Starch Technology
OCCURRENCE OF STARCH

Starch constitutes the nutritive reserves of many plants. During the growing season, the green leaves collect energy from the sun. In potatoes this energy is transported as a sugar solution down to the tubers and it is down there 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. Next spring enzymes are also responsible for the re-conversion of starch to sugar - transported upwards as energy for the growing plant.

The potato, *Solanum tuberosum*, is a perennial plant of the *Solanaceae* family, grown for its starchy tuber. The potato originated in the Andes, South America and is grown in the temperate climatic zone round the world.

STARCH QUALITY BEGINS IN THE CLAMP.

On roots or stored in clamps during winter the tubers stay alive and need air for respiration and life activity.

Potatoes consume a small amount of their own starch during winter to maintain life functions until spring. This requires fresh air and the respiration causes generation of heat.

If the surrounding temperature falls with a risk of frost, the tubers try to save their skin by extensive conversion of starch to sugar in order to lower the freezing point in the cell juice. If this does not suffice, the tubers die. Potatoes therefore must be adequately covered when stored.

If the potatoes get warm, respiration increases, raising the temperature further. A lot of starch is used for the respiration and the tubers will die of heat.

Unfavorable storage conditions and damage during transport cause starch losses and, in the worst case, dead and smashed potatoes, which are disruptive for the process. Supplies of bad potatoes have to be rejected.

EFFICIENT CLEANING AND WASHING.

Approximately 5% dirt is adhering to the potatoes at delivery. Some is removed on a rotating bar screen before the potatoes are temporarily stored. The potato store is a necessity to secure the supply of potatoes overnight and in some places during weekends.

Soil and dirt not removed in the washing station give problems later. The washing is therefore very important. The washing is a counter current process, with fresh water or condensate added through pressure nozzles in the final step.

The potatoes are flumed by water in channels - passing a stone trap - to the washing station. The stone trap take advantage of the difference
in specific weights between stones and potatoes - an upstream water flow carries the potatoes over the stone trap, while the heavier stones are trapped and collected on a stone conveyor.

The water level in the washing drum is kept low so potatoes do not float. The washing ensures that the potatoes rub vigorously against each other. The rubbing is essential for the removal of surface impurities. Impurities resembling starch in specific density and size cannot be removed otherwise. The floating water is recycled after screening and settling of sand in pools.

The quantity of water used for fluming and washing is identical with the quantity of clean water applied in the final high-pressure spray.

<table>
<thead>
<tr>
<th>Typical by-products</th>
<th>Per ton of potatoes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stone and sand</td>
<td>15 kg</td>
</tr>
<tr>
<td>Soil</td>
<td>40 kg</td>
</tr>
<tr>
<td>Straw and floating material</td>
<td>10 l</td>
</tr>
<tr>
<td>Washing water</td>
<td>300 l</td>
</tr>
</tbody>
</table>

The washed potatoes are conveyed to a buffer bin feeding the rasper.

RASPING.

Rasping (grating) is the first step in the starch extraction. The goal is to open all tuber cells and release the starch granules. The slurry obtained can be considered as a mixture of pulp (cell walls), fruit juice and starch. With modern high-speed rasper, rasping is a one-pass operation only.

USE OF SULFITE.

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 colored components, which adhere to the starch.

Sulfur dioxide gas or sodium bisulfite solution therefore has to be added. A considerable reduction potential of the sulfite compounds prevents discoloration. Sufficient sulfite has to be added to maintain the juice and pulp light yellow.

EXTRACTION.

Powerful washing is needed to flush the starch granules out 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 extraction takes place in closed systems allowing flushing with the potato juice itself. It has the advantage that the juice can later be recovered in concentrated and undiluted form, reducing cost for evaporation, transport and landspreading.
The released starch discharges from the extraction sieves along with the fruit juice, and the cell walls (pulp) are pumped to the pulp dewatering sieves. The pulp leaves the dewatering sieve as drip-dry - i.e. 12-15% dry matter. The extraction is a counter current process in which the pulp-dewatering screen is actually the last step.

The extraction takes place on rotating conical sieves, where centrifugal power increases the capacity per unit of area. The high efficiency makes it feasible to utilize high quality sieve plates made of stainless steel, which will withstand abrasion and CIP-chemicals. The sieve plates have long perforations only 125 microns across.

**CONCENTRATION AND REFINING.**

Excess juice is removed on 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 process used today.

A dual refining option operating with two refining lines in parallel is of particular advantage in large plants. The overflow from the traditional main refining line is adjusted to a rather generous content of starch and this stream is then refined in a separate fine granule line designed to process the relative smaller starch granules in this flow. The refined starch from both lines is combined before dewatering and drying.

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 fiber 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 fibers 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 fibers and the smaller starch granules into the overflow and the larger granules into the underflow.
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 tuber 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 color or whiteness may be improved by the sparing use of sulfite 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 colored components, which have to be removed in the water treatment plant.

**COOLING**

Cold process water retards bacterial growth. Cooling the fruit juice recycled to the extractor's retards microbial growth and contributes to the control of microbial breakdown of protein and the development of bad smell in the effluent.

**CIP - CLEANING IN PLACE.**

Cleaning In Place (CIP) is done with caustic and hypochlorite as cleaning agents. Caustic is a powerful agent for removal of the protein build-up on 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 refined and concentrated starch milk is dewatered on rotating vacuum filters.
The moist starch from the rotating vacuum filters is dried in a flash dryer with moderate hot air. The air is indirectly heated. Potato starch is dried to 20% moisture.

Before delivery the starch is sifted on a fine sieve in order to remove any scale formed in screw conveyors etc.

Instead of drying right away the purified starch milk may by modified by chemical means before drying or it may be hydrolyzed and further processed into glucose or fructose syrup.

**MODIFICATION**

Most starch is used for industrial purposes. Starch is tailor made to meet the requirements of the end-user giving rise to a range of specialty products. Many and sophisticated techniques are applied.

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

These specialty products are named modified starches. They still 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.

A multi-purpose reactor and process may be designed for the wet modification of a range of products like thin-boiling starches, ethers and esters covering specialty starches used by the paper, textile and food industries.

**Viscosity**

In the food industry potato starch is valued because of its high viscosity and its clear gel when cooked. In essence the food manufacturer buys functionality and viscosity is the prime reason for applying starch.

Potato starch is the only commercial starch already "modified" by nature. Its high content of chemically ester-bound phosphorous is responsible for its high and unique viscosity.

The Brabender Viscograms illustrated in the figure above are made with 4% potato starch and 6% tapioca starch respectively to reach comparable levels of the viscosity curves - a most dramatic difference explaining the competitive edge of potato starch.

**Application.**

Potato 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 or biogas fermentation.

The concentrated fruit juice is rich in protein - half of which may be heat-denatured, recovered and dried. The potato protein is used in the fermentation industry and in feed compounds. Combined with a water saving process 9-10 kg of commercial protein may be recovered from one t of potatoes.

Starch finds uses in fast food, sweets, sausages, tablets, and paper, corrugated board etc. and plays a prominent part in our everyday life.

**ECONOMICS**

The estimated world production of potato starch 2004 is close to 3½ million t per annum. Production in areas outside those represented in the graph is negligible. The European figure includes Russia. The production is confined to the temperate climatic zone. The high European output is due to ideal climatic conditions and a protective policy in the European Union.

The factory portrayed in the above financial break down is owned by approximately 300 farmers.

Operational expenses are moderate. Personnel expenditure is made up of salaries and wages to a total crew of 35 people - ten of which are process operators. Weekend shifts are only manned with two persons. Their output is typical 750 t of starch per day - non-stop during a 100 days production campaign.

The Danes are the highest ranking potato starch producers in the world calculated per capita followed by other European Union member states.
DETERMINATION OF STARCH CONTENT IN POTATOES.

The starch content of fresh potatoes is correlated with potato density. A sample of 5050 g potato in a net basket is weighed above water and then again immersed in clean water of maximum 18 °C.

\[ W_o = \text{weight of the potato sample} \]
\[ W_u = \text{weight of sample under water} \]
\[ \text{Density } d_{\text{potato}} = \frac{W_o}{W_o - W_u} \text{ g/ml} \]

Starch dry matter = \[ (d_{\text{potato}} - 1.015059) / 0.0046051 \% \]

The calculated figure in per cent deviate less than 0.05 from values read out of the EU-table enforced by the European Commission covering potatoes with 13% to 23% starch dry matter. A short version of the table - as valid per 1. July 1996 - is as follows:

<table>
<thead>
<tr>
<th>( W_o )</th>
<th>( W_u )</th>
<th>Density ( d )</th>
<th>Starch dry matter of potatoes</th>
<th>Potatoes to produce 1 t commercial starch kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>g</td>
<td>g</td>
<td>g/ml</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5050</td>
<td>352</td>
<td>1.075</td>
<td>13</td>
<td>6,533</td>
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<tr>
<td>5050</td>
<td>372</td>
<td>1.080</td>
<td>14</td>
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<td>412</td>
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<td>5050</td>
<td>545</td>
<td>1.121</td>
<td>23</td>
<td>4,056</td>
</tr>
</tbody>
</table>

1) Weight of potato sample above water.  
2) Weight of sample immersed in water.  
3) Calculated density = \( \frac{W_o}{W_o - W_u} \).  
4) Starch content according to the official table.

Exchange rate 1. March 2006:  
1 EUR = 1.187 USD

Unfavorable storage conditions may cause enzymatic conversion of starch to glucose affecting starch yield without changing the under-water-weight and density of potatoes. Therefore the method only applies to fresh potatoes.

CAP - COMMON AGRICULTURAL POLICY

The expiration of the European market regime for starch potatoes at the end of 2011 was expected within the industry to lead to a 30 % reduction in the production of starch potatoes. Two campaigns after expiration of the EU quota system have now demonstrated the opposite effect in Denmark. The Danish potato starch production has started to expand again.