) dried but not ground.**
> **(2) "Fibre" means that part of the tapioca root which is not tapioca.**
> **(3) "Foreign matter" means matter which is not dried tapioca, fibre or sand.**

2. Dried tapioca must be light in colour, without admixture of foreign matter and free of unusual odour.

3. Dried tapioca shall be divided into two grades, the standard for each being prescribed as follows:

> **(a) Special grade, having a starch, including water-soluble carbohydrate, content of not less than 72 percent by weight and a moisture content of not more than 13 percent by weight. If there is sand or fibre it must not exceed the following rates:**
>
> > **(i) sand not more than 2 percent by weight;**
> > **(ii) fibre not more than 4 percent by weight.**

(b) First grade, having a starch, including water-soluble carbohydrate, content of not less than 70 percent by weight and a moisture content of not more than 14 percent by weight. If there is sand or fibre it must not exceed the following rates:

(i) sand not more than 2 percent by weight;
(ii) fibre not more than 4 percent by weight.

4. In case of any argument, problem or dispute concerning the colour, the latest samples established at the Goods Standards Office shall be deemed the standard.

5. In the event of sale of dried tapioca in accordance with a sample, the standard of such dried tapioca must not be lower than that of the sample agreed to by the purchaser and the moisture content must not be higher than 14 percent by weight. Approval of the Goods Standards Office must be obtained.

6. Packing materials for dried tapioca must be gunny bags in good condition, suitable for export, free from tears, leaks and bad odour, the mouth sewn with a doubled hemp cord for sewing gunny bags, at least eleven stitches each way forward and back.

Re: Manioc meal standards

By virtue of the power conferred in Section 4 of the Export Standards Act B.E. 2503, the Minister of Economic Affairs issues a notice as follows:

1. Manioc meal standards prescribed in the schedule annexed to the Notification of the Ministry of Economic Affairs dated the 28th March 2505 Re: Manioc meal standards are cancelled.

2. Manioc meal standards are as prescribed in the schedule annexed hereto.

Effective from the 1st April 2506.

Published on the 16th January 2506 (1962)

KASEM SRIPHAYAK
Minister of Economic Affairs

Manioc meal standards

1. Definitions

(a) "Manioc meal" means the product derived from grinding the root of the cassava plant (Manihot utilissima Pohl) but shall not include manioc flour.

(b) "Fibre" means that part of the cassava root other than the manioc.

(c) "Foreign matter" means substances other than manioc meal, fibre, sand and moisture.

2. Manioc meal shall be divided into two grades, the standards for maniac meal of each grade being as follows:

(a) Special grade: a soluble flour including carbohydrate content of not less than 72 percent by weight and

(i) sand not more than 2 percent by weight;
(ii) fibre not more than 4 percent by weight;
(iii) moisture not more than 13 percent by weight.

(b) First grade: a soluble flour including carbohydrate content of not less than 70 percent by weight and

(i) sand not more than 3 percent by weight;
(ii) fibre not more than 5 percent by weight;
(iii) moisture not more than 14 percent by weight.

3. Both grades of manioc meal must be of light colour, have no foreign matter mixed in and no unusual or bad odour.

4. In the event of differences or a dispute over colour, the latest samples of the Goods Standards Office shall be taken as the standard.

5. In the event a sale of manioc meal is by sample, the governing standards shall not be lower than the standard of the sample agreed to by the purchaser and approved by the Goods Standards Office.

6. Packing materials for manioc meal must be gunny sacks in good condition suitable for export, free from tears, leaks and bad odour, and the mouth must be sewn with a double hemp cord for sewing gunny bags, forward and backward, at least eleven stitches each way.

List of processing equipment for a cassava starch factory producing 24 tons per day

Cleaning of fresh roots

3 belt conveyors with suitable gear motors and supports for transporting the roots

1 rotating root washer with gear motor
1 root breaker with motor for chopping washed roots
1 bucket conveyor with gear motor
1 pre-grater with motor
1 pump with stainless steel rotor and motor

Extraction of starch

3 sets of extractors with sieves and motors or a set of DSM screens for the separation of starch from fibres
2 screw conveyors with gear motors for grated material
4 pumps with stainless steel rotor and motor

Purification of starch

3 centrifugal separators or continuous channel separators with motors or Dorr Cloves
3 stainless steel stirrers with gear motors for the agitation of starch milk in basins
3 pumps with stainless steel rotors and motors

Dewatering and drying of starch

1 rotary vacuum filter with vacuum pump and motors or basket centrifuge
1 flesh drier complete with steam heating, pneumatic cooking system, ventilation, insulation, supports and motors
3 screw conveyors with gear motors
2 bucket-type elevators with gear motors
1 warm blending machine with conical mixer and gear motor
1 sifter and motor
1 sack-filling screw with two sack-filling sockets equipped with motors

Sulfurous acid plant

1 air compressor with motor
1 sulfur burning furnace with filler cap and water cooling
1 absorption tower (wood or ceramics)
1 storage tank (wood or concrete)
1 stainless steel pump with motor

Waler supply and piping

Drilling of two artesian wells
2 centrifugal pumps for well water

Piping inside factory (includes valves, fittings and condenser line for boiler)

Material handling equipment

2 storage tanks for fuel oil
2 platform scales for roots and starch fork-lift truck and handcarts

Other

Packaged boiler to supply steam for drying starch
Power generation (stand-by unit)
Electrical installation, including switch gear, power distribution, transformer
Outside lines for water, power and sewage
Maintenance shop equipment
Quality control laboratory equipment
Trucks for transporting roots and starch

Fao studies

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The importance of cassava in the agricultural economy of many tropical countries has grown remarkably in recent years. Governments, institutions and individuals are seriously interested in studying problems concerning the production, processing and marketing of cassava and cassava products.

The Food and Agriculture Organization of the United Nations has been especially interested in this subject. The first edition of this publication was published in 1956, and since then FAO has carried out many studies in various countries, mostly upon the request of the governments concerned. Although reports of these studies are listed in the bibliography, summaries of the most important of them are presented below.

NIGERIA

The Government of the Federation of Nigeria was determined to develop light and rural industries and especially to mechanize the manufacture of the cassava product gari. For this purpose it requested FAO to advise on the improvement and development of gari processing in the pilot plant established for this purpose at the

Federal Institute of Industrial Research in Lagos and to study the possibility of commercial processing of cassava.

After completion of his mission, G.W. Bumer, FAO expert, submitted his report (1962), which included the following main recommendations:

> **(a) mechanized processing of gari should be improved;**
> **(b) establishment of gari processing plants should be encouraged;**
> **(c) the manufacture of other cassava products should be encouraged.**

DOMINICAN REPUBLIC

In order to stabilize the rural economy, the Government of the Dominican Republic decided to promote the diversification of agricultural crops other than the traditional ones, such as sugar, coffee and cocoa. For this purpose it requested FAO to advise on the possible development of cassava culture and the processing of cassava starch and other products derived from cassava. L.W. Holleman was assigned as FAO expert; his report (1964) included the following recommendations:

> **(a) extension of the planted area and promotion of new agricultural methods;**

(b) improvement of the methods of preparing cassava and other local food products made of cassava;

(c) introduction of cassava chips manufacture as a rural industry;

(d) establishment of a cassava starch factory of medium size;

(e) introduction of cassava starch in industries as a substitute for other starches.

COLOMBIA

At the request of the Government of Colombia, an FAO/UNDP mission was sent to Colombia in 1967 to start a pilot project for the production, processing and utilization of composite flour made from locally produced raw materials. A member of the mission, R. Gallien, made a technical and economic survey on cassava in Colombia; the mission's report included the following main recommendations.

(a) The Government should initiate a feasibility study for one year, including the preparation of baked products made of locally produced raw materials, the testing of those products and the possibility of their acceptance by the public.

(b) From the results of this study, a detailed cost-structure analysis should be

made. The Government should redefine its policies regarding cassava and soya production and processing to allow commercial bakeries to be provided with sufficient quantities of composite flours of standard quality at a price competitive with wheat flour.

GHANA

The Food Research and Development Unit in Accra (FAD/SF project) submitted a report (1968) dealing with crop storage problems, including the role of relative humidity in deterioration by microorganisms and its relationship to the moisture content of stored foodstuffs and the application of insecticides.

The preservation of cassava tubers by dehydration and the preparation of the local kokonte flour from cassava were investigated.

MALAYSIA

The Government of Malaysia is attempting to diversify agriculture to decrease the country's dependence on one crop - rubber. Cassava is among the major crops which have been considered for this purpose. At the Government's request, a study was conducted through the FAO-sponsored Food Technology Research and Development

Centre on the production, processing and marketing of cassava and cassava products.

The FAO experts M.R. Grace, O. Wahby and C. Ericksen submitted a report (1970), which included the following main recommendations.

(a) Cassava can occupy an important place in the agricultural diversifcation programme. However, there is a need to improve agricultural practices and the selection of new varieties.

(b) The present cassava-products industry should be improved and new equipment should be introduced for modernizing the industry.

(c) There is a need to establish an industrial board to promote the production, processing and marketing of cassava starch and its products. Special attention should be given to the improvement of quality and the lowering of prices of various products in order to compete in the world market.

(d) The establishment of a local livestock feed industry using cassava products should be encouraged.

SENEGAL

One of the problems which was studied by the FAO-sponsored Institute of Food Technology at Dakar was the possibility of making French-type bread of wheat flour mixed with different local products' including cassava starch, millet flour, soya and others.

SRI LANKA

In order to improve the standard of living of the farmers, the Government of Sri Lanka asked FAO to provide some technical aid and demonstration equipment for the processing of cassava. Accordingly, FAO drafted a proj ect, "Demonstration and Training in the Processing of Cassava in Ceylon." and J.A. Nijholt was appointed as an expert for this purpose. After completion of his assignment' the expert submitted his report (1964) which included the following main recommendations:

> **(a) to select new varieties and to improve the agricultural practices in order to increase the yield of cassava roots;**
>
> **(b) to teach in farm schools the making of dried chips starch and sago products from cassava with simple equipment for home use;**

(c) to establish three factories for cassava starch to replace imports.

TANZANIA (ZANZIBAR)

The economy is based on agricultural production and sugarcane has been grown since the twelfth century, but still basic foodstuffs represent 40 percent of imports. In order to revive the ancient sugar industry and to become more self-sufficient in staple food crops' the Government of Tanzania requested assistance from FAO in the form of the services of experts in agricultural industries. A. Eisenloeffel and J. Fischer' the FAO experts assigned for this purpose, recommended in their report (1967) that the Government should encourage the production and local consumption of cassava. organize the marketing of cassava and promote cassava drying and the milling industry for export.

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