Starch

Application Sheet

Content:

Efficient liquefaction of starch

Alpha-amylases are widely used by starch processors to unlock the dextrose components in a liquefaction process. Whether the end-product is high fructose syrup, dextrose, maltose, maltodextrins or polyols, the process starts with an alpha-amylase that can be applied under a wide range of processing conditions.

Novozymes' alpha-amylase range provides the right tools for starch liquefaction.

Benefits

Novozymes offers a range of alpha-amylases that enables the starch processor to optimise the liquefaction process in terms of cost, quality and efficiency. The key features offered by the liquefaction product range are:

- Efficient DE development – when high DE development in a short time is a key parameter
- High dextrose yield – with minimal by-product formation
- Fast viscosity reduction – enabling high dry substance levels
- Low colour formation – reducing refinery costs
- Savings on chemicals and ion exchange costs by eliminating calcium addition

Products

Novozymes' starch liquefaction product range consists of five different alpha-amylases: Liquozyme® X, Liquozyme® Supra, Liquozyme Supra 2.2X, Termamyl® 120 L type L and Termamyl 2X.

The most important characteristics of the products in the alpha-amylase range are given in Table 1 below.

		Product		
Characteristics		**Liquozyme X**	**Liquozyme Supra and Liquozyme Supra 2.2X**	**Termamyl 120 L, type L and** Termamyl 2X
DE development power under standard conditions (see Fig. 1)		12.5	11.1	8.2
pH range		5.2-5.6	5.2-5.6	6.0-6.4
Calcium requirement (ppm)		5-15	5-15	40-70
Low maltulose generation		++++	++++	+
Low panose formation	With inactivation	+++++	+++++	+++++
	Without inactivation	+++++	+++	+
High DX	With inactivation	+++++	+++++	+++++
	Without inactivation	+++++	+++	+
Saccharif. savings	With inactivation	+++++	+++++	+++++
	Without inactivation	+++++	+++	+
Low colour formation		++++	++++	+
Chemical savings		+++++	+++	+
Ion exchange savings		+++++	+++	+
Viscosity reduction		++++	+++++	+++++
Ease of inactivation		++	+	++++

Table 1. Characteristics of Novozymes' alpha-amylase product range.
Note 1: in addition to the above liquefaction product range, BAN 480 L is also available for starch liquefaction.
Note 2: DE development power is measured as DE/120 min. under standard liquefaction conditions (see Fig. 1).
Note 3: best choice = +++++.

Termamyl 2X gives 2 times the performance of Termamyl 120 L, Type L. The dose can therefore be reduced. Likewise, Liquozyme Supra 2.2X gives more than 2 times the performance of Liquozyme Supra.

Further information on the above-mentioned products is available from the Novozymes Customer Centre. Other product variants may be available on request.

Performance

DE development

DE development in liquefaction is determined by enzyme dosage, process conditions and enzyme efficiency. The difference in efficiency between Termamyl 120 L type L, Liquozyme X and Liquozyme Supra is shown in Figure 1 below.

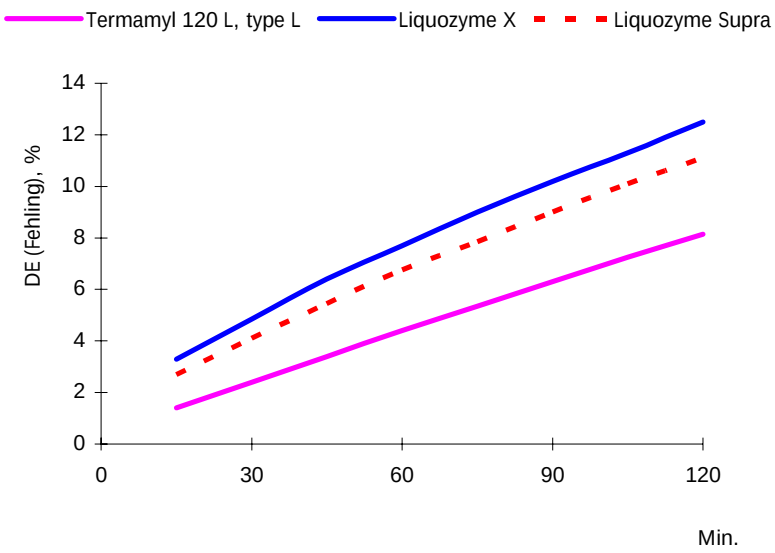

Fig. 1. DE develoment. *Liquefaction with Termamyl 120 L type L (0.4 kg/t DS; 70 ppm Ca; pH 6.2), Liquozyme X (0.4 kg/t DS; 5 ppm Ca; pH 5.5), and Liquozyme Supra (0.4 kg/t DS; 5 ppm Ca; pH 5.5).*

High dextrose yield

Maltulose (disaccharide) and panose (trisaccharide) are both undesired conversion products that reduce the yield of dextrose in saccharification.
The content of maltulose and panose becomes apparent after saccharification of the starch hydrolysate. The maltulose content of the final saccharified syrup can be minimised by running the liquefaction process at a low pH. When Liquozyme X, Liquozyme Supra or Liquozyme Supra 2.2X are applied, the maltulose content is typically 0-0.2% on DS.

Panose formation can be minimised by applying either Liquozyme X, Liquozyme Supra or Liquozyme Supra 2.2X in the liquefaction. Liquozyme X in particular (but also to a lesser extent the Liquozyme Supra products) hydrolyses the starch dextrins in such a way that only small amounts of panose precursors are produced.

With Termamyl 120 L type L and Termamyl 2X it is necessary to inactivate the enzyme prior to saccharification to achieve the same low panose formation.

Reduction of maltulose and panose concentrations allows for higher glucose content (DX) in saccharification, which is often of great value. Alternatively, a saving in saccharification enzyme dosage could be achieved.

Viscosity reduction

When starch is gelatinised, the viscosity of the starch slurry initially increases. However, the alpha-amylase immediately starts to hydrolyse the starch and the viscosity is reduced.
The viscosity profiles for three different alpha-amylases are shown in Figure 2.

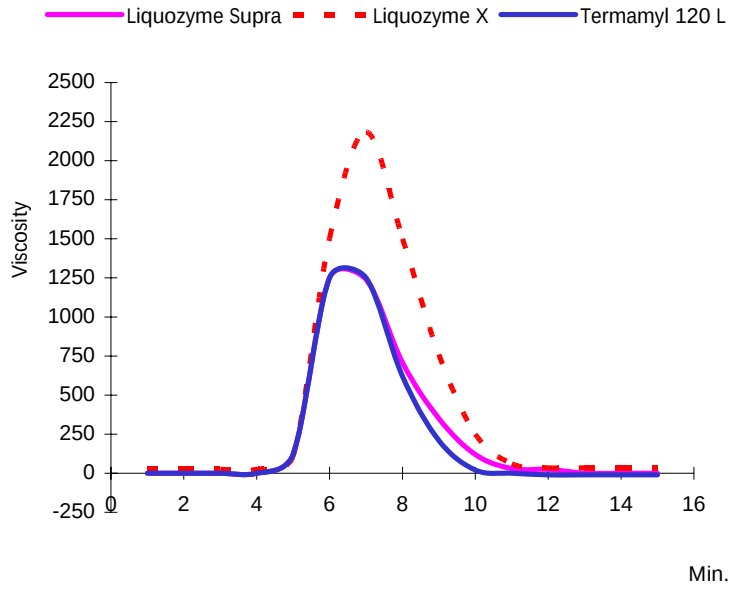

Fig. 2. Viscosity reduction in liquefaction. *Viscosity development in a 12% DS starch slurry heated from 50℃ to 95℃ (122℉ to 203℉) with added alpha-amylase. Termamyl 120 L type L (0.54 kg/t DS; 70 ppm Ca; pH 6.2), Liquozyme X (0.4 kg/t DS; 10 ppm Ca; pH 5.4), and Liquozyme Supra (0.4 kg/t DS; 10 ppm Ca; pH 5.4).*

Colour formation

Liquozyme X and the Liquozyme Supra products can be applied at low pH. This makes it possible to reduce colour formation by e.g. Maillard reactions that take place much faster at higher pH.

Savings on chemicals and ion exchange costs

Compared with Termamyl 120 L type L, Liquozyme X and the Liquozyme Supra products can give significant cost savings. The calcium dosage can be reduced or, in most cases, completely eliminated because Liquozyme X and the Liquozyme Supra products are stable even at 5 ppm calcium.

When applying Liquozyme X or the Liquozyme Supra products, the amount of pH adjustment chemicals required to increase the pH of starch slurry and to decrease the pH of starch hydrolysate prior to saccharification can be reduced because it is possible to run liquefaction at lower pH values.
When Liquozyme X or the Liquozyme Supra products are applied in liquefaction at low calcium concentration and low pH, the reduced chemical addition results in major savings on ion exchange costs. These savings give better overall process economy because the savings are normally greater than the additional enzyme cost.

IX savings consist of reduced regeneration chemical consumption, lower resin consumption due to longer operation cycles, and savings on water consumption and wastewater treatment.

Please contact Novozymes' Technical Service for a calculation of possible savings on production costs.

Usage

Application/process type

Termamyl 120 L type L, Termamyl 2X, Liquozyme X and the Liquozyme Supra products are designed to perform well in primary and secondary liquefaction of starch for sweetener production.

In most applications, the liquefaction alpha-amylase should be added in a single dosage to the starch slurry after pH adjustment and possible calcium salt addition, but prior to steam jetting for the low-temperature process (105-108°C/221-226°F). For the high-temperature process, the alpha-amylase is added after flashing and pH adjustment. The retention time in the starch slurry tank should be minimised to make full use of the enzyme activity.

Typical liquefaction processes

The recommended parameters for the low-temperature process are as follows:

- Enzyme added to starch slurry tank
- Primary liquefaction: 105-108°C (221-226-°F) for 5-10 minutes depending on raw material
- Flashing to vacuum
- Secondary liquefaction: 90-120 minutes at 95°C (203°F)

The recommended parameters for the high-temperature pasting process are as follows:

- Primary liquefaction (no enzyme): 130-160°C (266-320°F)
- Flashing to atmosphere
- pH adjustment
- Enzyme addition
- Secondary liquefaction: 90-120 minutes at 98°C (209°F)

Dosage

The dosage requirement for liquefaction alpha-amylase depends on the process conditions. The applied pH, DS, calcium, temperatures and reaction times are very important. However, the process equipment design also plays a significant role. Primary liquefaction reactors normally consist of tubular coils and/or mixed, multistage reactors. Secondary liquefaction reactors normally consist of a number of reactors (in parallel or in series), with or without agitation.

For both primary and secondary liquefaction, it is important to design the reactor system in such a way that a relatively narrow residence time distribution is achieved.

The design of reactors in liquefaction determines the target DE. With a tubular coil for primary liquefaction and 12-16 agitated tanks in series for secondary liquefaction, a target DE of 8-10 is possible. For a smaller number of reactors, a higher target DE is necessary.

Use the graphs below to establish the necessary dosage of liquefaction alpha-amylase. Start by defining your target DE and desired liquefaction pH.
The target DE should normally be as low as possible so that the risk of retrogradation is negligible.

The liquefaction pH should be as low as possible, considering the overall economy of the process. Lower pH gives lower chemical and IX operation costs, but requires a somewhat higher enzyme dosage.
Termamyl 120 L type L and Termamyl 2X performs well in the pH range 6.0-6.4 but can be applied to pH levels as low as 5.8 (see Figure 3 below).

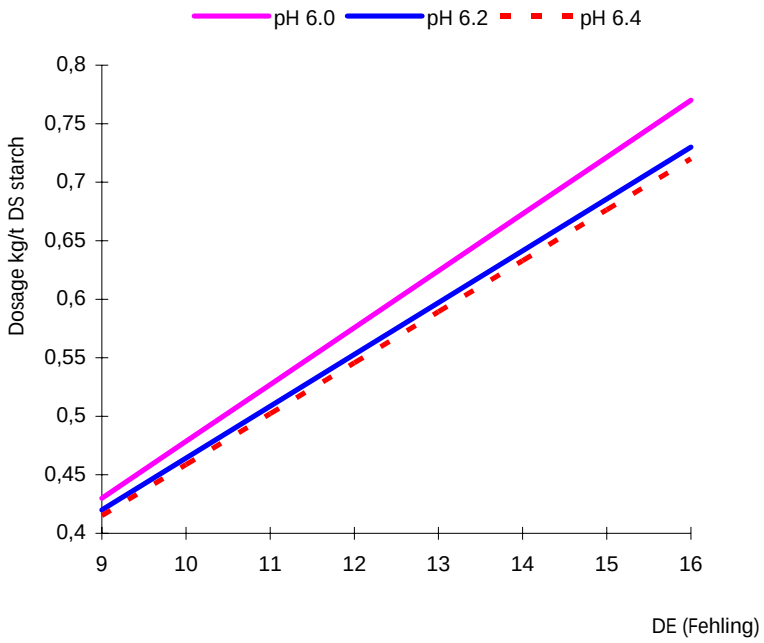

Fig. 3. Required dosage of Termamyl 120 L type L versus required target DE.
70 ppm calcium.120 min.

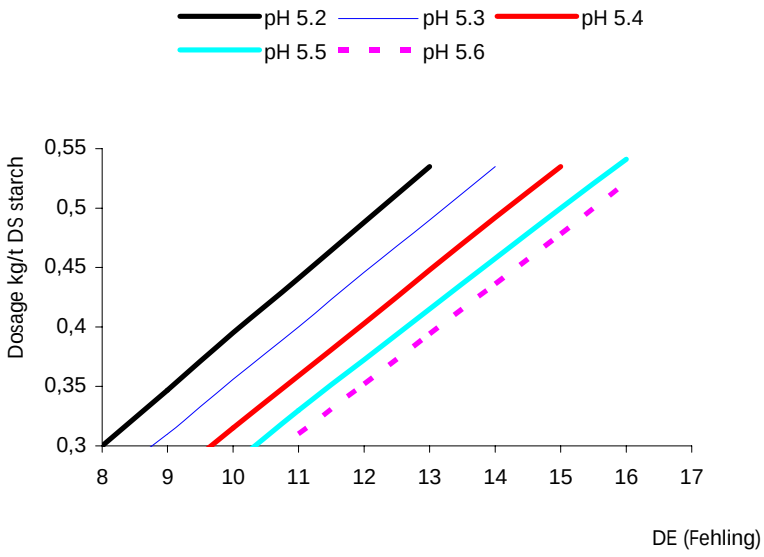

Fig. 4. Required dosage of Liquozyme X versus required target DE.
10 ppm calcium and 120 min.

Liquozyme X, Liquozyme Supra and Liquozyme Supra 2.2X perform well in the pH range 5.2-5.6 but can be applied in the 4.9-5.7 range.

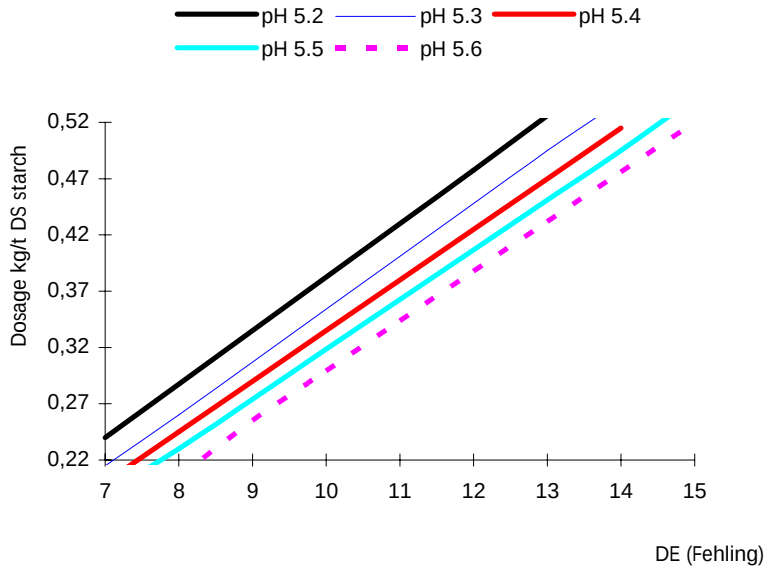

Fig. 5. Liquozyme Supra Dosage versus target DE at different pH,at 10 ppm calcium and 120 min.
Required dosage of Liquozyme Supra versus required target DE.

Calcium level
The free calcium concentration is not important for Liquozyme X and the Liquozyme Supra products. Only 5 ppm is necessary to stabilise the enzyme during liquefaction. In most cases, this level of free calcium is readily supplied by the starch raw material and/or the process water.

When the calcium concentration is increased, the enzyme becomes slightly more stable during primary and secondary liquefaction. With liquefaction conditions of 105°C (221°F) for 5 minutes followed by 95°C (203°F) for 120 minutes, DE is approximately 0.3% higher at 35 ppm compared with 10 ppm calcium. For Termamyl 120 L type L and Termamyl 2X, the recommended level of free calcium is 40-70 ppm.

Conductivity
Liquefaction alpha-amylases can be applied at specific conductivities as low as 300-400 µS/cm without any influence on DE development. At lower specific conductivities, the dosage must be increased. It should be noted that when the pH of the starch slurry is lowered and when calcium addition is reduced, the conductivity of the slurry will also decrease.

Activity and stability
All five alpha-amylases are thermostable and suitable for normal liquefaction conditions with primary liquefaction at 105-110°C (221-230°F) for 5-10 minutes followed by secondary liquefaction at 95°C (203°F) for 90-120 minutes.

The enzymes can be inactivated by lowering the pH and holding at 95°C (203°F).

Depending on the required degree of inactivation, the enzyme should be held for 5-10 half-lives.

Enzyme	pH	Calcium (ppm)	T½ (min.)
Termamyl 120 L type L Termamyl 2X	4.3	18	~1
Liquozyme X	3.8	18	~2
Liquozyme Supra Liquozyme Supra 2.2X	3.8	10	~4

Table 2. Enzyme half-lives at 95°C (203°F).

For Termamyl 120 L type L and Termamyl 2X, inactivation prior to saccharification is achieved by adjusting the pH to 4.3 and holding in a tank or coil for 5-10 minutes at 95°C (203°F). Liquozyme X and the Liquozyme Supra products are much more stable, but inactivation before saccharification is normally not necessary. For the production of certain specialty syrups (e.g. 80+% maltose) or for the complete inactivation of liquefaction enzyme in final products, we recommend carrying out thermal inactivation by increasing the temperature to 115-135°C (239-275°F) for a short time.

Production of maltodextrin

For the production of low DE maltodextrin, BAN 480 L may be applied. BAN 480 L is an alpha-amylase that performs well at temperatures up to 85°C and pH around 6.0, and requires 50-100 ppm calcium for stabilisation.

BAN is typically used in secondary liquefaction, where its dextrin breakdown pattern and ease of inactivation are beneficial.

Production of glucose and maltose syrups

When BAN 480 L or Fungamyl® 800 L are used to produce a specific sugar composition during saccharification of glucose or maltose syrups, it should be ensured that the calcium concentration is sufficient (50-100 ppm).

Thus, if the liquefaction process is run with Liquozyme Supra, Liquozyme Supra 2.2X or Liquozyme X at low calcium concentration, it may be necessary to add calcium for saccharification.

Storage in application

Recommended storage conditions are 0-25°C (32-77°F) in sealed packaging, protected from the sun. The product has been formulated for optimum stability. However, enzymes gradually lose activity over time. Extended storage and/or adverse conditions such as higher temperature may lead to a higher dosage requirement.

Safety, handling and storage

Safety, handling and storage guidelines are provided with all products.

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