



## 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 neighborhood, 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 rasps*

Engine-driven rasps 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 rasps 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 1 000 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**

Variety	Rasping effect		Rasping energy <sup>1</sup>	
	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	-
São Pedro Preto	67.4	68.7	5.21	3.44
Bogor	62.1	60.5	4.47	4.05

<sup>1</sup> 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 be 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 bears 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 be 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 <sup>1</sup>		
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

<sup>1</sup> 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 1 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 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.

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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 rasps*

Engine-driven rasps 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 rasps 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 1 000 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**

Variety	Rasping effect		Rasping energy <sup>1</sup>	
	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	-
São Pedro Preto	67.4	68.7	5.21	3.44
Bogor	62.1	60.5	4.47	4.05

<sup>1</sup> 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 "settling" 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 be 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 bears 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 be 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 <sup>1</sup>		
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

<sup>1</sup> 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 1 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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## Cassava Starch Production

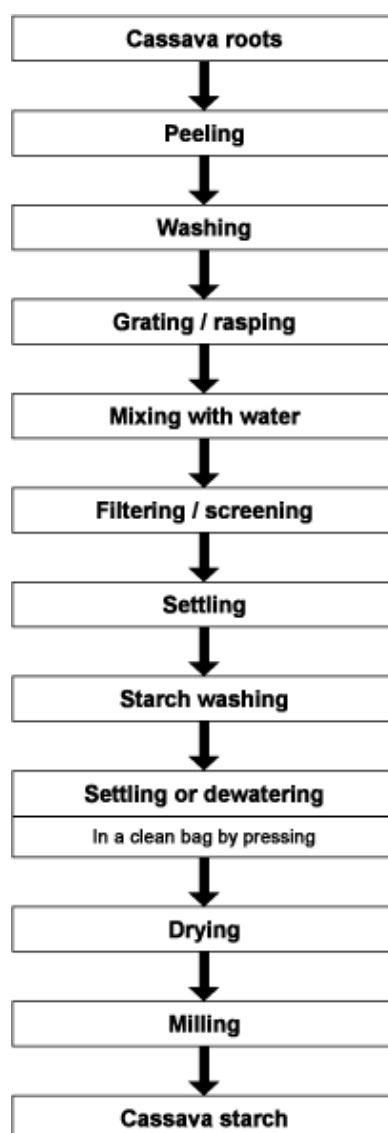
Starch is one of the most abundant substances in nature, a renewable and almost unlimited resource. Starch is produced from grain or root crops. It is mainly used as food, but is also readily converted chemically, physically, and biologically into many useful products to date, starch is used to produce such diverse products as food, paper, textiles, adhesives, beverages, confectionery, pharmaceuticals, and building materials. Cassava starch has many remarkable characteristics, including high paste viscosity, high paste clarity, and high freeze-thaw stability, which are advantageous to many industries

### Simple process for cassava starch production.

Cassava starch is produced primarily by the wet milling of fresh cassava roots but in some countries such as Thailand it is produced from dry cassava chips. Starch is the main constituent of cassava. About 25% starch may be obtained from mature, good quality tubers. About 60 % starch may be obtained from dry cassava chips and about 10 % dry pulp may be obtained per 100 kg of cassava roots.

Fresh tubers are processed during season and dry chips during the off-season in some countries. Extraction of starch from fresh cassava roots (Fig. 1) can be divided into five main stages: preparation (peeling and washing), rasping/pulping/grating, purification (starch washing), dewatering and drying, and finishing (milling and packaging).

For cassava, the process of starch extraction is relatively simple as there are only small amounts of secondary substances, such as protein, in the roots. When cassava roots are harvested or selected for starch extraction, age and root quality are critical factors. Cassava roots need to be processed almost immediately after harvest, as the roots are highly perishable and enzymatic processes accelerate deterioration within 1-2 days. A first-rate quality starch can be obtained from cassava using only water, and this makes the processing of cassava starch and flour particularly suitable for developing countries and rural industries.



### Cassava Utilization

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- Pressers
- Extruders
- Millers
- Dryers
- Pelletizers
- Sealers
- Packing machines

### Advantages of cassava starch

Cassava has many advantages for starch production.

- High level of purity.

- Excellent thickening characteristics.
- A neutral (bland) taste.
- Desirable textural characteristics.
- A relatively cheap source of raw material containing a high concentration of starch (dry-matter basis) that can equal or surpass the properties offered by other starches (maize, wheat, sweetpotato, and rice).

Cassava starch:

- is easy to extract using a simple process (when compared to other starches) that can be carried out on a small-scale with limited capital.
- is often preferred in adhesive production as the adhesives are more viscous, work more smoothly, and provide stable glues of neutral pH
- has clear paste.

The development of both the food and non food uses of cassava starch has made much progress and continues to have a bright future. Both old and important new products, such as modified starches, starch sugars, starch-based plastics and fuel alcohol, are reviewed briefly.

### **Native starches**

Starch can be classified into two types: native and modified. Native starches are produced through the separation of naturally occurring starch from either grain or root crops, such as cassava, maize, and sweetpotato, and can be used directly in producing certain foods, such as noodles. The raw starches produced still retain the original structure and characteristics and are called "native starches". Native starch is the basic starch product that is marketed in the dry powder form under different grades for food, and as pharmaceutical, human, and industrial raw material. Native starch has different functional properties depending on the crop source, and specific types of starch are preferred for certain applications. Native starch can be considered a primary resource that can be processed into a range of starch products.

Native starches have limited usage, mainly in the food industry, because they lack certain desired functional properties. The native starch granules hydrate easily when heated in water, they swell and gelatinize; the viscosity increases to a peak value, followed by a rapid decrease, yielding weak-boiled, stringy, and cohesive pastes of poor stability and poor tolerance to acidity, with low resistance to shear pressure, as commonly employed in modern food processing.

However, food, metallurgic, mining, fermentation, construction, cosmetics, pharmaceutical, paper and cardboard, and textiles industries among others use native starch in its traditional form.

### **Modified Starches**

For those characteristics, which are unattainable with native starch, modified starch can be used for other industrial applications through a series of techniques, chemical, physical, and enzymatic modification. Thus, modified starch is native starch that has been changed in its physical and/or chemical properties. Modifications may involve altering the form of the granule or changing the shape and composition of the constituent amylose and amylopectin molecules. Modifications are therefore carried out

and amylopectin molecules. Modifications are therefore carried out on the native starch to confer it with properties needed for specific uses. Some of these modified starches, their methods of modification and desirable properties are shown in Table 6. When a starch is modified chemically or physically, the properties of the native starch is altered. Various modifications give the starch properties that make it useful in many industries such as food, pharmaceutical, textile, petroleum, and paper pulp industries.

The different ways of modifying native starch consist in altering one or more of the following properties: paste temperature, solids/viscosity ratio, starch paste resistance to reduction of viscosity by acids, heat and or mechanical agitation (shear), retrogradation tendencies, ionic and hydrophilic nature. Modifying starch is important to provide the following properties: thickening, gelatinization, adhesiveness and/or film-formation, to improve water retention, enhance palatability and sheen and to remove or add opacity.

The reasons why native starch is modified are:

- To modify cooking characteristics (gelatinization).
- To reduce retrogradation.
- To reduce paste's tendency to gelatinize.
- To increase paste's stability when cooled or frozen.
- To increase transparency of pastes and gels.
- To improve texture of pastes and gels.
- To improve adhesiveness between different surfaces, such as in paper applications.

Modification can be as simple as sterilizing products required for the pharmaceutical industry or highly complex chemical processes to confer properties totally different from the native starch. A simple modification process is represented by washing, air classification, centrifugation, and pre-gelatinization.