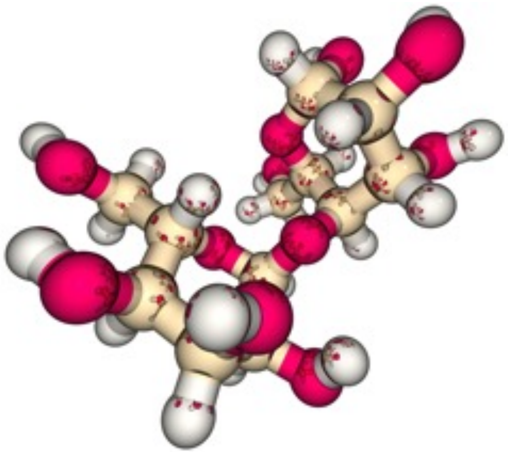
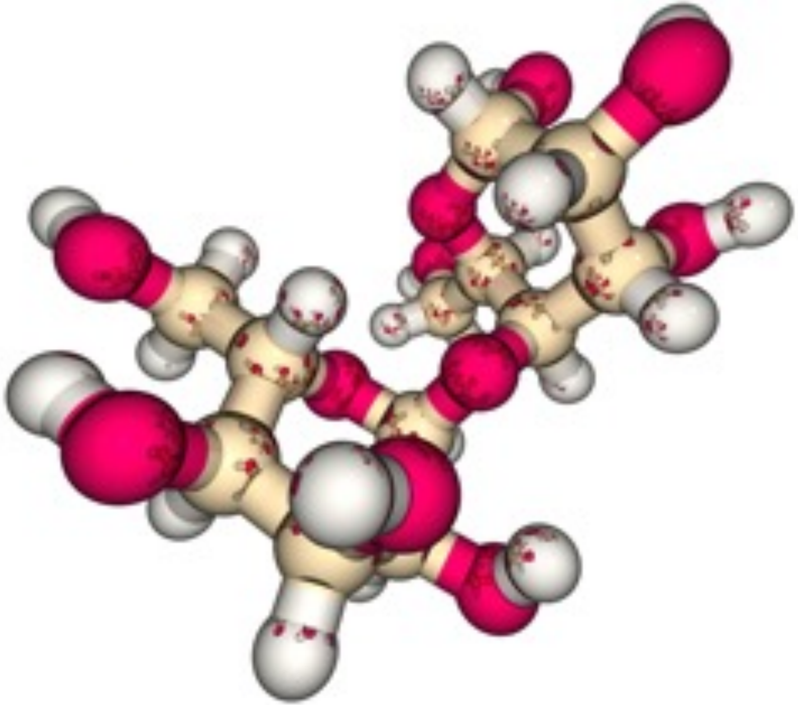


Lactose: Lactose for health and nutrition: breakthrough innovation or old news for new people?

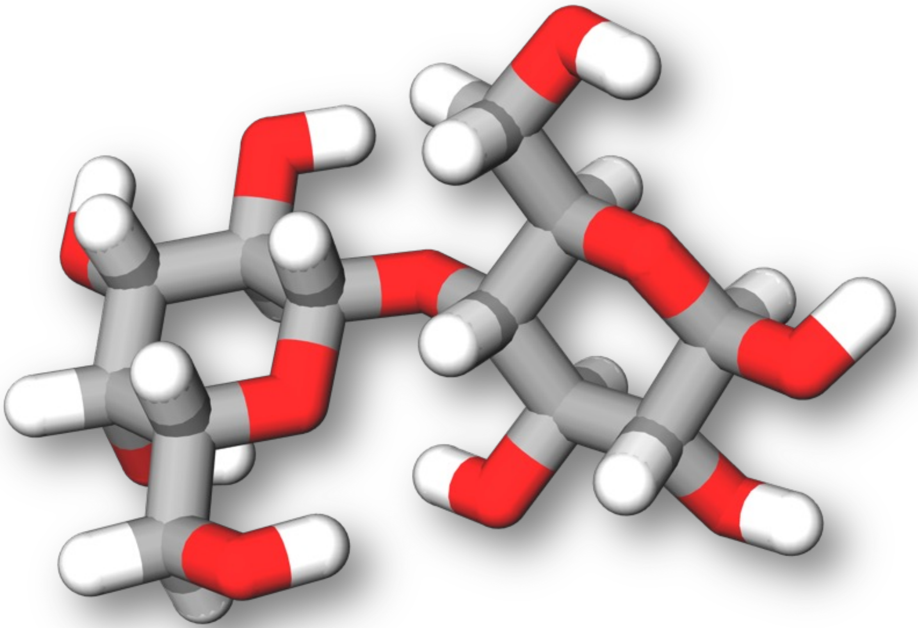
Thom Huppertz| 25 April 2024

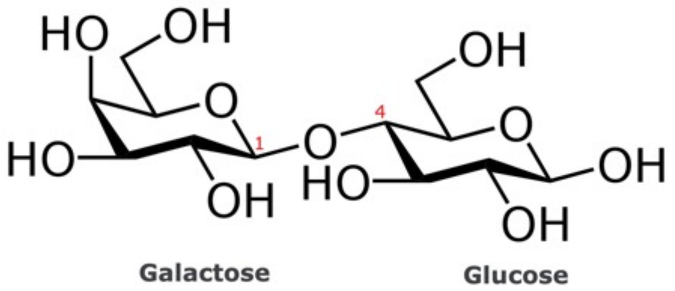
"ALL NEW NEWS
IS OLD NEWS
HAPPENING TO
NEW PEOPLE"

-MALCOLM MUGGERIDGE



Lactose, or milk sugar, is a major component of milk



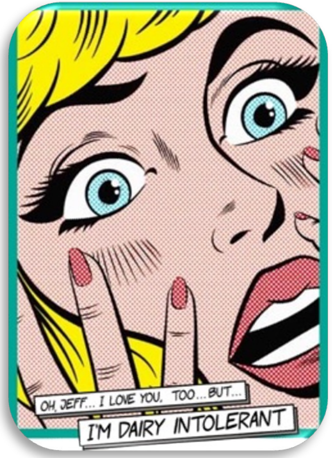


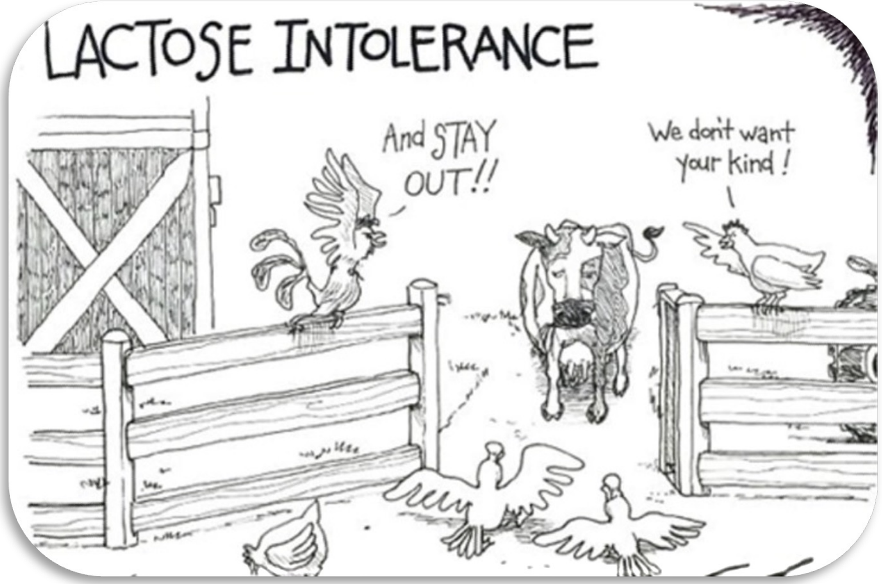
Jensen, R. G. (1995). Handbook of milk composition. Academic Press

Lactose = **galactose** coupled to **glucose** by a **β1,4 glycosidic bond**

Cow: ~4.6%, Human: ~7%

Lactose in the (social) media



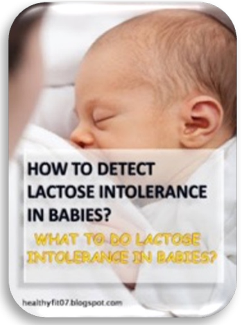


4 million Aussies self-diagnosing food allergies, study reveals

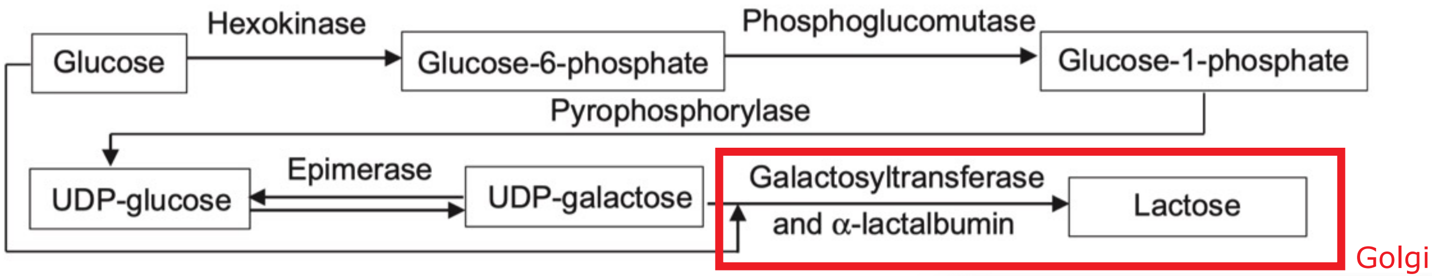
Monday, 06 July, 2020

Research conducted by YouGov has revealed that almost a quarter of Australians report self-diagnosing a food intolerance (22%) and more than a third of people who identify as having an intolerance have never consulted a healthcare professional to diagnose or manage their symptoms (35%). The research demonstrated that, of the most common intolerances and allergies (such as gluten intolerance and nut and dairy allergies), lactose intolerance is the most likely to be self-diagnosed, with one in 10 Australians admitting they are unsure of the difference between lactose intolerance and dairy allergy (32%).

Of those who report having lactose intolerance, almost half say they removed dairy entirely from their diet as one of the first steps to relieve symptoms (43%).

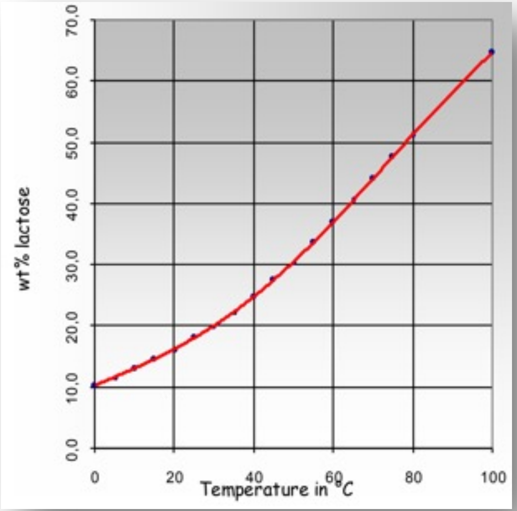


Lactose: an excellent osmolyte and energy source



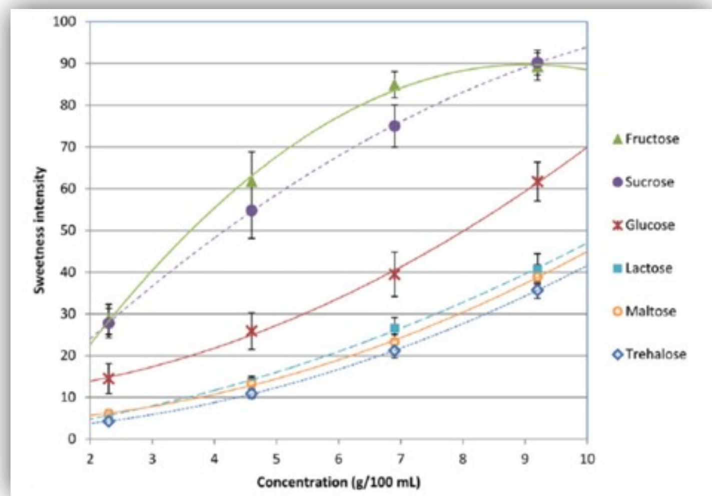
Lactose has **low solubility** (10% that of sucrose at 25°C) but **great stability** in solution.

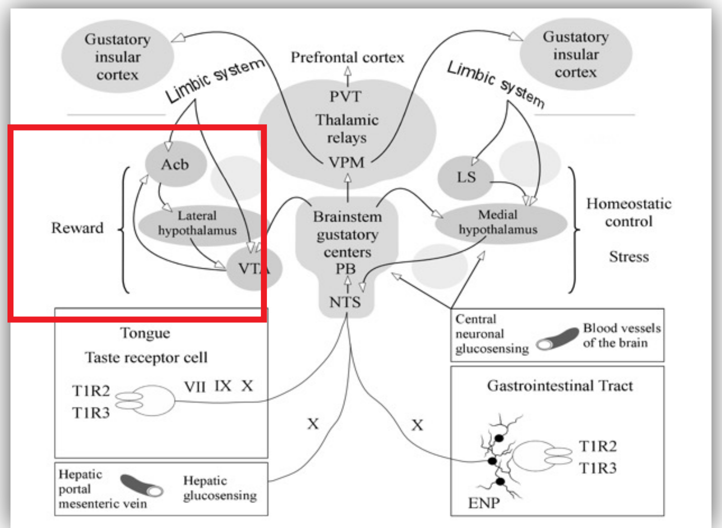
Lactose can therefore not diffuse out of the Golgi- and secretory-vesicles inside the gland cells. Lactose is easily secreted, and aids in drawing water into these organelles, thereby determining the volume of the milk produced.



Paques, M. and Lindner, C. (2019). Lactose. 1st ed. Academic Press

Lactose has low sweetness and does not induce reward effects





The neuronal network activated by sugar intake

VII – facial nerve; IX glossopharyngeal nerve; X – vagus nerve; Acb – nucleus accumbens; Amy amygdala; ENP – enteric nervous plexus; LS – lateral septum; NTS – nucleus of the solitary tract; PB – parabrachial nucleus; PVT – paraventricular thalamic nucleus; T1R2/3 – sweet taste receptor subunits; VPM – ventral posteromedial nucleus of the thalamus; VTA – ventral tegmental area

Lactose is free of analgesic and reward effects

Impact on development of taste preference?

Impact on development of overweight/obesity?

Paques, M. and Lindner, C. (2019). Lactose. 1st ed. Academic Press
Clemens et al., Comp. Rev Food Sci Food Safety, 2016
Delaveau, Ann Pharm Fr, 2002
Timofeeva and Mitra, Sucrose: Properties, Biosynthesis and Health Implications, 2013

nutrients

Article

Adverse Effects of Infant Formula Made with Corn-Syrup Solids on the Development of Eating Behaviors in Hispanic Children

Hailey E. Hampson [1,2], Roshonda B. Jones [1], Paige K. Berger [1], Jasmine F. Plows [1], Kelsey A. Schmidt [1], Tanya L. Alderete [3] and Michael I. Goran [1,*]

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[2] Department of Epidemiology, University of Southern California, Los Angeles, CA 90007, USA
[3] Department of Integrative Physiology, University of Colorado Boulder, Boulder, CO 80309, USA; tanya.alderete@colorado.edu
* Correspondence: goran@usc.edu

Abstract: Few studies have investigated the influence of infant formulas made with added corn-syrup solids on the development of child eating behaviors. We examined associations of breastmilk (BM), traditional formula (TF), and formula containing corn-syrup solids (CSSF) with changes in eating behaviors over a period of 2 years. Feeding type was assessed at 6 months in 115 mother–infant pairs. Eating behaviors were assessed at 12, 18 and 24 months. Repeated Measures ANCOVA was used to determine changes in eating behaviors over time as a function of feeding type. Food fussiness and enjoyment of food differed between the feeding groups ($p < 0.05$) and changed over time for CSSF and TF ($p < 0.01$). Food fussiness increased from 12 to 18 and 12 to 24 months for CSSF and from 12 to 24 months for TF ($p < 0.01$), while it remained stable for BM. Enjoyment of food decreased from 12 to 24 months for CSSF ($p < 0.01$), while it remained stable for TF and BM. There was an interaction between feeding type and time for food fussiness and enjoyment of food ($p < 0.01$). Our findings suggest that Hispanic infants consuming CSSF may develop greater food fussiness and reduced enjoyment of food in the first 2 years of life compared to BM-fed infants.

Lactose is the least cariogenic of all fermentable sugars and causes no harm to dental surfaces when part of milk products


Caries Res. *10:* 427–441 (1976)

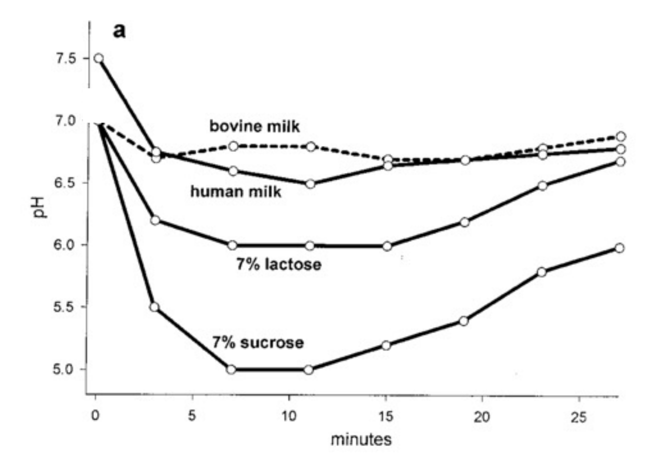
Cariogenicity of Nine Sugars Tested with an Intraoral Device in Man

T. Koulourides, R. Bodden, S. Keller, L. Manson-Hing, J. Lastra and T. Housch

The Institute of Dental Research and Departments of Oral Diagnosis and Dental Radiology, School of Dentistry, University of Alabama in Birmingham, Birmingham, Ala.

Key Words. Cariogenicity test · Sorbitol · Sugars · Xylitol

Abstract. Nine sugars and sugar alcohols were assessed for their effect on experimental caries with an Intraoral Cariogenicity Test (ICT). Sample bovine enamel surfaces were submitted to simulated cariogenic conditions in the human mouth. The extent of experimental cariogenesis after 1 week was measured by means of surface microhardness tests on enamel samples. Each test sugar was compared to sucrose control, and supplied to one of the two ICT plaques at the same time. There was no detectable difference in the effect of glucose, fructose, and raffinose on ICT cariogenesis. Lactose, mannitol, melibiose, and sorbitol were significantly less cariogenic than sucrose ($p<0.05$), while xylose and xylitol were noncariogenic.



Johansson, Scan J Nutr, 2002

Lactose is the least cariogenic of all fermentable sugars and causes no harm to dental surfaces when part of milk products

nutrients

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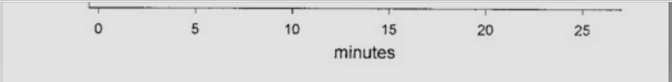
Review

Impact of Dairy Products and Plant-Based Alternatives on Dental Health: Food Matrix Effects

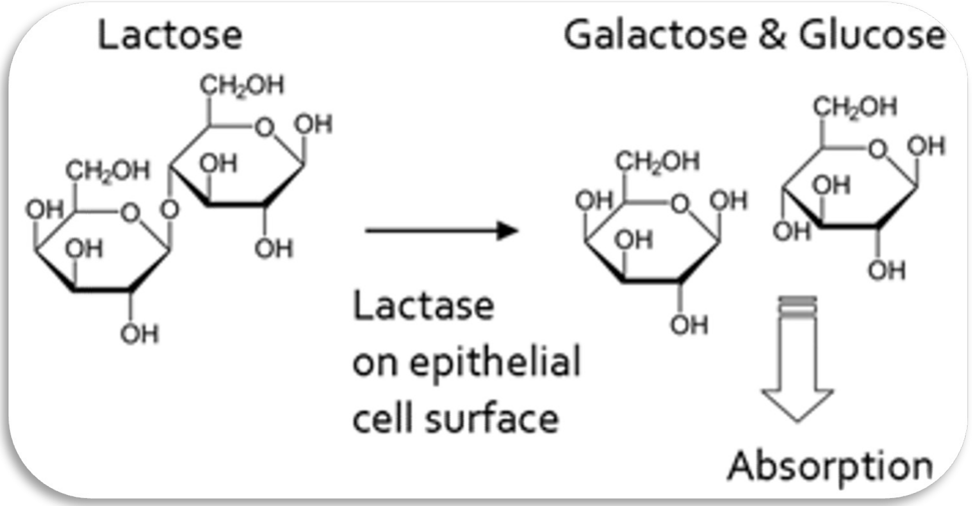
Blerina Shkembi [1] and Thom Huppertz [1,2,*]

Abstract. Nine sugars and sugar alcohols were assessed for their effect on experimental caries with an Intraoral Cariogenicity Test (ICT). Sample bovine enamel surfaces were submitted to simulated cariogenic conditions in the human mouth. The extent of experimental cariogenesis after 1 week was measured by means of surface microhardness tests on enamel samples. Each test sugar was compared to sucrose control, and supplied to one of the two ICT plaques at the same time. There was no detectable difference in the effect of glucose, fructose, and raffinose on ICT cariogenesis. Lactose, mannitol, melibiose, and sorbitol were significantly less cariogenic than sucrose ($p < 0.05$), while xylose and xylitol were noncariogenic.

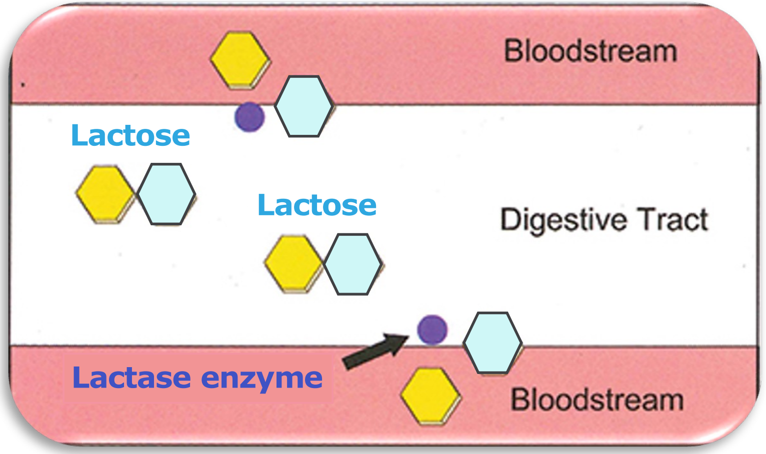


Johansson, Scan J Nutr, 2002

Benefits of lactose digestion



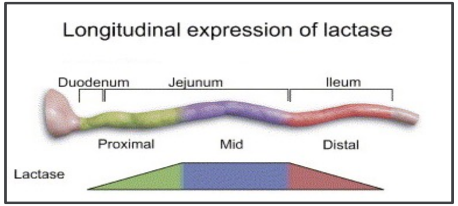
Lactose is broken down in the small intestine by the enzyme lactase

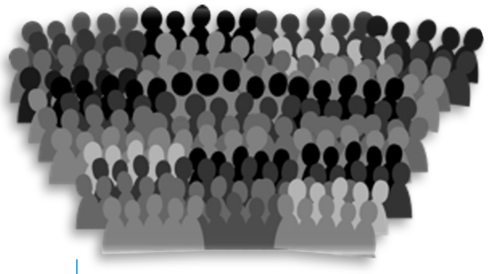


Lactase

Lactase-Phlorizin Hydrolase

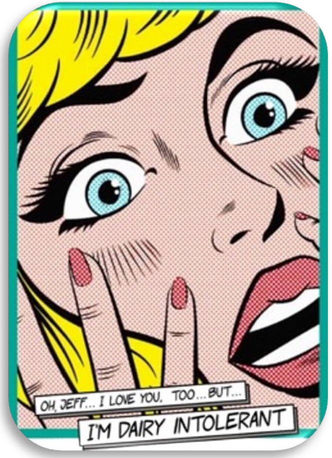
EC number: 3.2.1.108

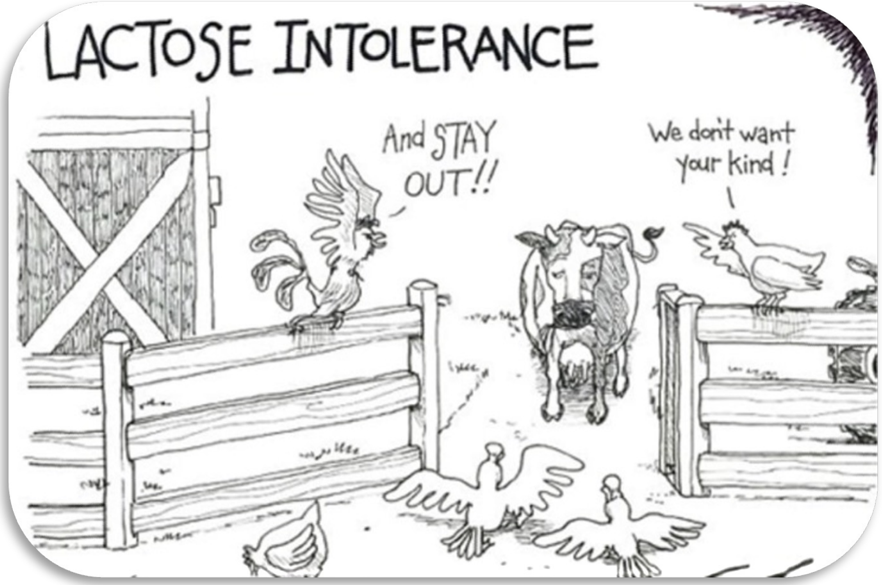




Almost all known mammals – including the majority (~65%) of humans – experience a 90% to 95% **decrease in lactase production** in the years **after weaning** (a condition known as Lactase Non-Persistence (LNP)). LNP individuals become **lactose maldigesters** (LD) and **can** suffer from **lactose intolerance** (LI) complaints when consuming milk and dairy products into adulthood. Most LNP individuals can still consume about 12 grams of lactose (~1 glass of milk) without LI complaints.

Lactose in the (social) media



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4 million Aussies self-diagnosing food allergies, study reveals

Monday, 06 July, 2020

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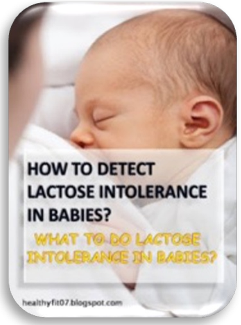
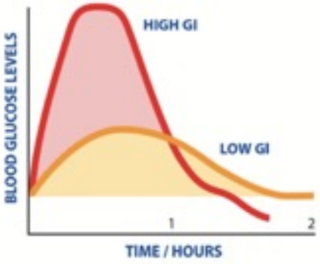
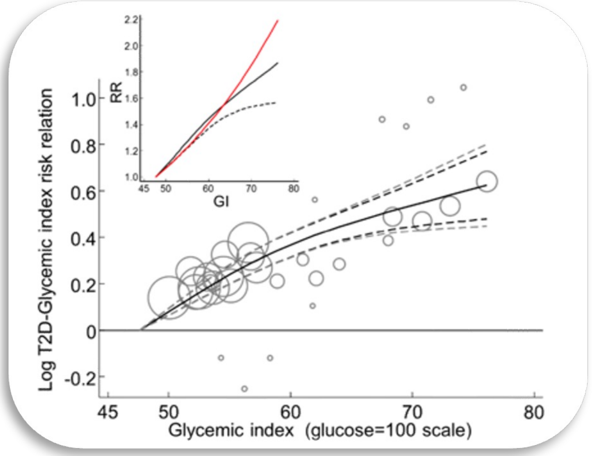
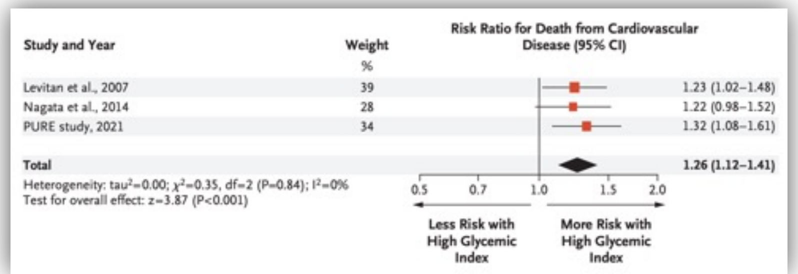
Of those who report having lactose intolerance, almost half say they removed dairy entirely from their diet as one of the first steps to relieve symptoms (43%).



Lactose has a low glycemic index (GI=46) and supplies the body with energy and building blocks (Glu & Gal)







- Glycemic index is a nutritional property of an ingredient/food/dietary pattern
- Lactose has a low glycemic index (e.g., GI < 55).
- Many studies showed that low glycemic index diets contribute to diabetes prevention.
  - A meta-analyses of intervention studies showed that low GI diets reduce blood sugar levels (*Livesey et al, Am J Clin Nutr, 2008*)
  - A meta-analyses of cohort studies showed that low GI diets are associated with a lower risk of type 2 diabetes (*Livesey et al, Nutrients, 2019*; *Hardy et al, Nutr Metab Cardiovasc Dis, 2020*)

foods

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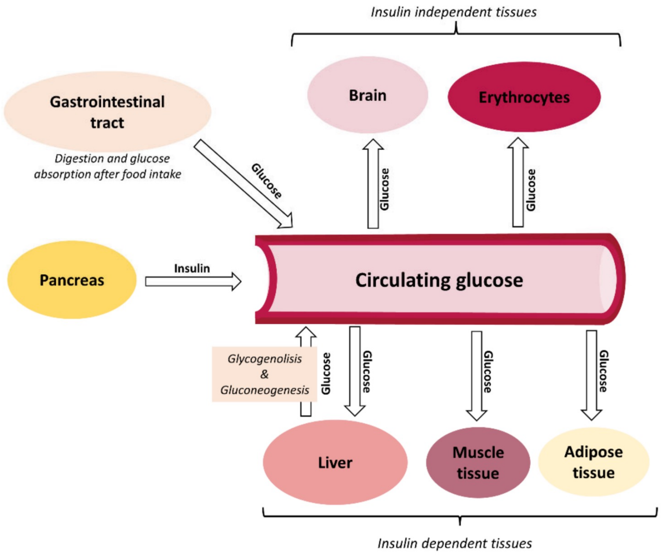
Review

Glycemic Responses of Milk and Plant-Based Drinks: Food Matrix Effects

Blerina Shkembi [1] and Thom Huppertz [1,2,*]



Foods	Experimental Portion § (mL)	GI	II	GL (Per Portion)	Portion Size * (g or mL)
Hemp milk unsweetened		59.94		0.21	250 g
Organic macadamia drink		49.47		3.71	250 g
Organic oat drink		59.61		7.98	250 g
Quinoa drink		53.28		4.51	250 g
Organic rice drink natural		97.74		18.33	250 g
Organic brown rice drink		99.96		16.85	250 g
Organic soya drink, calcium		47.53		3.01	250 g
Plain UHT organic soya drink		54.02		1.24	250 g
Soya organic, wholebean		49.49		0.57	250 g
Soya original		61.50		4.87	250 g
Fresh milk, pasteurised & homogenised		46.93		4.03	250 g

foods

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Review

Glycemic Responses of Milk and Plant-Based Drinks: Food Matrix Effects

Blerina Shkembi [1] and Thom Huppertz [1,2,*]

Dairy matrix effects:

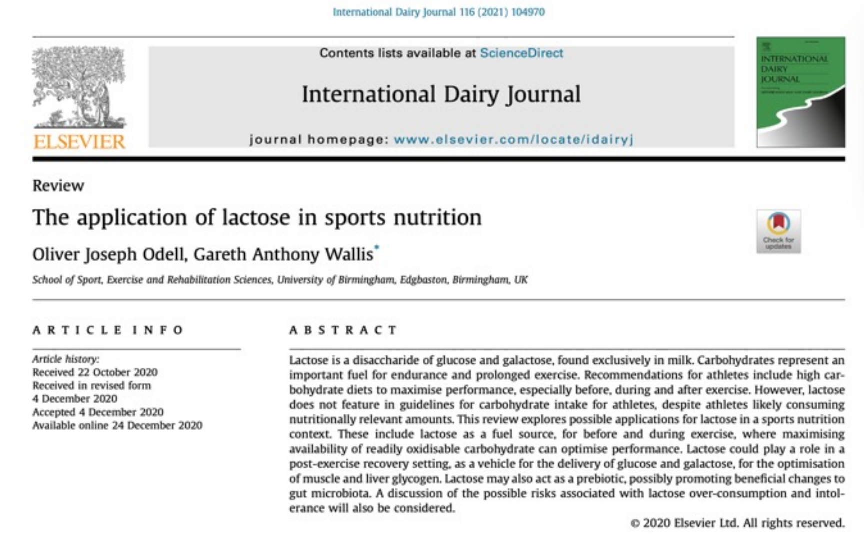
- GI of lactose is lower than $[GI_{(glucose)}+GI_{(galactose)}]/2$
  $GI_{(glucose)}=100$, $GI_{(galactose)}=23$
  This due to slower hydrolysis and absorption of lactose.
- Milk:
  - Slower gastric emptying due to caseins and fat.
  - Buffer capacity of milk.
  - Whey proteins activate incretins affecting gastric pH and glycaemic control.
  - Milk is the only liquid product that can be consumed in the form of the whole food produced as primary commodity.
- Cheese:
  - Hardly any lactose present.
- Yoghurt:
  - In stirred yoghurt, whey proteins and caseins are subject to rapid gastric emptying.
  - Lactate reduces gastric emptying rate.

In plant-based dairy alternatives, carbohydrate type and content determine GI and GL for the most part. Effects on gastric emptying?

"...glycaemic responses following consumption of these products vary widely and can also vary substantially from milk. Such differences can be attributed to compositional differences, but also to specific matrix effects for the milk matrix, which will add adequate control of postprandial blood glucose levels. For plant-based drinks, such effects have received only limited attention to date but should be considered to avoid excessive glycaemic responses following consumption."

Shkembi and Huppertz, *Foods* (2023), 12, 453.

Lactose possesses interesting features as a carbohydrate source for exercise


International Dairy Journal 116 (2021) 104970

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Review

The application of lactose in sports nutrition

Oliver Joseph Odell, Gareth Anthony Wallis*

School of Sport, Exercise and Rehabilitation Sciences, University of Birmingham, Edgbaston, Birmingham, UK

ARTICLE INFO

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ABSTRACT

Lactose is a disaccharide of glucose and galactose, found exclusively in milk. Carbohydrates represent an important fuel for endurance and prolonged exercise. Recommendations for athletes include high carbohydrate diets to maximise performance, especially before, during and after exercise. However, lactose does not feature in guidelines for carbohydrate intake for athletes, despite athletes likely consuming nutritionally relevant amounts. This review explores possible applications for lactose in a sports nutrition context. These include lactose as a fuel source, for before and during exercise, where maximising availability of readily oxidisable carbohydrate can optimise performance. Lactose could play a role in a post-exercise recovery setting, as a vehicle for the delivery of glucose and galactose, for the optimisation of muscle and liver glycogen. Lactose may also act as a prebiotic, possibly promoting beneficial changes to gut microbiota. A discussion of the possible risks associated with lactose over-consumption and intolerance will also be considered.

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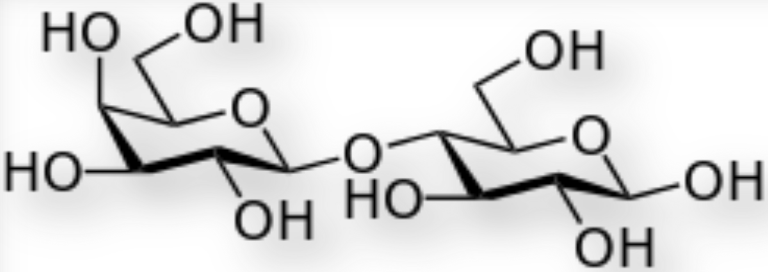
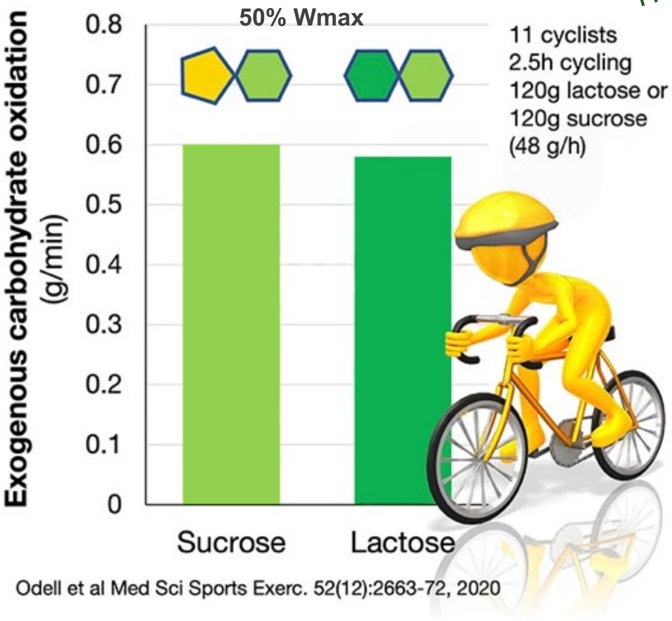


Lactose **matches sucrose** as an **energy substrate**

Lactose as a carbohydrate source during exercise

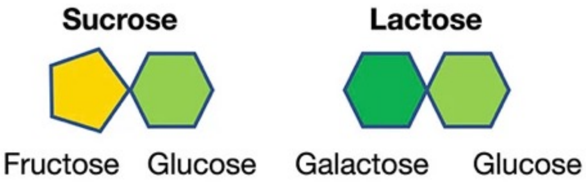
Hardly any complaints of GI discomfort!



Odell et al Med Sci Sports Exerc. 52(12):2663-72, 2020

Sources of lactose (g/100g)

Milk	5.0
Yogurt	4.5-6.0
Ice cream	3.3-6.0
Whey protein concentrate	3.5



Lactose is an alternative energy source during exercise with oxidation rates, similar to sucrose (at least when ingested at moderate rates)

Lactose **permits metabolic flexibility*** during exercise

*Switching between energy substrates.

Sparing of glycogen

Lactose, being less insulinogenic than sucrose, permits fat oxidation

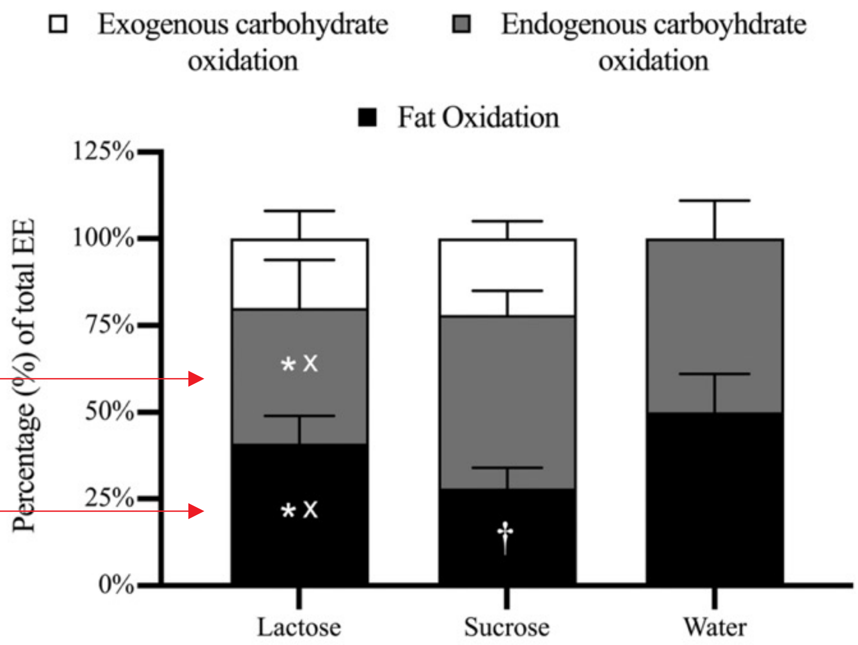
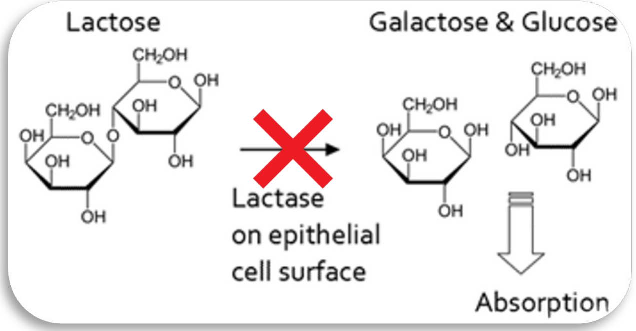


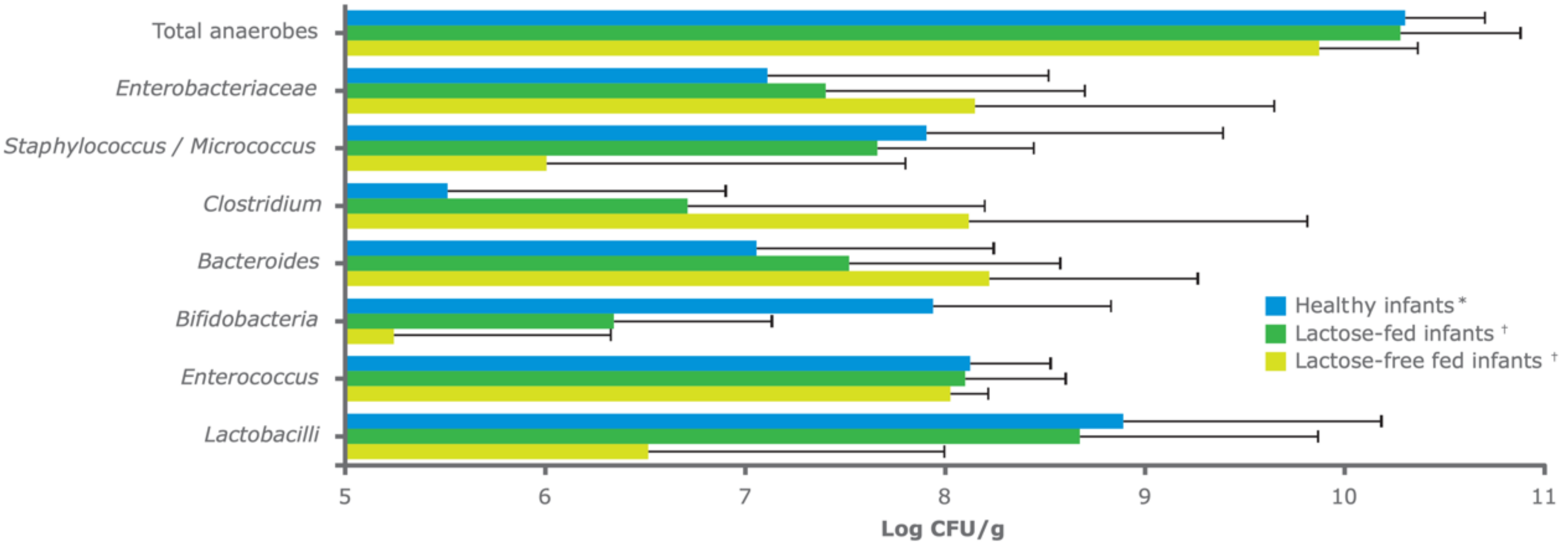
FIGURE 2—Substrate contributions to total EE from 60 to 150 min. *A significant difference ($P < 0.05$) between lactose and sucrose. [x]A significant difference ($P < 0.05$) between lactose and water. †A significant difference ($P < 0.05$) between sucrose and water.

Benefits of **un**digested lactose



Undigested lactose can exert microbiota shaping effects that improve gut microbiota composition

Lactose significantly increases the growth of *Bifidobacteria* and *Lactobacilli*



Also in adults (especially LNP) lactose shapes the microbiota, a phenomenon associated with increased lactose tolerance (i.e., colonic adaptation)

*Healthy breastfed infants without cow's milk allergy. Breastmilk contains around 7% lactose (wet basis).
Francavilla et al, Pediatr Allergy Immunol, 2012

The American Journal of Clinical Nutrition xxx (xxxx) xxx

ASN EST. 1928 American Society for Nutrition Excellence in Nutrition Research and Practice

The American Journal of CLINICAL NUTRITION

journal homepage: https://ajcn.nutrition.org/

Original Research Article

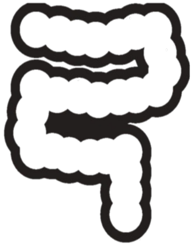
Changes in gut microbiota and lactose intolerance symptoms before and after daily lactose supplementation in individuals with the lactase nonpersistent genotype

Lonneke JanssenDuijghuijsen [1,*], Ellen Looijesteijn [2], Maartje van den Belt [1], Beatrix Gerhard [3], Martin Ziegler [3], Renata Ariens [1], Reina Tjoelker [2], Jan Geurts [2]

[1] *Wageningen Food and Biobased Research, Wageningen University & Research, Wageningen, The Netherlands;* [2] *FrieslandCampina, Amersfoort, The Netherlands;* [3] *Biomax Labvantage, Planegg, Germany*

To assess whether repetitive consumption of an increasing dose of dietary lactose in LNPers:

- induces colonic microbial adaptation



- decreases symptoms of lactose intolerance

Study design - Lactastic study

25 Males and females of Asian ethnicity

18-50 years
Healthy

LNP genotype (13910C>T)
Based on buccal swab testing

Avoiding dietary lactose in habitual diet
Self-reported via questionnaire

Screening

3*4-week course of an increasing dose of lactose (3, 6 and 12 gram).
Twice a day

Dose-response single-blinded intervention study

- 2* 3 gr lactose + 9 gr dextrose
- 2* 6 gr lactose + 6 gr dextrose
- 2* 12 gr lactose

Intervention: 3 * 4 weeks

Microbiome: (P)
- α-Diversity
- β-Diversity
- Microbial composition
- Functional analysis

Gastrointestinal function: (S)
- Hydrogen breath test
- Fecal lactase activity
- Gut comfort

Microbial activity: (T)
- SCFAs

22 Participants in analysis

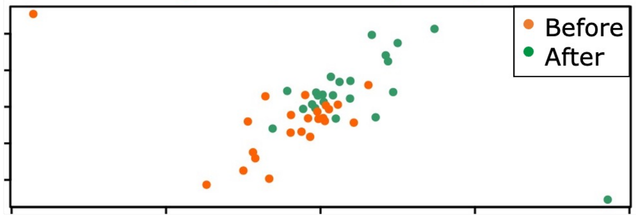
Outcomes

Lactose intervention increases relative abundance of *Bifidobacterium*

Alpha diversity (n=23)

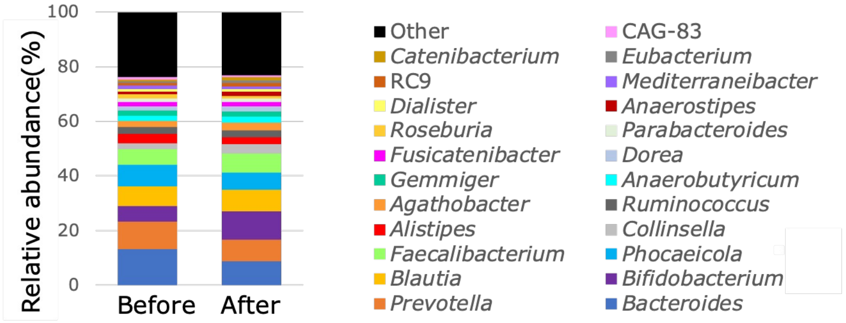
	Before	After	p-value
Shannon	4.54 (0.62)	4.51 (0.58)	0.687
Simpson	0.95 (0.04)	0.95 (0.05)	0.643

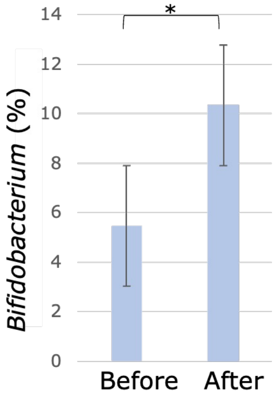
Beta diversity - Bray Curtis (n=23)

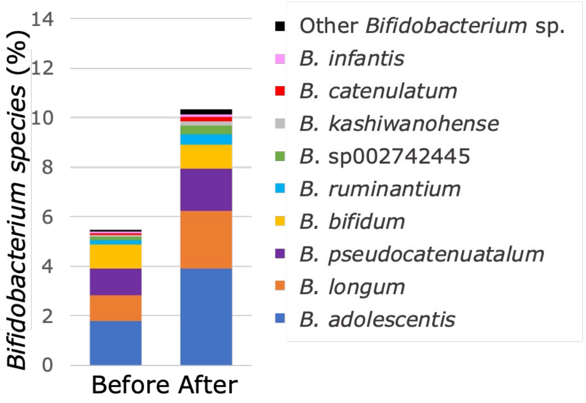


Significant shift of microbiota PERMANOVA (*p*=0.037)

Microbial composition (n=23)

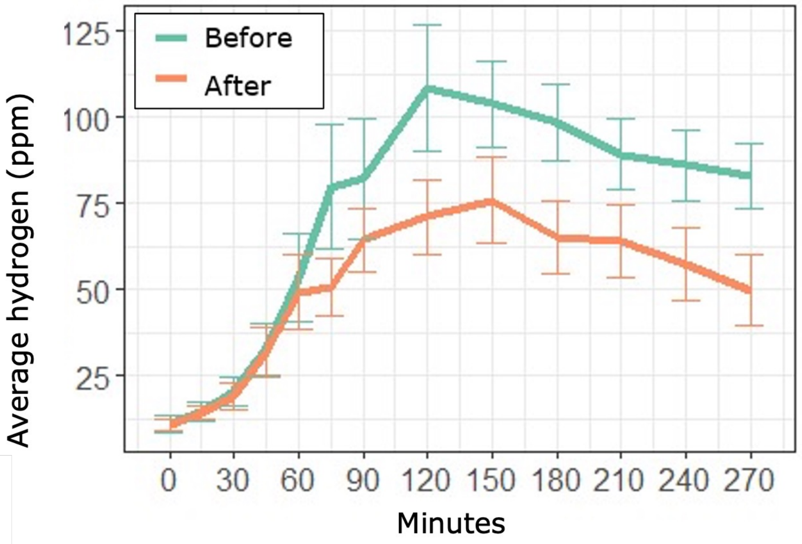




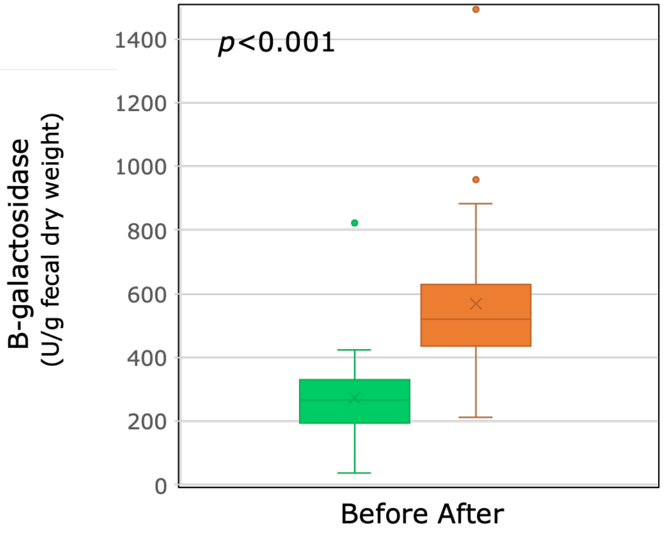


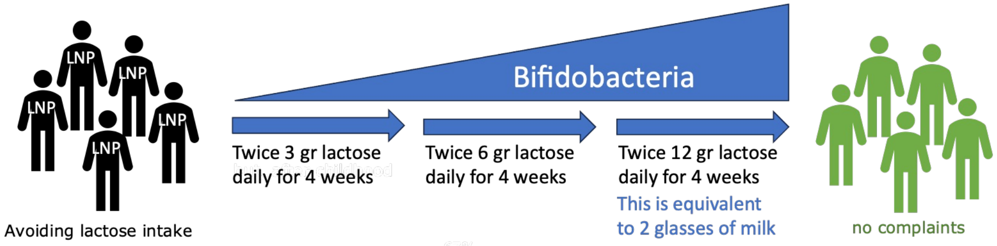
Lactose intervention increased lactose tolerance via adaptation of the gut microbiota

Hydrogen breath test (n=23)



Fecal β-galactosidase (n=23)





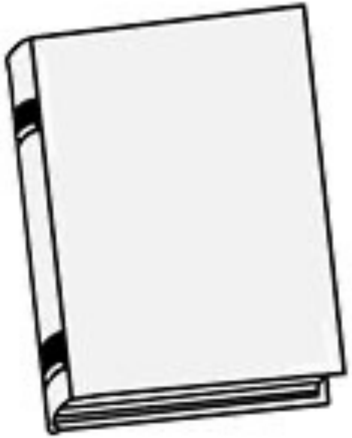
Take-outs:

- Repetitive consumption of lactose increases beneficial bifidobacteria in the gut microbiome of LNP individuals. Lactose acts as a dietary fibre.
- This increase in bifidobacteria leads to an increased capacity to metabolize lactose without gas production.
- Lactose consumption up to 24 grams per day is well-tolerated by LNP individuals and results in a reduction in expired breath hydrogen.
- Regular consumption of lactose, whereby the amount of lactose is gradually increased, enables most LNP individuals to keep dairy products in their diet and thereby profit from the nutrient-richness of those foods.

* JANSSEN DUIJGHUIJSEN, L. ET AL. (2023). AM J CLIN NUTR, S0002-9165(23)66349.

Take home messages

- There is more to lactose than lactose intolerance!
- Lactose is characterized by low sweetness and low cariogenic potential.
- In healthy infants and young children, lactose supports healthy growth & development by supplying energy as well as as building blocks (glucose and galactose) and beneficially impacting the (developing) gut microbiota.
- In all other age groups, the physiological effects of lactose depend on the lactase level in the GI-tract. If lactase levels are normal, lactose behaves as a low-GI sugar and provides energy and building blocks, if lactase levels are insufficient (e.g., LNP) lactose behaves as a dietary fiber and interacts with the gut microbiota.
- Lactose permits metabolic flexibility due to its low insulinogenic character.



"ALL NEW NEWS
IS OLD NEWS
HAPPENING TO
NEW PEOPLE"

-MALCOLM MUGGERIDGE


Thank you!