Starch Technology
THE OCCURRENCE OF STARCH

Starch makes up the nutritive reserves of many plants. During the growing season, the green leaves collect solar energy. This energy is transported as a sugar solution down to the roots, and it is down there, that the sugar is converted to starch in the form of tiny granules occupying most of the cell interior.

The conversion of sugar to starch takes place by means of enzymes. Then, the following spring, enzymes are also responsible for the re-conversion of starch to sugar, which is transported upwards as energy for the growing plant.

CASSAVA ROOTS.

Cassava is cultivated in most equatorial regions and is known by many names, e.g.:

- Indonesia: Ubi kettella, Kaspe
- South America: Manioca, Yucca, Mandioca, Aipim
- Africa: Manioc, Cassava
- India: Tapioca
- Thailand: Cassava

In Europe and USA cassava is the term usually applied to the plant and its roots, and tapioca is the name given to starch and other processed products.

The plant grows to a height of 1 - 3 m and several roots may be found on each plant. Cassava prefers a fertile sandy-clay soil.

There are many varieties of cassava, but they fall into two main categories - bitter and sweet cassava (*Manihot palmata* and *Manihot aipi*) - depending on their content of cyanohydrin. For industrial purposes bitter varieties are most frequently used because of higher starch content. Sweet cassava is preferred for food because of its taste and dough forming ability. It “pounds” well.

A typical composition of the root is:

- Moisture 70%
- Starch 24%
- Fibre 2%
- Protein 1%
- Other 3%

Starch content may be as high as 30%.

QUALITY OF RAW MATERIAL.

The roots are living plants and need air for respiration and life activity. During storage the roots consume a small amount of their own starch to maintain life functions until spring. This will require fresh air, and the respiration causes development of heat. If the roots get warm, respiration increases raising the temperature further. A lot of starch is used for respiration and the roots will die of heat.

Unfavourable storage conditions cause starch losses and, in the worst case, dead and smashed raw materials, which are disruptive for the process. Therefore roots are processed in the order they are delivered to the factory, and the roots must be processed within 24 hours after harvest.
ROOT RECEPTION.

At the factory gate the lorry is weighed on a platform scale. Roots are sampled and washed. The ratio of dirt is found as the difference in weight before and after washing and the starch content is calculated from the density determined by the under-water weight method. Both figures are used to settle the account with the farmer and encourage the delivery of high quality roots rich in starch.

The roots are stored in the reception yard on a concrete floor in a way to accomplish the processing of the oldest roots first. At this point the roots are still bulky with an average weight of 600 - 650 kg per m³. A yard conveyor below floor level enables the use of a Bobcat for feeding the factory.

RAW MATERIAL HANDLING.

Stalks must be removed during harvest. Stalks will interfere with the peeling, blunt the rasps, and increase the fibre mass with adverse effect on the process.

Loose soil is removed by a rotating bar screen prior to washing. Thorough dirt removal lessens the problems with stones and sand later.

The soil also contains considerable quantities of nutrients, which will dissolve in the washing water and contribute to the environmental burden created by the effluent.

From the bar screen the roots enter the washing station via a stone catcher. Paddle washers are still in use, but rotary washers introduced by International Starch Institute have proved their efficiency.

EFFICIENT WASHING HELPS REFINING.

Soil and dirt not removed in the washing station cause problems later. High quality washing improves refining, because many impurities resemble starch in specific weight and size, so washing is the only way to get rid of them. The rubbing in the washing machine is a most important quality factor.

The quantity of impurities adhering to the surface upon delivery depends to a great extent on weather conditions and the soil.

The rotary wash machine continuous removes dirt and peel. The wash water may be recycled after filtering off peelings on a rotary screen and settling of sand in basins. Spend process water (fruit water) from the refining station replaces the loss of wash water.

The washed roots are conveyed on an inspection belt to the pre-cutter. In order to feed the rasps properly, the roots are chopped into pieces.
**RASPING.**

Rasping (grating) is the first step in the starch extraction process. The goal is to open all the root cells and release all starch granules. The slurry (rasping) obtained can be considered as a mixture of pulp (cell walls), fruit juice, and starch. On modern high-speed machines, rasping is a one-pass operation only. An even feed of rasping is essential for a steady flow throughout the rest of the plant.

![Raspers](image)

The hydrogen cyanide and cyanohydrin are released during rasping and go with the juice and process water.

**USE OF SULPHITE.**

The cell juice is rich in sugar and protein. When opening the cells, the juice is instantly exposed to air and reacts with the oxygen, forming coloured components adhering to the starch.

Food grade sulphur dioxide gas or sodium bisulphite solution has to be added. The great reduction potential of the sulphite prevents discoloration. Sufficient sulphite has to be added to turn the juice and pulp light yellow.

**EXTRACTION.**

Powerful flushing is needed to release the starch granules from the cells - the cells are torn apart in the rasper and form a filtering mat retaining the starch. Water has previously been used for the extraction, but today the extraction takes place in closed systems, allowing the use of the juice itself or process water from the refining step.

The starch is flushed out and leaves the extraction sieves along with the fruit juice. The cell walls (pulp) can be concentrated further on dewatering sieves to a drip-dry pulp with 12 - 15 % dry matter.

The extraction takes place on rotating conical sieves. The high efficiency makes it feasible to utilise high quality sieve plates made of stainless steel, which will withstand abrasion and CIP-chemicals. The sieve plates have long perforations that are only 125 microns across.

The extraction is a counter current process. It is followed by a fine fibre washing on conical sieves also. The washed fibres are combined with the pulp and may be used as cattle feed.
THE MILLENIUM PROCESS.

Excess juice is removed on a couple of hydrocyclone concentrators. The concentrated starch - crude starch milk - is washed on the refining line.

The concentrating and refining lines split the crude starch milk in:

- Starch Underflow
- Fruit Juice Overflow 1. split
- Fruit Water Overflow 2. split

Fruit juice is the natural juice initially removed in the concentrators. Fruit water is spent process water mixed up with residual fruit juice removed during refining. The split of the effluent in fruit juice and fruit water is an option of the Millennium process - named after its first introduction.

REFINING

The concentrated crude starch milk is washed with fresh process water in order to remove residual fruit juice and impurities.

With hydrocyclones it is feasible to reduce fibre and juice to low levels with a minimum of fresh water. To save rinsing water the wash is done counter currently - i.e. the incoming fresh water is used on the very last step and the overflow is reused for dilution on the previous step, and so on.

In the strong gravitational fields of a hydrocyclone and a centrifuge, the starch settles quickly, while fibres (pulp residuals) just float in the water.

The hydrocyclone has no moving parts and the separation is dependent on the pressure difference over the cyclone.

Each hydrocyclone is adjusted to force the light fraction of fibres and the smaller starch granules into the overflow and the larger starch granules into the underflow.

Impurities of equal density as starch cannot be separated from starch by centrifugal force. That is why it is so important to remove as many impurities as possible from the root surface in the washing station.

Although some impurities go with the starch in the underflow, there is, by means of a sieve, a last chance to remove the larger particles. Impurities not removed this way are not removable by any known technique.
Starch is among the most pure of all agricultural products. Actually, purity is the most important parameter for being competitive.

No significant amount of juice is left in the starch. The colour or whiteness may be improved by the use of sulphite in the right place and dosage, and by removing iron and manganese from the process water. Oxides of iron and manganese (e.g. rust) are dark coloured components, which have to be removed in the water treatment plant.

**CIP - CLEANING IN PLACE.**

Cleaning in Place is done with caustic and hypochlorite as cleaning agents. Caustic is a powerful agent for removal of the protein build-up on the interior walls and the hypochlorite is an efficient germ killer. During CIP it is of the utmost importance to keep the pipes filled up. Tanks are most efficiently CIPed with rotating disc nozzles - and covered tanks are required.

**DRYING AND SIFTING.**

The purified starch milk is dewatered on a continuous rotating vacuum filter or a batch operated peeler centrifuge. The moist dewatered starch is dried in a flash dryer with hot air. The inlet air temperature is moderate. High temperatures may increase cold-water soluble starch. The moisture of tapioca starch after drying is normally 12-13%.

**MODIFICATION**

Most starch is used for industrial purposes. Starch may be modified to meet the requirements of the end-user giving rise to a range of specialty products. Sophisticated techniques are applied.
A most versatile principle comprises a three step wet modification:

- Preparation
- Reaction
- Finishing

By applying different reaction conditions - temperature, pH, additives - and strict process control, specialty products with unique properties are made.

These specialty products are called modified starches. They retain their original granule form and thereby resemble the native (unmodified) starch in appearance, but the modification has introduced improved qualities in the starch when cooked. The paste may have obtained improved clarity, viscosity, film-forming ability, etc.

**APPLICATION.**

Tapioca starch is used in the manufacture of sweeteners, sizing of paper and textile and is in particular an excellent food starch used as a thickener and stabilizer. The pulp is used as cattle feed. Juice and spent process water are valuable fertilizers disposed of by land spreading.

Being a pure renewable natural polymer starch has a multitude of applications.

The viscosity (torque) is recorded on a Brabender instrument during controlled heating of starch slurry and subsequent cooling. Temperature is drawn in red. Native cornstarch develops a characteristic set-back when cooled (green line). Tapioca starch is characterized by its peak viscosity during cook-up and moderate set-back when cooled (blue line). The tapioca starch was tested in 6% suspension and the cornstarch in 8% - illustrating the viscosity difference.

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