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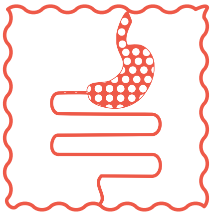
This review provides an overview of the functions of the dairy sugars lactose and galactose and offers insight to their digestive and nutritional effects.

A publication for health professionals

Dairy sugars:

Lactose and galactose





Milk and dairy products have a key role in development throughout life[1] and scientific evidence supports the essential role of milk and dairy products as part of a healthy eating pattern.[2] However, a Swedish study by Michaëlsson et al.[3] controversially showed that a high intake of milk was associated with a higher mortality risk (in both men and women) and with a higher fracture incidence in women.

In an effort to identify possible mechanisms, Michaëlsson et al.[3] cited an animal study[4] and hypothesised that galactose derived from lactose in milk may induce oxidative stress, chronic inflammation, a decreased immune response and neuro-degeneration, thus contributing to the risk of mortality and fracture. However, the authors acknowledged that the possibility of residual confounding and reverse causality could not be ignored (for example, women who were aware that they had osteoporosis may have consumed more milk than women without osteoporosis). Following the initial publication, the same authors reported that a high intake of fruit and vegetables diminishes the risk of mortality associated with milk consumption.[5] In view of the mentioned limitations and in the absence of evidence from randomised controlled trials, experts suggest cautious interpretation of these results.[6-8] However, the study has cast doubt on the health benefits of milk. This brief review therefore aims to evaluate the evidence on the health effects of dairy, with special reference to lactose, naturally present in milk, and its metabolite galactose.

Important functions of lactose and galactose

A number of studies suggest that lactose and galactose are beneficial rather than detrimental to health.[9,10] The carbohydrate lactose consists of a galactose molecule bound to a glucose molecule. Dietary galactose is liberated by the action of lactase in the brush border of the small intestine.[9] Milk from different animals vary in its lactose concentration, with human milk having the highest lactose content while cow's milk contains a notably lower concentration.

Lactose is of key importance in animal life as it is the main source of energy from milk whereas galactose is essential during the early developmental stages of mammalian infants, when they are exclusively dependent on milk.[1] However, the biological importance of galactose goes beyond its importance as an energy substrate, as it also enhances cellular communication and control processes. As a structural component of glycolipids and glycoproteins, galactose has a critical role in maintaining the integrity both of cell membranes and of the cellular matrix.[9] Galactose is crucial for the glycosylation of complex molecules such as myelin, in which galactocerebroside is the predominant glycolipid. Galactose is therefore often referred to as 'brain sugar' in lay terms owing to its role in supporting brain structure and development during the neonatal period and early life.[1] Galactose also serves as a substrate for cerebrosides, gangliosides and mucoproteins in the brain and nervous system, which confirms its critical neural and immunological role.[11] Galactose has furthermore been shown to have therapeutic potential, especially in disorders affecting brain function such as Alzheimer's disease[12] and nephrotic syndrome.[13]

Enzyme deficiencies

A deficiency in any of the enzymes involved in lactose digestion and galactose metabolism can lead to metabolic disturbances such as lactose intolerance and galactosemia.

Lactose intolerance

As mentioned, the enzyme lactase is needed to hydrolyse lactose to glucose and galactose for absorption across the intestinal mucosa. Full-term newborn infants generally have sufficient lactase activity to digest milk. However, galactosidase activity declines after weaning in most humans (a condition termed lactase non-persistence), especially in those from East Asian and African heritage.[14-17] According to Leonardi et al.,[18] only about 35% of the human population can digest lactose beyond the age of about seven or eight years.

Lactose intolerance refers to the digestive symptoms that are associated with lactose maldigestion. Undigested lactose moves from the small intestine to the colon, where it is fermented by bacteria. This sometimes produces gas, which leads to symptoms such as abdominal discomfort, nausea, cramps, bloating, flatulence and diarrhoea.[14,16] Those who consider themselves lactose intolerant may decrease their dairy intake, resulting in compromised intake of the nutrients and other beneficial compounds in dairy. However, most people who are lactose intolerant can eat small amounts of dairy foods without experiencing discomfort by applying the following easily applied strategies:[14,15,17]

- A low lactose load (<6 g lactose is present in half a serving of milk) is unlikely to cause symptoms, even in lactose-intolerant individuals. Using small amounts of dairy at a time or consuming milk as part of a meal slows the release of lactose into the small intestine, which reduces the load to be digested. Less discomfort is subsequently experienced.
- Dairy foods such as hard cheeses, active-culture yoghurt and fermented products such as buttermilk contain limited lactose and can be eaten without causing gastrointestinal discomfort. These foods are

fermented by lactic acid bacteria during production, which convert some of the lactose to lactic acid.

- Although more expensive, reduced-lactose or lactose-free milk is also available. This milk has many health benefits over dairy substitutes such as soy milk.
- Taking a lactase tablet with milk improves digestion.
- Tolerance can be built up gradually over time. Consuming lactose-containing foods encourages an intestinal flora population with active lactase. This can improve the ability of the bacteria in the gut to break down lactose and so gradually increases tolerance of lactose-containing foods. Intake can be increased gradually by, for example, adding half a glass of milk to one meal on the first day, half a glass to two meals on the next day, etc.
- Chocolate milk is better tolerated than white milk (possibly owing to a higher osmolality or energy content).
- Probiotics that include lactase-containing organisms can help to relieve symptoms.

Galactosemia

Galactosemia develops when the conversion of galactose into glucose in the liver is blocked by a deficiency in any of the enzymes involved in the Leloir pathway. This is a rare congenital error of metabolism that affects a number of organ systems, including the liver and brain.[9,10] Although dietary restriction of galactose resolves the symptoms of galactosemia, long-term complications such as cognitive and fertility impairments remain in these individuals owing to the inability of the body to metabolise the endogenous production of galactose.

Galactose restriction is thus only required in the rare cases of genetic disorders where individuals cannot metabolise free galactose, and not in healthy individuals as a result of exposure to the galactose content in food such as dairy. Galactose is also present in legumes and some fruits and vegetables.[1,19] In the absence of any enzyme deficiencies, normal circulating levels of galactose do not cause pathological effects.[9,10]

Effects of lactose and galactose as prebiotics

The recent emphasis on the human microbiome has focused attention on the potential role of probiotics and prebiotics in promoting human health. Prebiotics are non-digestible compounds that stimulate the growth and activity of bacteria in the digestive system.[20] Lactose and oligosaccharides in milk are considered to be bioactive ingredients that may create healthy microbiota owing to their bifidogenic effects.[14,21]

In individuals with lactase non-persistence, lactose is not fully digested and thus proceeds to the colon, where it has a prebiotic effect. In lactase-persistent persons, most lactose will be digested in the small intestine, although some may reach the large intestine.[20] According to Venema,[22] the colonic microbiota hydrolyse and ferment lactose, producing metabolites such as short-chain fatty acids (primarily acetate, propionate and butyrate), which serve as a source of energy to the microbiota and colonocytes. They can also be absorbed into the portal circulation and transported to the liver, where they may have beneficial systemic effects.[14] In particular, dairy prebiotics and probiotics may influence gut microbiota in such a way that insulin sensitivity and the action of glucagon-like peptide are positively affected.[21] Kwak et al.[23] further suggest that the short-chain fatty acids and other organic acids produced from lactose digestion promote the growth of lactic acid bacteria and enhance the absorption of calcium.

Galactose is present in the so-called raffinose family of oligosaccharides and galactose oligosaccharides (GOS).[21] These prebiotic oligosaccharides have been found to exert beneficial effects in the gastrointestinal tract of humans not only by stimulating growth of selected members of the intestinal microflora but also through their anti-adhesive activity. Specifically, GOS were found to directly inhibit infections by enteric pathogens owing to their acting as structural mimics of the pathogen-binding sites that coat the surface of gastrointestinal epithelial cells.[19]

Conclusion

Scientific evidence confirms that lactose and its metabolite galactose, which are naturally derived from milk and dairy products, are unlikely to be detrimental to health and should thus not be targeted in attempts to reduce dietary sugar intake.

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