International
Starch
Institute

WHEAT STARCH WET MILLING TM33-2e

"Worldwide, wheat is a most important cereal crop with 600 million metric tones of grain per year - close to that of corn and rice. The high protein content of wheat grain makes it an important item of human nutrition. By-products of wheat processing are wheat germ oil, wheat gluten and wheat starch. Also the straw finds special applications as reinforcement of building materials and as bio-fuel".

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THE OCCURRENCE OF STARCH

Starch makes up the nutritive reserves of many plants. During the growing season, the green leaves collect energy from the sun. This energy is transported as a sugar solution to the starch storage cells, and 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 - released from the seed as energy for the growing plant.

WHEAT VARIETIES

Wheat is a cereal plant of the genus *Triticum* of the family Gramineae (grass family). Modern wheat varieties are usually classified as winter wheat (fall-planted) and spring wheat - most of the wheat grown is winter wheat. Some ancient varieties of wheat like einkorn (*T. monococcum*), emmer (*T. dicoccum*) and spelt (*T. spelta*) are still being cultivated for specialty purposes. *Triticum aestivum* is by far the most important of all wheat species.

Flour from hard varieties derived from bread wheat (*T. aestivum)* contains a high gluten content and is preferred in bakery products. The hardest-kernelled wheat is durum - macaroni wheat (*T. durum*); it is essential for the manufacture of pasta products.

WHEAT GLUTEN

Gluten is proteins of the wheat. Gluten forms long molecules insoluble in water. This gives dough its characteristic texture and permits breads and cakes to rise because the carbon dioxide released by the yeast is trapped in the gluten superstructure.

Gluten is particular important in the manufacture of starch from wheat because gluten is a most valuable by-product representing half the turnover. In fact the starch is by some manufacturers considered the by-product and gluten the main product.

If the gluten is extracted and gently dried in hot air at moderate temperatures it maintains it's characteristics. If so it is designated "vital gluten". Vital gluten may be added as a dry powder to flour otherwise low in gluten and thereby improve the baking qualities of the flour. The Danish and Scandinavian climate favours weak wheat of poor baking qualities. The gluten content is low and the texture of the gluten is short. A remedy is mixing it with French or Canadian wheat known for their better gluten quality. As an alternative the baking characteristics may be improved by mixing it with vital gluten powder.

Commercial gluten is dried to minimum 90% dry matter and a typical composition is:

- 70 - 80 % crude protein,
- 6 - 8 % crude lipids,
- 10 - 14 % carbohydrates,
- 0.8 - 1.4 % minerals.

Gluten in general is used as a meat extender in both food and feed. The fermentation industry consumes large amounts of gluten and by acid hydrolysis it is used for production of hydrolyzed vegetable protein and glutamic acid. A gluten based meat analogue was invented by the International Starch Group. It replaces up to one third of minced meat in popular meat balls. Another invention combines emulsifiers and gluten into a spray dried powder improving both baking quality of the flour and shelf life of the bread.

A KITCHEN EXPERIMENT.

Gluten is an invisible integrated part of the wheat flour. To make it visible and to illustrate its vital properties a small and simple experiment may serve the purpose. Form flour into a dough with a little water. Knead by hand a small lump of dough under a squirt of tap water. Apply water sparingly while kneading. The white starch will run off with the water and may be collected while the dough stays coherent. Gradually the starch is washed out and the remaining dough is made up of pure gluten with a cohesive chewing gum like consistence. Pulling the dough at this point will elongate the lump until it bursts. The elongation before bursting indicates the baking quality of the flour.

WHEAT STARCH

Wheat starch granules are divided in two groups by size, B-starch (15 - 20 %) is 2 - 15 µm diameter and the larger A-starch granules (80 - 85 %) are 20 - 35 µm. B-starch is contaminated with pentosans, fibres, lipids and protein to an extent requiring special treatment in the factory

WHEAT GERM OIL

Wheat germ oil is contained at 8 - 12 % in the fresh wheat germ which is 2½ % of total grain weight.

Its fatty acid composition (%) is:

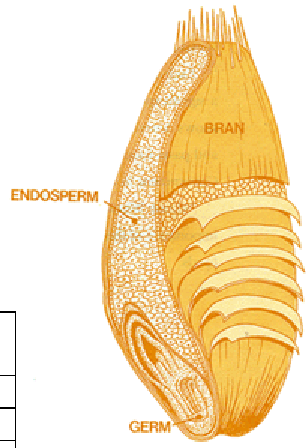
C16:0	C18:0	C18:1	C18:2	C18:3
11-20%	1-6%	13-30%	44-65%	2-13%

Due to its high level of linoleic acid (C18:2) wheat germ oil is used for dietary purposes and in cosmetic preparations.

Wheat germ oil is expelled or extracted from the germ. Because the germ is removed from the endosperm during the dry milling it is not a by-product from the industrial wet milling of wheat.

RAW MATERIAL FOR STARCH

Wheat grain may be taken in as raw material as is the case with corn, but typically the starch manufacturer prefers to buy flour from a flour mill.



Composition of the wheat kernel	
Bran	12½ %
Germ	2½ %
Endosperm	82 %

The number of parts by weight of flour that is produced from 100 parts of wheat is termed the extraction rate. Flour extraction ranges from 73 to 77 % resulting in an average mill feed production of about 25 %. It is apparent that the mill feed contains, in addition to the bran, a significant portion of the starchy endosperm.

Typical flour composition on dry matter basis	
Moisture content:	13.5 %
Total protein content:	13 %
Fibre content:	1.0 %
Ash content:	0.75 %

The flour must be suitable for human consumption and it has to be milled to a specific particle size distribution.

THE MARTIN PROCESS

The kitchen experiment previously described is also a demonstration of the old Martin process still in use. The process resembles

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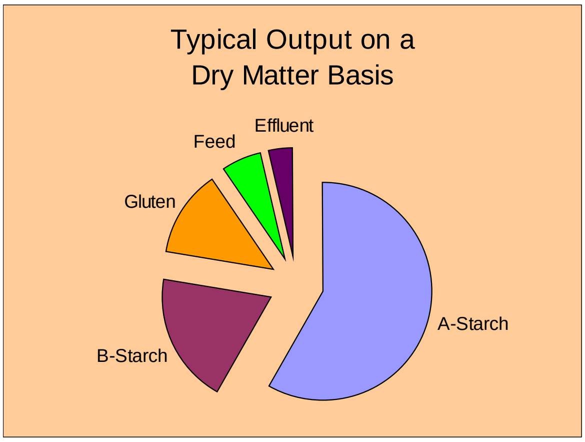
very much the described experiment demonstrated by washing out the starch from a lump of dough with tap water. The classic Martin process uses ordinary baking equipment for the kneading and maturing of the dough. The combination of kneading and time develops the gluten and makes it cohesive. Until matured by kneading and time gluten will not allow the starch to be flushed out without falling apart with losses of both starch and gluten.



Actual ratio of end products varies with the flour.

THE SCANDINAVIAN PROCESS

Slurry processes (batter processes) are more industry friendly and make closed continuous handling possible. Several variants have been practiced over time, but the Scandinavian Process is by far the most elegant and efficient.

The Scandinavian process is based on wheat flour as raw material and it is designed to process even weak (soft) Scandinavian wheat difficult to process otherwise and nevertheless obtain vital gluten of excellent properties. The Scandinavian process also works well with completely fresh and unconditioned flour minimizing storage capacity requirement. In general the Scandinavian process is very robust and of advantage to any wheat.

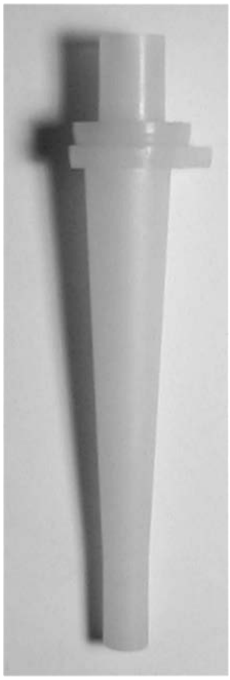
Flour is pneumatically conveyed from intermediate silos into a feeding bin equipped with means to separate air and flour. The control system continuously discharges flour into a stream of warm water. Water and flour is mixed in-line and the slurry obtained is homogenized in a high-speed in-line disintegrator.

The homogenized slurry is right away separated into the following fractions by a three-phase decanter (tricanter):

- Starch - *Heavy phase*
- Gluten - *Middle phase*
- Pentosanes - *Light phase*

THE STARCH FRACTION is the heavy phase containing the major part of A-starch. It is re-slurred and refined - much in the same way as starch of any other origin as described in "Starch Refining".

THE PENTOSANE FRACTION - the light phase from the tricanter - contains various gums. It is preferably mixed with other by-products and used as a wet feed. The wet feed may be dried, mixed with bran or sold as such.



Hydrocyclone (cyclonette) manifolded in systems of hundreds of units.

THE GLUTEN FRACTION is the complex middle phase. It contains the gluten, fibres, solubles, B-starch and some A-starch. After maturing of the gluten these constituents are split into sub-fractions.

Gluten Maturing. Before separating the gluten fraction the stream is carefully treated in a maturing reactor. The reactor is specially designed for the maturing of gluten. During maturing the “gluten matrix” of

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wheat flour is softened and bound starch granules are released. Glutenin and gliadin proteins can now start to form long molecular chains i.e. gluten formation can take place.

Gluten Agglomeration and Recovery. The gluten maturing step is followed by a treatment in special gluten agglomerators.

In the agglomerators the matured gluten is combined into lumps formed of glutenin and gliadin. The gluten lumps are screened off and washed on bend screens.

The wet gluten is dewatered on screw presses and dried. By gentle drying in hot air in a ring dryer the gluten retains its vital properties. After in-line milling and classification the product leaves the dryer ready for packing and sale as Vital Gluten.

B-starch recovery. After gluten recovery the residual fraction is separated on hydro-cyclones. The heavy A-starch goes in the underflow and the lighter B-starch goes with the overflow.

A-starch recovered with the underflow is concentrated and combined with the A-starch main stream.

B-starch is recovered from the overflow by special recovery cyclones and dewatered on a decanter. The B-starch is dried in hot air in a ring dryer or drum dried and used as pre-gelatinized starch.

Hydrocyclone Unit

Solubles. A clarifier removes the last bit of starch from the overflow and only solubles and water remains. The clarified overflow leaves the factory as an effluent to be disposed of by landspreading or biogas digestion.

A-STARCH REFINING

Starch is refined by washing with fresh clean water. With hydrocyclones it is feasible to reduce fibre and solubles including soluble protein to low levels with a minimum of fresh water. To save 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.

By using multi stage hydrocyclones all soluble materials and fine cell residues are removed in a water saving process. The refined starch milk contains an almost 100% pure starch slurred in pure water.

Starch is among the most pure of all agri-cultural products. Actually, purity is the most important parameter in being competitive.

A-STARCH DEWATERING.

The purified A-starch milk is discharged to a peeler centrifuge for dewatering. The peeler filtrate is recycled to the process. The dewatered starch is batch-wise peeled off and discharged by gravity to the moist starch hopper.

A-STARCH DRYING

From the moist starch hopper the A-starch is fed by a metering screw conveyor into a flash dryer and dried in hot air. The inlet air tem-perature is moderate. The dried starch is

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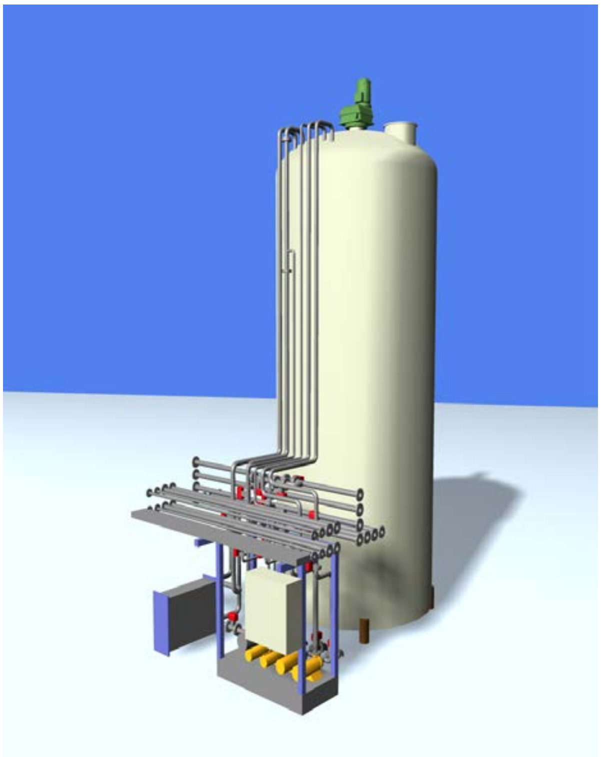
Peeler Centrifuge

pneumatically transported to a starch silo ready for screening and bagging. The moisture of starch after drying is normally 12-13 %.

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

CLEANING IN PLACE (CIP)

To secure a high standard of sanitation in the



plant a cleaning system is necessary. To minimize shutdown periods and thereby causing production losses, all equipment is designed to minimize the need of frequent cleaning. Cleaning and preventative maintenance must be planned once a month.

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. 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 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.

STARCH SWEETENERS

Starch sweeteners are an important outlet for wheat starch and in many plants starch is not dried at all. In stead the refined A-starch slurry is further processed into starch syrups.

For wheat starch the glucose is particular important. Basic and typical units of operation are:

LIQUEFACTION. The refined A-starch slurry is pH-adjusted and enzymes are added. The prepared slurry is heated by direct steam in a steam jet. The liquefaction is typically a two

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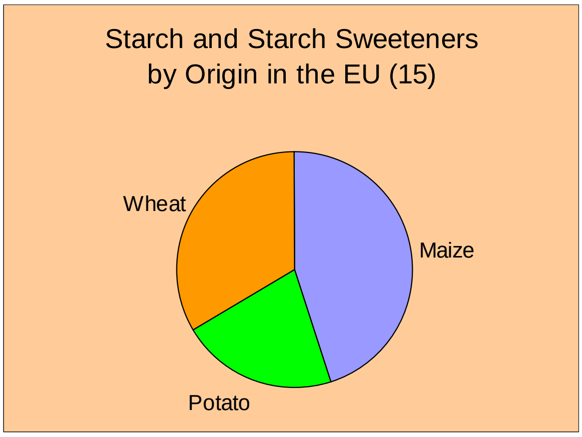
stage process. The combination of heat and enzymes gelatinizes and thins the starch. The enzyme does the work by cutting the long starch molecules into pieces by hydrolysis. A low DE hydrolysate is formed and at this point the starch has been converted into a maltodextrin. (DE= Dextrose Equivalent).

SACCHARIFICATION. The low DE hydrolysate is pH and temperature adjusted once again and new enzymes added to produce glucose with a higher DE. Glucose of different composition can be made depending on the enzymes added and the process applied - even products close to pure dextrose.

PROTEIN FILTRATION. New technology allows cross-flow membrane filtration of the hydrolysate. By dia-filtration glucose may be recovered from the filter residue leaving a protein rich mud to be discharged as animal feed.

CARBON TREATMENT. The glucose

Liquefaction Converter



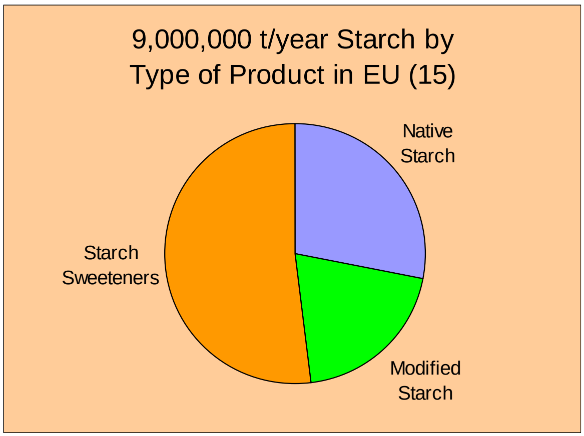
The European wheat starch industry has expanded 2½ times during a decade - a growth rate of 14% p.a..
To a large degree the wheat starch sector is competitive by virtue of its high by-products credits in relation to the cost of the basic agricultural crop.

hydrolysate is heated and treated with activated carbon to remove impurities and colour bodies and then filtered.

ION EXCHANGE. The glucose hydrolysate is demineralised with ion exchange resins in a "merry go round" arrangement. Cation resins remove various ions as sodium, calcium, traces of iron and some amino acids. Anion resins remove ions like chloride, sulphate, phosphate and most residual amino acids.

EVAPORATION. The refined glucose syrup is concentrated by evaporation to its final commercial dry matter content. The syrup is now ready for drumming off or for road tanker transport.

A MULTITUDE OF SWEETENERS. By varying the procedures a range of commercial products can be made and the pure dextrose syrups may even form basis for further processing into High Fructose Syrups utilizing sophisticated techniques like enzymatically isomerising and chromatography.



Starch hydrolysates are found in more than 50% of European processed foods.

Application.

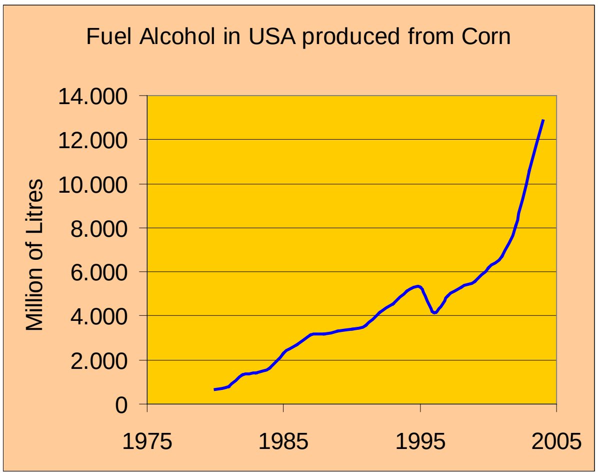
Being a pure renewable natural polymer, starch has a multitude of applications.

Commercial wheat starch is used in the manufacture of sweeteners, sizing of paper and textile and as a food thickener and stabilizer.

Nine million t per annum of starch and starch sweeteners are manufactured in the European Union and one third is originating from wheat.

In the European Union 40% of native and modified starches is consumed by the paper industry being the most important outlet at present.

Increasing amounts of grain, however, is supposed to be consumed by the new bio-fuel industry. In USA this development has already started on maize as raw material. In Europe wheat is the prime candidate.



In Europe wheat is the candidate as raw material for future bio-fuel production.

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