BASIC STARCH TECHNOLOGY

VERSION 2.0
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What is starch?

Plants store their energy reserves in the form of carbohydrates e.g. starch. Starch is usually closely packed as small granules in the tubers, seeds, leaves or roots of the plants.

The plant produces energy through photosynthesis. The plant uses starch to produce further energy when it is unable to produce energy through photosynthesis (e.g. in the winter). It uses enzymes to degrade the starch into glucose.

Why this interest in starch?

• Starch is – second to cellulose – the most widespread biological material on earth
• Approx. 75% of the energy consumed world wide comes from starch or starch based products
• Starch plays a big role in industry, e.g as stabilizer, binding agent, texturizer, gelling agent, filler, energy for fermentation, filter in yeast production and for production of glucose and starch sugars.

Only few plants are used in the production of starch. As examples we can mention corn, wheat, tapioca, barley, rice and potatoes.

The structure of starch

No matter which plant the starch comes from it consists of two large molecules:

• Amylose
• Amylopectin

Both molecules are constructed of the simplest sugar in nature – glucose. The glucose is bound together in long chains, see fig. 1.

Fig. 1: Amylose & amylopectin

Amylose
The amylose molecule consists of long chains of glucose units that are twisted together in helixes.

Amylopectin
The amylopectin molecule consists of several branched chains of glucose units.
The starch granule

The amylose and the amylopectin are packed together in units called starch granules. The granules will, depending on their origin, vary in size and shape. The starch from a certain plant will be typical for that plant. As an example the corn starch granules are small and edged with the potato starch granules being large and oval, see fig. 2.

The granules are not only different in size and shape, the content of amylose and amylopectin is also different from variety to variety. As an example, corn starch contains approx. 27% amylose and potato starch approx. 20%. Waxy maize is a type of starch that does not contain any amylose, but has an amylopectin content of 99-100%.

It is not exactly known what the surface of the starch granule looks like, but it is described as a furry pool ball.
The starch granules’ capacity to absorb water

In its natural state, starch is not soluble in cold water. The explanation for this insolubility is outlined in fig. 3.

In a cold medium the starch chains are kept together by electrical links. This has the effect that the water is unable to get between the chains.

During heating, these electrical links are broken and the water is able to get between the chains and bond them. This phenomenon is called a gelatinization. Fig. 4 illustrates what happens to the starch granule as it is heated and starts to absorb water.
For the starch to start to absorb water it is necessary to supply a certain amount of heat.

As heating is increased the granules swell more and more as the starch absorbs more and more water. The granules can swell to approx. 100 times their original size. You can compare this process to a balloon being inflated.

After a while the granules cannot hold any more water and they burst. Just prior to the granules bursting the viscosity is at top level. This viscosity is called the peak viscosity.

After bursting and further heating, the granules break, first into big fragments and then into smaller and smaller fragments. Finally the starch will be completely dispersed and a complete gelatinization has taken place.
Measuring the viscosity

You can measure the viscosity in many different ways. In the starch industry you often use a Brabender Viscograph (hereafter called a Brabender). A Brabender can in one curve show the gelatinization temperature, the peak viscosity, the viscosity at a certain temperature and like parameters (fig. 5).

On a Brabender the viscosity is measured in Brabender Units (BU). The viscosity is measured continuously, while stirring, through a well defined heating- and cooling process.

A typical temperature sequence on a Brabender (fig. 6), begins with a temperature of 35°C. The suspension of starch and water is then heated with 1.5°C/min. to 95°C and kept at this temperature for 30 minutes. After 30 minutes the suspension is cooled with 1.5°C/min. to 25°C and kept at this temperature for 30 minutes.
For the quality control of the viscosity you usually analyze in de-ionized water. This is sufficient when comparing the same type of starch, e.g. starch of the same origin and with the same kind of modification. But when comparing starches of different origin and with different kinds of modification you need to do this in the product for which they are meant (fig. 7).

Comparison between fig. 6 and 7 shows there is a big difference between an analysis in de-ionized water and an analysis in a product. This stresses the importance of knowing the target product.
Why use starch in food?

Superior Potato Starch, which is native (non-modified) starch from KMC is used in a number of applications in the food industry such as:

- Texturizer
- Thickening agent
- Gelling agent
- Stabilizer

Typical areas of application are:

- Processed meat products
- Instant noodles
- Instant soups
- Tablets

Modified starch

Native starch has its limitations in food applications. Some of the disadvantages include:

- Retrogradation – syneresis
- Loss of viscosity at low pH values, high processing temperatures or mechanical treatment
- Long texture

The native starch swells quickly and loses its viscosity almost as quickly again during continued heating and forms a viscous coherent gel. This quality is perfect in some applications, but undesirable in other applications.

When you modify the starch you can adjust the properties of the starch to fit specific applications and to resist some of the actions which the native starch yields to (fig. 8).

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Fig. 8: Limitations of native starch
Cross-linking

The most common method of modification is cross-linking. When you cross-link starch, a chemical bond takes place between the starch chains (fig. 9).

By cross-linking the starch you get the following properties (compared to native starch)

- Shorter texture
- Stability at low pH values
- Heat/shear stability

The KMC standard name for cross-linked starches is X-AMYLO.

In fig. 10 below some of the abovementioned properties are illustrated.
As you can see, the gelatinization temperature is higher in a cross-linked starch than in the native starch and at the same time the relatively high breakdown is no longer seen in the X-AMYLO 100. The viscosity, especially after cooling, is also significantly higher than in native starch. During the holding period at 95°C it is furthermore evident that the cross-linked starch is stable when stirred.

By cross-linking the starch a lot you can produce a starch which under normal circumstances has almost no viscosity. If this starch is subject to either low pH, high temperature, heavy mechanical processing or all of these at the same time, the starch will, however, produce some viscosity (fig. 11).

Heavily cross-linked starches therefore “demand” a heavy treatment in order to give any viscosity whereas other starches subject to the same conditions will collapse with a weak or no viscosity as the result. The most cross-linked standard product in the KMC range is X-AMYLO 75.

Typical applications for cross-linked starches are:

- Meat products that are heated for a long time or that are autoclaved, e.g. canned goods
- Instant soups/gravies where a creamy consistency is desired after warm water is added

The international designation for KMC’s cross-linked starches is: **Di-starch phosphate**. This indicates that two starches are bound together with a phosphate bridge. Cross-linked starches also have an EC-code: **E-1412**.
Stabilized starches

After being heated to a boil followed by cooling, native starch will retrograde (revert to its original state) which again can cause syneresis (water will separate) = the starch loses its ability to hold water. Syneresis is often seen as water forming on the surface.

To avoid retrogradation you can stabilize the starch and you can thereby avoid the syneresis. There are several ways in which to stabilize the starch. KMC uses a so called acetylation (fig. 12).

**Fig. 12:**
Chemical structure of acetylation

**Fig. 13:**
Viscosity curve for Amylacetate M170 compared with native potato starch

AMYLACETATE M 170 is one of KMC’s most sold acetylated starch products. As shown in fig. 13, the viscosity changes a little when you acetylate. The most important change is a lower gelatinization temperature.
Acetylated starches can – as other modified starches – be more or less acetylated. It is shown (fig. 14) that the acetylation causes small changes in the viscosity profile of the starch. The most important change in the profile is the lower gelatinization temperature in the more acetylated starch.

![Viscosity curves for different degrees of acetylation](image)

When the starch is acetylated you get the following properties (compared to native starch):

- Improved stability against retrogradation
- Lower gelatinization temperature
- The boiled starch is more transparent
- Improved elasticity.

Typical applications for stabilized starches:

- Instant noodles
- Soups
- Gravies
- Snacks
- Frozen fish products

The standard name for KMC’s stabilized starches is **AMYLACETATE**. The international designation for KMC stabilized starches is **Acetylated starch**. The EC-code is: **E-1420**.
Combinations of modifications

A combination of processing methods is often seen in the modern food industry – with both a low pH, a relatively high processing temperature and also a demand that the product does not form syneresis. An example of such a product might be tomato soup which typically is homogenized and autoclaved, the texture must be short and the product may not form syneresis.

In order to function as well as possible, the starch for such a product needs to be both cross-linked and stabilized. Such a starch is often called a combination starch.

The above (fig. 15) is an example of native starch compared with a combination starch. In addition to the typical sequence for cross-linking you will especially notice that the gelatinization temperature - in spite of the product being cross-linked - actually is rather low compared to the native starch. This is the effect of the acetylation.

By using the combination starches it is actually possible to tailor the starch to a specific application. In spite of being developed with a certain application in mind, most starches can easily be used in other applications.

The standard names for the KMC products with this type of modification are: X-AMYLACETATE and ADAMYL.

The international designations for KMC’s combination starches are:

**X-AMYLACETATE**:

**ADAMYL**:
Acetylated di-starch adipate – EC-code: E-1422.
Thin boiling starches

In certain applications a high content of starch is desirable in order for the starch to be able to form a gel as in e.g. wine gums and licorice. If you use native starch or the previously mentioned modified starches as the gelling agent the paste would become too viscous during heating as a very high starch concentration is required to form a gel. In such applications you can with advantage use the thin boiling starches.

Thin boiling starches have a low viscosity compared to native starch and this enables you to use these starches in high concentrations without the viscosity getting too high.

In other applications, for example in instant soups, thin boiling starches are often used as a filler without any specific technical function.

The thin boiling starches have been degraded. The most common methods of degrading the starches are oxidation, acid hydrolyzing and enzymatic degrading. We will only address oxidation and acid hydrolizing.

Oxidation

Oxidation is the only type of modification where two different forms of modification take place simultaneously – a degrading and a stabilization like the acetylation (fig. 16).

Fig. 16: Chemical structure of oxidation

By oxidation the starch chains are broken down into smaller chains at the same time as the starch is being stabilized in the form of carboxyl groups.

The standard name for KMC’s oxidized starches for the food- and confectionery industry is GELAMYL.

The oxidized starches - in high concentrations - are characterized by giving a very low viscosity during boiling and a very high viscosity during cooling due to the high content of dry matter (fig. 17).
Like the other types of modified starches, oxidized starch can be produced with different degrees of oxidation, see fig. 18 below.

Typical applications for oxidized starches:
- Wine gums
- Licorice
- Pastilles
- Instant soups
- Anti-caking agent

The international designation for KMC’s oxidized starches is: **Oxidized starch.**
The EC-code is: **E-1404.**
Hydrolysis

As mentioned earlier, another way of degrading the starch is through an acid hydrolysis. When you use acid hydrolysis, the starch chains are degraded almost the way they are when oxidation is used. The difference is that the starch is NOT stabilized as it is with the oxidation. This shows in a much higher end-viscosity than with oxidation which is shown in fig. 19.

![Viscosity curves for different modification for thin boiling starches](image)

As you can see, the oxidized starch has a much lower end-viscosity than the acid hydrolized starch, which is due to the earlier mentioned carboxylic acid groups stabilizing the starch. When you acetylate the oxidized starch the result is a more stable starch which also appears from the figure.

Cook-up starches versus pre-gelatinized

As mentioned earlier, starch is not soluble in cold water. These starches are sometimes called “Cook-Up” starches because – as the name indicates – they need to be boiled/heated before gelatinization starts.

You can find starches in the market today that have been physically modified to be soluble in cold water. KMC does NOT produce such starches. We will, however, mention that these starches often are called “Pre-gelatinized starches”. The trade names often start with “Pre...”, e.g. Prejel VA70T from AVEBE or “Instant...”, e.g. Instant Pure-Flo from National Starch.

You usually produce the pre-gelatinized starch on a drum dryer, which in principle is a heated drum. The starch mixed with water is applied to the drum where it gelatinizes and is scraped off in flakes. The flakes are then crushed and sifted and the starch is ready.
Ask for more

The different types of starch and modified starch presently available from KMC cover a large number of applications.

There will, however, be cases when these starches are not sufficient. In these cases we please ask you to contact us, and our R&D department will work with you to tailor a starch to fit exactly your requirements.

All and any questions about this material are very welcome.