Technical Article on Modification of Native Starches

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All over the world the most common source for starch are the seeds of various types of grain. Main starch sources are: maize, wheat, potatoes, rice and cassava. Other raw materials for starch production, including sorghum, sweet potato, barley, oat, rye, pea, bean, and lentil, play a subordinate role. This Article discusses only Maize and Potato starches, hence only these sources are considered.

Starch and modified starches have a broad range of applications both in the food and non-food sectors. The food industry uses it as a thickening agent, in sauces, as binder and various other.

The largest users of starch are the paper, cardboard and corrugating industries. Other important fields of starch application are textiles, cosmetics, pharmaceuticals, construction and paints. In the medium and long run starch will play an increasing role in the field of "renewable raw materials" for the production of biodegradable plastics, packaging material and moulds.

Source of Starches:

Maize: A mature maize kernel consists of the pericarp, the germ and the so-called endosperm in which the starch is stored. It is composed of approx. 70 % starch, 8 % protein and 4 % fat. The rest is composed of water, fibers, sugar and various mineral nutrients.

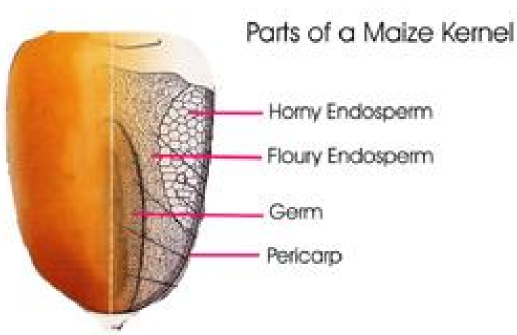

Fig1: Maize composition.

Potato: This tuber contains approx. 18% - 20% starch and approx. 75% water.

Fig2: Potato- source of potato starch.

Extraction of starch from Maize:

Supply / Cleaning
First, supplied maize has to pass the incoming inspection. It involve separation of foreign particles, stones, impurities, dust particles, etc. Then it passes on for steeping process.

Steeping
Well-conducted steeping is an important prerequisite for high yield and good starch quality. At first the purified maize kernels are transferred into a tank containing steep water. This step is conducted at 50 °C and lasts about 40 to 50 hours and several series connected steeping tanks are used. For optimal steeping conditions steep-water is kept at pH 4 by addition of sulphuric acid or hydrochloric acid and treated with sulphur dioxide. These conditions guarantee optimal water absorption of the maize kernel, and also loosening of the protein matrix. At the same time steep water causes the softening of the kernels and the release of solubles. Growth of lactic acid bacteria suppresses unwanted microorganisms such as yeasts, molds and other bacteria. During steeping the size of kernels nearly doubles and the water content increases from 15 % up to 45 %.

Coarse grinding and de germination
After steeping one is able to mash the maize kernels with a finger nail and remove the skin easily. After this processing step it is also possible to take the germ out of the broken maize kernel. This effect is utilized during the so-called degermination step. To free the germs the kernels are coarsely ground in an attrition mill. The grinding has to be conducted with care to

avoid oil leakage out of the germs. Otherwise the oil is soaked up by the starch granules, which leads to reduced starch quality. Separation of specifically lighter germs is conducted by means of special hydro-cyclones. For complete degermination the grinding and degermination steps are performed twice. Afterwards the germs are washed and dried and finally sold to companies which utilize them for corn oil production.

Fine grinding and extraction:
The germ removal step is followed by fine grinding in an impact mill to completely disrupt the cells of the endosperm and release the starch granules. The resulting suspension is led over bend green cascades for separation from fibre and other maize components. The starch milk, which contains the protein fraction, the so-called gluten, passes through. The bend screen cascades are connected in series. For complete washing out of the starch and separation of the fibres they are operated by counter flow principle. Additionally, washing water is added to the last process stage.

The separated residues are dehydrated and dried for use as an animal feed component referred to as maize feed.

Gluten separation
The crude starch milk still contains all the dissolved proteins. This fraction is called gluten, and most of it is separated off By means of two successive nozzle type continuous centrifugal separators. The process utilizes density differences between starch and protein. The protein fraction is dehydrated by means of a rotary drum filter, then dried and used as a high protein feed additive in pet feed formulations.

Starch refining
The starch milk, which still contains approximately 2 % of protein and fibers after separation, is then refined in a multi-step cyclone plant. The last stage of the multi-step cyclone plant is the one and only step of the wet milling process where fresh water is added.

By optimal construction and adjustment of the plant it is possible to reduce the protein content in the starch below 0.3 % on dry matter. Hydro-cyclone plants have become accepted for starch refining for their high performance, their low water consumption, and their low maintenance efforts.

Dehydration and drying
The refined starch milk, having a water content of approximately 65 %, is dehydrated in peeler centrifuges to a residual water content of about 40 %. The inner layer of the filter cake is coloured yellow and contains high amounts of protein. It is reintroduced into the process. Pure starch is finally dried by means of a flash dryer. For optimal shelf life residual moisture must not exceed 14 %.

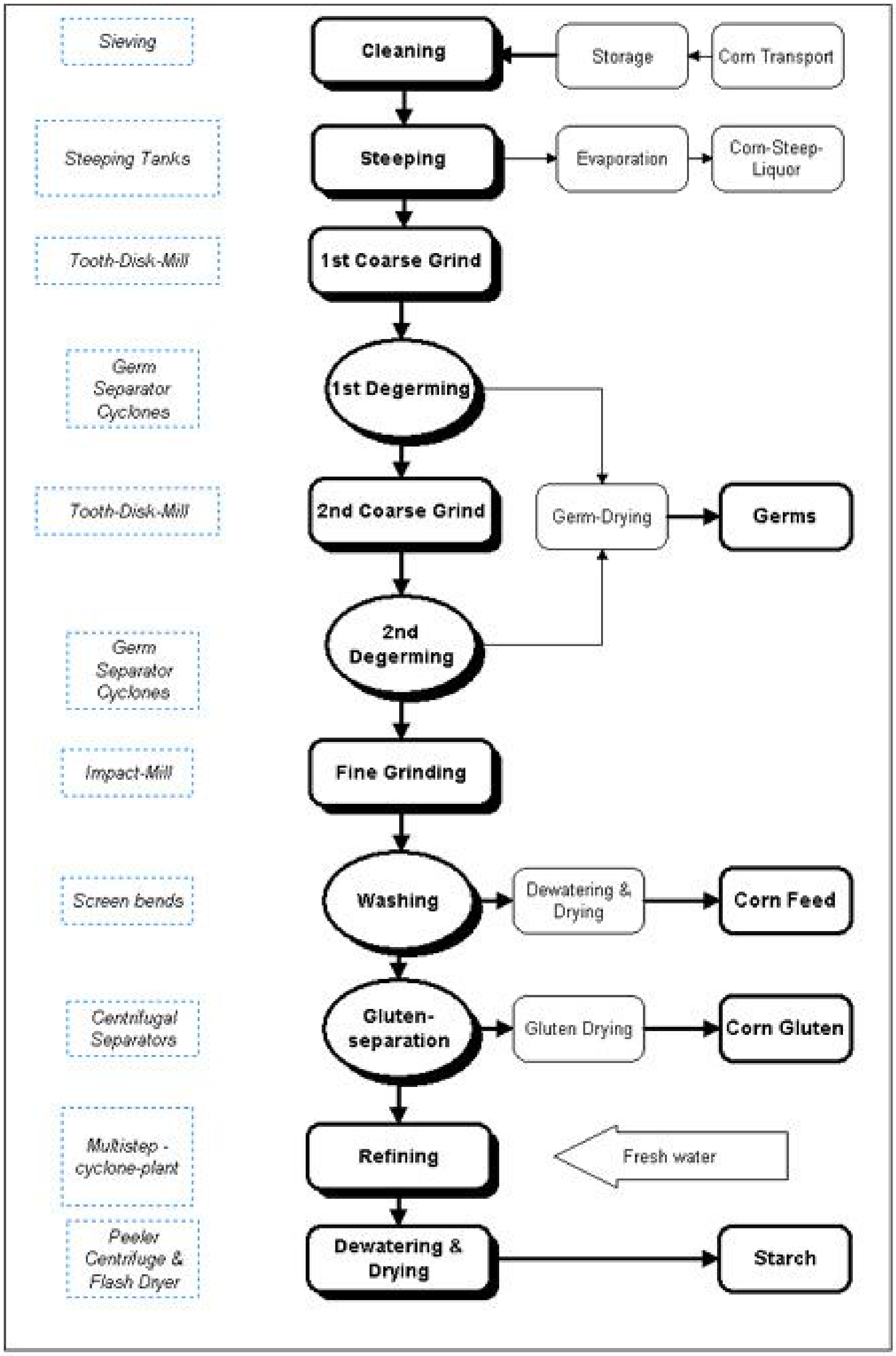

Fig. 3 Flow Chart for extraction of starch from maize crop:

Potato Starch Extraction:

After the delivery, the potatoes are coarsely cleaned for removal of soil, earth and stones and then stored. They are transported into the factory by flumes, which are equipped with strow and stone separators. The main cleaning is conducted in a trough washing machine where the potatoes are spinned around. Constant abrasion completely removes soil and also most of the skin. The washing water is then pumped into clarification pools for sand and stone removal and reintroduced into the process.

Rasping
The purified potatoes are mashed by means of a rotary saw blade rasp. In these rasps rows of saw blades are closely arranged on a drum which is driven by high rotation speed. Sharp saw teeth convert the potatoes into a fine mash. This process results in an almost complete disruption of the potato cells, which therefore release the starch. Simultaneously the potato skins are only roughly torn. This is inevitable to avoid that fine skin fragments pass through the sieves during the following extraction step and remain in the starch, which would lead to poor starch quality.

Extraction and fruit water separation
Firstly coarse skin and cell fragments, the so called pulp, have to be separated from the rasped potatoes. This separation step is conducted by means of conical rotating sieves, the so called centrisieves. For better starch isolation water is applied to the sieves through nozzles. While starch and fruit water passes through, the fibers are retarded by the sieves. The remaining pulp is drained or pressed off and used directly as feed while still damp or dried in flash dryers. The pulp is used as mix feed because of its high feed value because of its protein and residue starch content.

In the next step, the fruit water is separated in several steps by means of hydro-cyclone plants. Separated fruit water has a high content of proteins, amino acids, and mineral nutrients. About one half of the soluble proteins are coagulated by treatment with acid and heat and then separated in decanters. The remaining fruit water is evaporated and used for fertilizing.

Dewatering and drying
Refined starch milk has a dry matter content of about 35 % to 40 %. The starch is dewatered by rotary vacuum filtration to moisture contents below 40 %.

Drying is conducted by means of a flash dryer. Starch must not exceed 15 % of residual moisture to be suitable for storage.

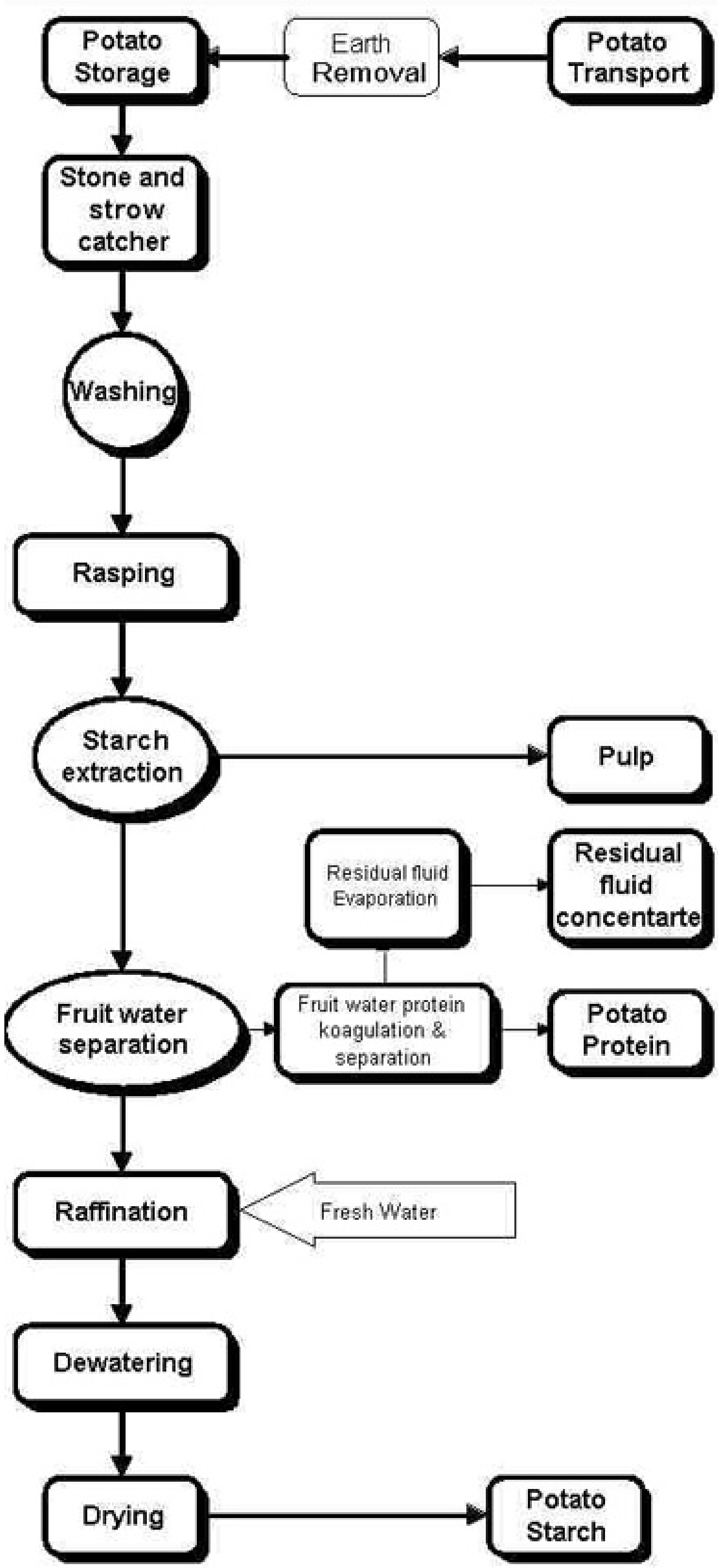

Fig.4 Flow Chart for Potato starch extraction

Modification of Native starches:

As we mentioned, native starch is cold water insoluble with very low WAI (Water Absorption Index). When We modify this starch, we can make it cold water soluble with much higher WAI. Some other useful Properties can be imparted when it is modified chemically by changing the molecular arrangement to change The molecular weight of native starch. Precooked starch has high WAI.

The modification of native starch can be carried out by:

1) Paste/Slurry Reaction- followed by Drum/Flash Drying to get Dry Powder/flake form.
2) Extrusion cooking arrangement.

We will discuss the technology used in 2), i.e. Extrusion cooking using a single screw Extruder.

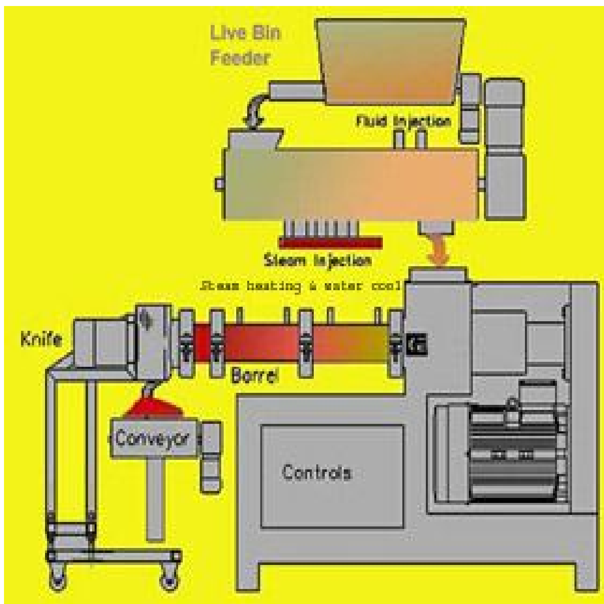

Fig5. Schematic of arrangement for Modifying native starches on Extruder.

Extruder is a Bio-reactor which can apply necessary temperature and shear to the Food materials and offer continuous shaping of the cooked materials by extruding through a suitably shaped die orifice. A Rotary cutter usually provides continuous cutting into short lengths, of the continuously emerging product. Thus an Extruder could be termed as Cooker, because pre-moistened ingredients are cooked to the required degree with proper control of the process conditions.

The equipment usually consists of a Single helically flighted screw shaft (rotor) which rotates inside a helically flighted barrel (stator). Twin screw Extruder with two working screws are also used but their use is limited in this application owing to their high capital cost over single screw machines.

The feed materials are dropped over one end of the screw (feeding end) and being continuously pushed forward (toward the die) get compacted and gelatinized (cooked) to the required degree by the external heat supplied (usually by steam) as well as the shear energy applied by the rotating screw. The helically flighted barrel inner liner also aids to build up the shear by minimizing the slippage of food materials inside the barrel and also ensures ingredients are positively conveyed for maximum output from machine.

However, great many types of Extruder are available for varying processing needs. They could be High shear, medium shear or low shear type. It is found, that for processing starchy materials, low shear type are most suitable, since excessive shear damages starch components by excessive working. The sticky nature of these materials also prevent normal extrusion since the materials tend to stick inside the machine, as well as die, thus affecting the quality and output of produce from machine. Hence, not only the screw is specially designed for this purpose, it is also it is advisable it be made in separate segments and assembled on a shaft. This also ensures trials with separate configurations and establish best configuration for a formulation. Since temperature is critical process parameter, it is desirable to have precision PID controllers because any undercooking or excessive cooking could be detrimental for final product quality. Usually screw speeds range is from 300-700 RPM for processing such materials. Water cooling circuits are used to remove the excess heat automatically when temperature overshoots limit. An Extruder with a L/D Ratio around 25/1 is desired with optimal Compression Ratio for the required degree of shear. In the Extruder, shear is built up by using multiple screw segments with varying pitch- increasing pitch at the feed end which gradually reduces as it approaches the die end for compression and cooking of ingredients. Various screw segments are held together by “shear locks” clamped between them to separate the Feed, Compression, Kneading and Cooking zone on the screw shaft.

Extruders usually have Melt pressure indicators so that it offers visual indication of the process pressure so that appropriate steps can taken. The indicators should be free of any hold up areas where material can enter making it difficult for them to clean in event of blockages. All temperature and pressure sensors must extend through barrel walls inside the material to take correct readings.

The Die is also an important area to be looked into. It should have greater residence time than inside the Extruder (in the Extruder, materials are usually between 10-20 sec). The ratio between the residence time in the Die/Extruder is very critical and can made difference. The goal is to gelatinize around 80% or more, so that the starch has good cold swell properties. The process temperature is usually between 60-110-120C from feed opening towards the die. Steam heating and water cooling circuits are employed for temperature regulation of the barrel which passes heat to the materials. Extruder pressures range between 400-600 psig. It is also important to have precision speed controllers for all drive motors so that retention time while hydrating/precooking and cooking could be easily controlled.

Also, it is necessary to hydrate the feed materials before feeding into the Extruder and proportions range between 17-30% m.c.b. It is desirable to introduce water by water spray nozzles which are supplied through dosing pumps. The right proportion of water coupled with screw speed and temperature gradient will ensures proper gelatinization of materials and produce starch with good cold swell properties. It is further desirable to use a Preconditioner for adding the water before feeding into the Extruder, and better to precook the ingredients so that it reduces SME (Specific Mechanical Energy) from Extruder and thus save delicate starchy components from danger of degradation. The mix should include some vegetable oil which functions as lubricant and assures good extrusion by minimizing sticking to machine and die. The Extruder should have extra injection ports on the barrel so that suitable chemicals could be metered in via appropriate dosing pumps if chemical modifications are to be done on the starch.

When using the Extruder for experimenting on starch, statistical analyses indicated that temperature, moisture content, screw speed and interaction between temperature and moisture significantly affected starch gelatinization during Extrusion. The cooking increased sharply with increasing temperature when moisture contents were 24-27%, but increased only gradually when moisture was 18 or 21%. Similarly, at low screw speeds, material didn’t sheared enough and cooking effect was less, but too high speeds also reduced gelatinization because of less retention time in the Extruder. Similarly the die nozzle size also influenced the cooking of starch- very large size die hole resulted in poor cooking because of low back pressure and less retention time of flour. Hence, by trial it is necessary to arrive at proper screw & die configuration as well as process conditions to get best results.

When a modified starch is prepared on Extruder, it contains appreciable moisture in excess of 20% while the goal is no more than 8-10% for storage. Hence, it is necessary to dehydrate or dry the wet product by using hot air dryer. The Dryer can be continuously operated if it accepts inputs directly from Extrusion stage. Then, after drying, the starch can be cooled down by suitable air coolers and then pulverized to free flowing powder form in suitable pellet mill or pulveriser.

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