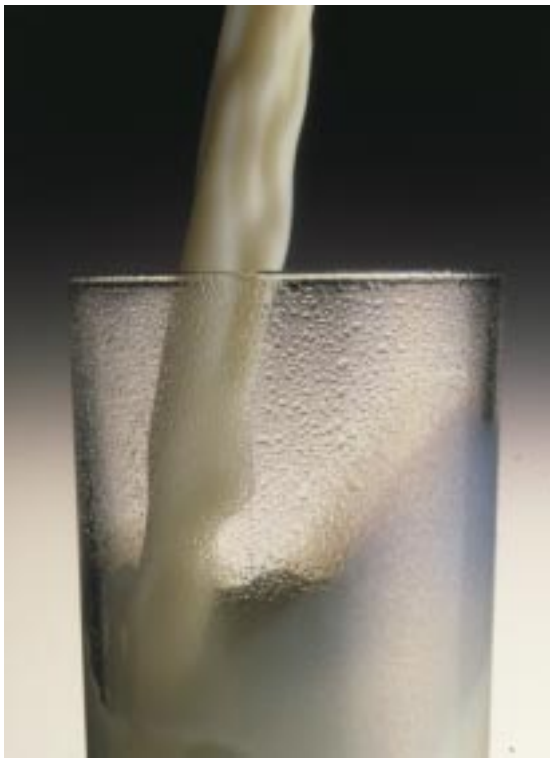


lactase: an optimum enzyme for low lactose dairy products

Lactose intolerance prevents many people in the Asia Pacific from benefiting from the nutritional value of dairy products. But the enzyme lactase has allowed the global dairy industry to develop and introduce successful new lactose reduced products that are fully acceptable to lactose intolerant consumers. A special contribution by C. Repelius of DSM Food Specialties, Dairy Ingredients.

LACTOSE or milk sugar is a disaccharide with relatively low sweetness intensity found in mammalian milk. It has a low solubility and it cannot be absorbed directly from the human intestine. Its constituents – glucose and galactose – are 3-4 times more soluble and are easily absorbed from the intestine. Only these monosaccharides are utilised as energy or building bricks in the body. The hydrolysis necessary for the utilisation of lactose is affected by the enzyme lactase, which is normally present in the small intestine.

The problem of lactose intolerance

With most individuals the lactase activity level reaches its maximum value at the moment of birth when lactase activity is most needed to utilise the lactose calories (mothers milk contains about seven percent lactose which supplies the majority of calories during the first year of life).

Problems with the lactase activity level occur in the following groups:

- Due to a very rare congenital disease, babies may lack lactase activity from the very moment of birth. The results are severe gastro-intestinal disorders, which can be fatal if other foods are not offered immediately.
- With a second group, premature birth results in insufficient lactase activity. Lactase activity is mostly fully restored within one or two months.
- A decline in lactase activity has also been demonstrated in people that normally are lactose tolerant but lose this capacity later in life. This seems to occur mostly at about 40-50 years. It is speculated that this reduction of lactase activity represents an important factor in the decalcification process of the skeleton.

Table 1: Tendency to lactose maldigestion

Area	Tendency (%)	Area	Tendency (%)
Western Europe		**Americas**	
Austria	15-20	North America (whites)	15
Balkans	55	North America (hispanics)	53
Finland	17	North America (blacks)	80
France (north)	17	South America	65-75
France (south)	<70		
Germany	15	**Africa**	70-90
Great Britain	5-15	Bedouins	25
Italy	20-70	Touareg	13
Scandinavia	3-5		
Asia			
India (north)	30		
India (south)	70		
Central Asia	80		
East Asia	90-100		

With all people, lactase activity, present during the weaning period, gradually declines between the second and fifth year of age. Only in populations that have been drinking milk as a part of their staple diet for many generations is lactase activity still present after the weaning period. These populations include Caucasian people and a number of cattle breeding tribes in Africa. A genetic selection process is considered to be the cause for this phenomenon. Table 1 lists the tendency to lactose maldigestion worldwide.

When lactose is not hydrolysed, it will not be absorbed and will reach the latter part of the small intestine and the colon. The micro-organisms present will grow on this lactose abundantly. The results are a change in the intestinal micro flora very often accompanied by excessive production of gas and acid, and withdrawal of water from the body into the colon, eventually resulting in intestinal disorders such as cramps and diarrhoea .

Lactose malabsorption

The result of lactose malabsorption is that for the majority of mankind the body cannot utilise the energy presented by lactose. (Depending on the fat content lactose represents 30-60 percent of the calories in milk). However, when the lactose is hydrolysed before consumption, lactase deficient persons can use this energy. This is particularly important in all cases where the energy requirements are inadequately or marginally met, for instance in food-aid programs.

It is a generally known fact that in these cases the proteins consumed are not converted into body proteins, but are burnt up. In other words: protein is only utilised as protein when the energy requirements have been met. Therefore with lactase-deficient persons the energy supply is increased by the presence of hydrolysed instead of ordinary lactose in their diet, thus improving the protein utilisation. Consequently with children suffering from malnutrition, and weakened patients, the positive results of the extra energy supply and the improved protein utilisation soon become noticeable.

Milk also supplies an important part of the necessary minerals, especially calcium. Lactose, and also some other sugars, being carriers for minerals through ligand-formation, is able to facilitate the absorption of minerals. If the lactose is not absorbed and therefore transported to the colon, which occurs with lactose-malabsorption, losses of calcium and other minerals will be the result. Hydrolysis of lactose therefore also influences calcium-absorption positively.

When not only lactose malabsorption but also intolerance symptoms occur, the appetite will be inhibited, so that even less food is consumed. If, on top of that, diarrhoea occurs, this also causes the direct loss of a quantity of food already consumed but not yet absorbed; valuable proteins, vitamins, minerals and calories of milk are only partly utilised.

Of course, it would be possible to remove milk products altogether from the diet. However, milk being a natural, essential and generally accepted food, it would be extremely difficult to find a substitute, which is as well balanced.

One can also consider removing the lactose from the milk by a physical process. The objection is that, together with the lactose, vitamins and minerals are also lost. The best solution therefore is to pre-digest the lactose enzymatically, resulting in dietary milk in which all the nutrients have been retained.

Natural sources of lactase

Lactase (β-D-galactoside galacto-hydrolase; E.C. 3.2.1.23), the lactose splitting enzyme, is found in the intestine of young mammals, in plants, fungi, yeasts and bacteria.

The pH optimum of lactases is the predominant factor determining a particular potential area of application. Yeast and bacterial lactase possess a neutral pH optimum, which makes them directly applicable for the treatment of milk, sweet whey permeate and lactose solutions. The pH of other substrates has first to be corrected to the proper range.

Lactases from fungi, with their low pH optima, are only suitable for acid wheys and whey permeates.

Commercial neutral lactase

The dairy yeast *Kluyveromyces lactis* was first described by Beyerinck in 1889. It is a well known dairy organism used in the production of certain fermented milk products like kumiss and kurung. It has also been frequently used as protein supplements for food and feeding purposes.

Efforts to use the enzymatic hydrolysis of lactose to improve milk products and milk processing have been strongly stimulated by the commercial development of *Kluyveromyces lactis* lactase preparations. Because of this, the applications described in the literature mainly concern 25 years of practical and commercial experience with this lactase.*K. lactis* neutral lactase preparations are available under the brand name Maxilact from Dutch food ingredients company DSM Food Specialties.

In the food industry, conditions for the use of enzymes, such as pH and temperature, are generally set by the substrate itself. In industrial practice, the lowest limit for pH is that of acid whey (pH 4-0-4.4) and the highest that of milk (pH 6.7- 6.8).

Being isolated from a dairy organism, it is not surprising that the optimum conditions of *Kluyveromyces lactis* lactase activity are found near the natural pH and temperature of fresh milk. Figures 1 and 2 show the pH activity and temperature activity curves for this lactase.

Enzyme activity is slowed by very low temperatures, but this enzyme still exhibits noticeable activity at temperatures around 4°C. Optimal activity occurs at 30-40°C but these temperatures present special problems due to microbial contamination, and so a short hydrolysis period of three to four hours is advisable if these temperatures are employed.

Figure 1: pH-activity profile for Kluyveromyces lactis lactase

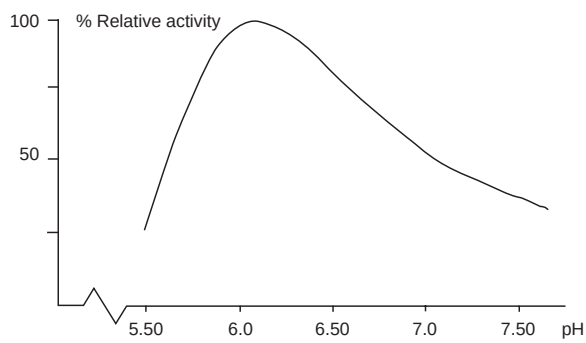


Figure 2: Temperature-activity profile for Kluyveromyces lactis lactase

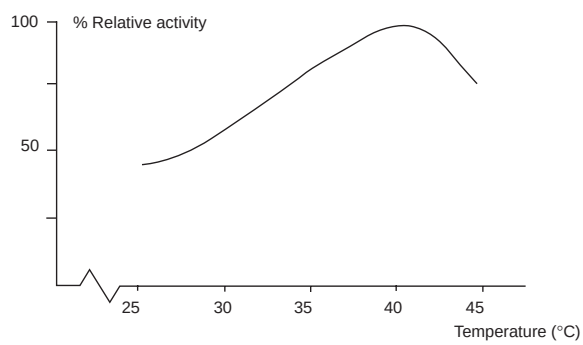
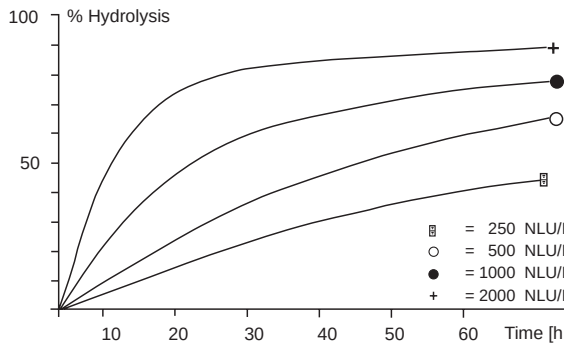
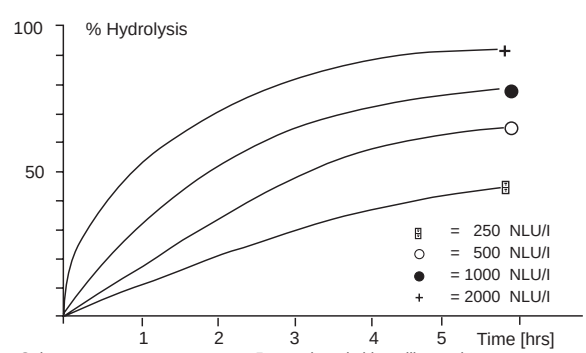


Figure 3: Conversion velocity with different amounts of Kluyveromyces lactis lactase at 6°C.



Substrate	: Reconsituted skim milk powder
Lactose	: 5.0%
Temperature	: 6°C
pH	: 6.6

Figure 4: Conversion velocity with different amounts of Kluyveromyces lactis lactase at 37°C.



Substrate	: Reconsituted skim milk powder
Lactose	: 5.0%
Temperature	: 37°C
pH	: 6.6

Often a longer period of 16-24 hours at low temperatures of 4-8°C is chosen to avoid the problems of microbial spoilage. Other important practical limitations in the enzymatic processes in the food industry are end-product inhibition and the equilibrium situation of enzymatic reactions.

The effect of higher enzyme concentrations on the conversion velocity is visualised in Figure 3 for a low temperature hydrolysis and in Figure 4 for a high temperature hydrolysis process.

Table 2: Lactase dosage for milk

Temperature	Degree of hydrolysis	Lactase dosage	Maxilact L2000 dosage	Incubation time
Milk				
6-10 (°C)	60%	1000 NLU/L	0.5 g/L	30 Hrs
	60%	2000 NLU/L	1.0 g/L	15 Hrs
37-40 (°C)	60%	1000 NLU/L	0.5 g/L	1.25 Hrs
	60%	2000 NLU/L	1.0 g/L	2.5 Hrs
Concentrated milk				
37-40 (°C)	60%	4000 NLU/L	2.0 g/L	2.5 Hrs
	60%	8000 NLU/g	4.0 g/L	1.25 Hrs

Approaches to milk hydrolysis for producing lactose hydrolysed milk & milk powder

Generally, milk is pasteurised and cooled back to the required incubation temperature (see section on commercial lactase above and section on hydrolysis process below) and put into the hydrolysis tank.

Alternatively, when producing hydrolysed milk powder, the milk will be concentrated first prior to spray drying. The dry matter concentration of the concentrate will then be about 50 percent. The drawback to this solution is that hydrolysis at such a high lactose concentration will lead to the production of a substantial amount of oligosaccharides.

Due to the fact that the lactose is hydrolysed to D-glucose and D-galactose, the chances for microbial growth are also increased because more micro-organisms can grow on glucose than on lactose. It is therefore very important that the milk is handled after pasteurisation as aseptically as possible, i.e. clean all piping and the hydrolysis tank, preferably by CIP (See Figure 5).

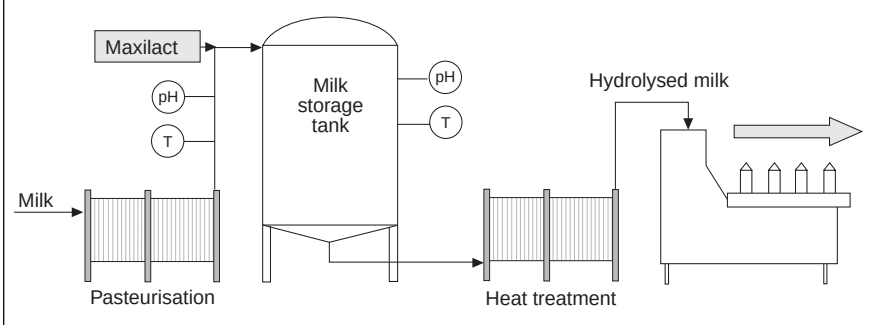
After hydrolysis the milk should be pasteurised again and packed. Recommended pasteurisation conditions before and after hydrolysis are 72-75°C/15 sec, but alternatively the hydrolysis can also be done after thermisation at 68°C/15 sec followed by a pasteurisation of 72-75°C/15 sec. In many countries double pasteurisation of milk is forbidden by law and in that case the latter method has to be used.

Conclusion

The consequent rapidly increasing demand for "low lactose" dairy products presents the dairy industry with a major opportunity to open up a new market segment and make dairy products acceptable to people previously unable to consume them. More and more, these consumers have the desire to gain access to the nutritional benefits of dairy products. Milk hydrolysis can be undertaken in several ways with good success. The optimal choice of the conditions is dependent on the logistic situation and storage capacity in the dairy plant.

Lactase enzymes such as DSM's Maxilact can convert the lactose content of milk to its component sugars and render milk acceptable to "lactose intolerant" consumers. Dairy products made from "low lactose" milk can also be consumed without alimentary tract problems. Products of dairy origin thus become readily available to consumers who previously had to avoid them. APFI

Figure 5: Production of lactose hydrolysed milk



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