



Considerations for development of lactose-free food

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HIGHLIGHTS

- Lactose-free products are known to have low nutritional and sensory quality and are more expensive than lactose-containing food.
- This review focuses on special considerations, which should be undertaken while developing lactose-free products.
- This is a unique and comprehensive review; and will help the processors to develop the lactose-free foods.

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ABSTRACT

Lactose intolerance is a pathophysiological situation that occurs due to insufficiency of the “lactase” enzyme present in the jejunum. Ingestion of lactose containing products leads to alteration in intestinal digestion and colonic fermentation, leading to diarrhoea and other clinical discomforts. The articles reviewed were selected based on the following key descriptors such as lactose, lactose intolerance, lactose-free diet, non-dairy products, cost, nutritional composition and sensory attributes. Some lactose-free products made from the lactose hydrolysed milk or from the alternate milk sources possessing low nutritional and sensory quality are available in the market. These alternatives are high-priced comparative to the foods containing lactose. So, there is a strong urge to develop lactose-free products that are nutritionally adequate, economical and well accepted by the consumers with main focus on special considerations viz., finding an alternate non-lactose source, ensuring sensory and nutritional attributes, compliance with the concerned regulatory guidelines and economics. This unique comprehensive review will help the manufacturers in developing lactose-free products.

1. Introduction

The primary role of diet is to provide sufficient nutrients as per the metabolic requirements thereby giving the consumer a feeling of satiety [1]. The threshold of a new frontier in nutrition sciences has led to deviate from the past emphasis such as survival and hunger satisfaction. This helps in surpassing the negative impact on health by giving special attention on utilization of foods needed to promote wellbeing and thus lowering the possibility of diseases. Such notions are ignorable in the light of rising cost of health care, the desire of older people for improved life quality and the steady increase in life expectancy [2].

The reclamation of health properties has led food and beverage market to arouse interest among the various companies, thus increasing consumers' enthusiasm for the purchase of functional foods [3]. The

rapid increase in consumer awareness and the great interest in the roles of health improvement of specific food or physiologically active food components is a tendency [4] to the convergence of various critical factors, namely the deterioration of personal health driven by a routine occupied with an inadequate selection of convenience food and insignificant physical activity, higher incidence of self-medication, higher level of knowledge of health authorities and media on nutrition and a strong link between nutrition and health [4,5].

Non-dairy probiotic products have global importance due to an ongoing trend of vegetarianism and high prevalence of lactose intolerance among various people all over the world [6]. The drawback associated with the intake of dairy products include lactose intolerance, cholesterol content and allergenic milk proteins, which makes the development of new non-dairy probiotic foods essential [7].

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Table 1
Lactose content in different types of milk.

Milk and milk based products		Lactose (g/100 ml)	References
Raw milk			
Cow	Milk	3.7–5.1	[14]
	Colostrum	4.3	[15]
Buffalo	Milk	4.5–5.5	[10]
	Colostrum	5.2	[16]
Goat	Milk	3.6–4.8	[17]
	Colostrum	2.9–4.4	[10]
Human	Milk	6.2–7.5	[10]
	Colostrum	5.3	[18]
Sheep	Milk	3.7–4.8	[19]
	Colostrum	3.3	[20]
Camel	Milk	3.3–4.8	[21]
	Colostrum	3.63	[22]
Yak	Milk	4.17–5.6	[23]
	Colostrum	3.2–4.7	[24]
Milk based products			
Skim milk		4.3–5.7	[25]
Low fat milk		3.7–5.5	[17]
Lactose Hydrolysed milk		0.43–0.6	[26]
Buttermilk		3.6–5.0	[27]
Chocolate flavoured milk		4.1–4.9	[17]
Cream		0.1	[28]
Whipping cream		2.8–3.0	[17]
Ghee (cow milk)		0.0	[28]
Yoghurt		4.70–4.76	[29]
Whey		5.1	[28]
Kumis		5.5	[28]
Cheese	Cheddar	0.09–0.5	[30]
	Cottage	1.0–3.1	[25]
	Mozzarella	0.1–1.59	[31]
	Goat cheese	2.2	[28]
Paneer		2–2.7	[32]
Condensed milk		9.9–14.0	[29]
Evaporated milk		10–11	[17]
Butter		0.8–1.0	[17]
Ice-cream		3.6–8.4	[17]
Kefir		4.0	[33]
Khoa	Cow milk	24.9–24.30	[34]
	Buffalo milk	22–24.20	[35]
Gulabjamun		15.04	[36]
Rabri		11.3	[37]
Basundi	Buffalo milk	11.1	[38]
	Cow milk	8.12–10.8	[39]
Peda		15.3	[40]
Milk cake		7.7	[41]
Burfi		12–15	[39]
Kheer Mohan		1.20	[42]

includes the elimination of food product or food ingredient that contains lactose, as it triggers lactose intolerance. Due to the valuable efforts made by the researchers recently, a wide range of lactose-free and lactose-reduced milk and milk products are available in most of the super markets in Western countries and are nutritionally similar [13] to regular milk and milk products. Table 1 enlists different types of milk and milk based products along with their lactose content which should be considered prior developing the lactose-free product.

Table 2
Alternate sources and their composition.

Sources	Carbohydrates (%)	Proteins (%)	Fat (%)	Moisture (%)	Calcium (ppm)	Reference
Soy Milk	1.5	3	1.5	94	3.90	[45]
Rice Milk	45–57.3	15.5	0.79–2.5	18.7	1.5–1.6	[46]
Coconut Milk	5.5–8.3	2.8–4.4	32.2–40.0	64.1–80.4	9.40	[47]
Oat Milk	12	0.7–1.0	1.3–1.52	–	–	[48]
Lactose Hydrolysed Milk	4.8	3.2–3.37	1.5–4.3	87.1–89	112.7–120	[20]

4.2. Alternate sources

Avoidance of lactose containing food products leads to the exclusion of major carbohydrate (lactose) source present in milk and milk products. The use of lactase treated dairy products or oral lactase supplementation can be opted which serves as an alternative for lactose containing food or dairy elimination [43]. The lactose content in animal and human milk is in high amount and eliminating lactose from diet completely would lead to deficiency of calcium among children and adults resulting into less dense, fragile bones that can easily cause fracture [44]. Therefore a research for exploring and developing the alternative sources is highly required in order to obtain the desired nutritional requirement of a human body corresponding to particular age group.

Probiotics represent one of the largest functional food markets. Among the non-dairy probiotic products, those made with soy stand out because of the inherent health benefits of soy [7]. Apart from this, other lactose-free sources that are being used for developing food products for lactose intolerant patient includes yogurt, cheese, kefir, etc. Some alternate sources of milk that can be used in place of lactose containing milk and for developing lactose-free products are listed in Table 2 along with their respective nutrient concentration.

Until now various researchers have made numerous attempts to design and develop lactose-free food for the lactose intolerant patients using various lactose-free milk and milk products which is reviewed in Table 3 along with the specific remarks.

Beside these, replacement therapy results in an efficacious strategy for lactose intolerant people with the use of different exogenous lactase enzymes (such as β -galactosidase and tilactase) and probiotic food (containing strains of *Bifidobacterium longum*, *Bifidobacterium animalis*, *Lactobacillus bulgaricus*, *Lactobacillus reuteri*, *Lactobacillus acidophilus* or *Lactobacillus rhamnosus*) represents one of the largest functional food markets. In accordance with these advantages, recent studied related to lactase enzymes and probiotics along with their effect on the lactose intolerance has been tabulated in Table 4.

4.3. Ensure sensory characteristics along with consumer perception of fluid milk

The demand for lactose-free dairy products/health food is constantly increasing, as consumers are becoming more health conscious day-by-day [80] and offer alternatives for the large population with lactose intolerance. Therefore, it is important to understand the sensory characteristics of lactose-free milk and its products compared to normal milk [81], since the acceptance of dairy products is mainly sensory driven [82]. Therefore, prior to the development of such products, consumer perception is highly required. Milk with probiotic benefits is an attractive attribute for both dairy and non-dairy consumers [83]. Because of the presence of the numerous nutritional compounds, cow's milk is recommended in the dietary guidelines for Americans. However, because of beliefs about lactose intolerance, non-dairy beverages are recommended for people with lactose intolerance, including milk substitutes in federal food programs. Recent studies on consumer perception and acceptance of substitutive beverages indicated the consumers

Table 3
Lactose-free products development from alternate sources.

Milk product Developed	Alternate Source Used	Remarks	Reference
Milk	Soybean	<ul style="list-style-type: none"> ● Cholesterol-lowering effects. ● High in PUFA thus, prevents heart disease, postmenopausal syndromes, cancers, aging, and osteoporosis. 	[49]
	Coconut	<ul style="list-style-type: none"> ● Boost immunity. ● Creates a more favourable blood cholesterol profile. 	[50]
	Rice	Higher carbohydrate and calcium content as compared to fresh milk.	[51]
	Oat	Plasma cholesterol lowering effects.	[52]
Cheese	Soy milk	<ul style="list-style-type: none"> ● Minimal of cheese moisture and consequently cheese weight. ● Increase in protein breakdown. 	[53]
	Coconut milk	Increase in the protein and fat content of cheese with the inclusion of coconut milk.	[50]
Creamed cottage cheese	Lactose Hydrolysed cream	Provides cheese with appropriate organoleptic and good textural properties.	[54]
	Coconut milk	Higher fat content and able to retain the natural aroma and flavour.	[55]
	Soy milk	<ul style="list-style-type: none"> ● Higher protein content. ● Presence of non-digestible oligosaccharide. 	[56]
Flavoured lactose hydrolysed milk powder	Low lactose milk	High quality protein and essential nutrients including calcium and minerals.	[57]
Kefir	Soy milk	Good source of isoflavone genistein that suppresses the growth of cancer cells.	[58]
	Oat milk	<ul style="list-style-type: none"> ● 15%–20% oat milk concentration is suitable for consumer preference. ● Oat milk results into an increase in total beta-glucan content, whey off and microbiological flora. 	[59]
Functional beverage	Peanut- Soy milk	Higher content of some essential amino-acids.	[60]
	Ripened jack fruit and soy milk	High protein % and low fat % in addition to nutritionally valuable fibre content.	[61]
	Soy milk	<ul style="list-style-type: none"> ● Good source of protein (3%) ● Heart-healthy source of plant-based fat (7%). ● Low cholesterol. 	[62]
Ice- Cream	Coconut milk	<ul style="list-style-type: none"> ● Yogurt produced from coconut milk was comparable with the skimmed cow milk in all sensory quality attributes. ● High nutritive value. 	[63]
	Rice milk	<ul style="list-style-type: none"> ● It is possible to produce highly acceptable soft ice cream with different nutritional and sensory characteristics using rice as the major ingredient. 	[64]
	Lactose Hydrolysed whey	A good quality product and organoleptically palatable.	[65]
Chocolate Bar	Soy milk	Reduced beany flavour.	[66]
	Soy milk powder	Incorporation of powder gave a positive result in terms of physical and organoleptic properties of the chocolate.	[67]

significantly had better preference that lactose-free cow's milk than all soy drinks. Furthermore, lean and fat-free cow's milk is better accepted than non-fat and lactose-free cow's milk [84].

Until the first half of the 1990s, because of the astringent taste, the product that contained soy extract such as juices and ice creams were not well accepted. Since then, various industries have developed with new technologies, including genetic changes and the use of successful ingredients for the acquisition of products with better sensory characteristics [85]. Recently, an increase in the demand for soy products has shown that consumers are including them in their regular diet by adapting their approach to soy and their derivatives and also changing their expectations for new soy-based probiotic products available in the market [7].

4.4. Nutritional value of lactose free products

Studies have shown that patients who follow a strict lactose-free diet often suffer from various nutritional deficiencies that can generate various health disadvantages, such as immune dysfunction, colon health, etc. [9]. Milk and dairy products are classified as nutrient dense foods. However, these products have an advantage over other foods, i.e., sources rich in calcium [44], which is one of the most important engines for the development of the dairy industry. By increasing the amount of cheese and yoghurt, the needs can be met with the right amount of energy (fat) by keeping the lactose intake below 12 g per meal. Therefore, such dairy products can meet the calcium requirement of lactose intolerant people [10].

A lactose-free product should not just be lactose-free rather it must be comparable with lactose containing products in nutritional profile. Numerous attempts have been made by different researchers for development of nutritionally enriched lactose-free food products

(Table 3).

4.5. To meet RDA requirement

The average daily dietary nutrient intake level sufficient to meet the nutrient requirement of nearly 97–98% healthy individuals in a particular life age is termed as RDA (Recommended Dietary Allowances) [86]. It has been observed that lactose-free diet therapy often has low content of certain nutrients i.e. it contains less than 0.01% lactose (the maximum permitted lactose content for lactose-free products by the authorities) and the glucose and galactose content is approximately 1.4% each. Due to the lower carbohydrate content [87] the product also contains less energy as compared to the corresponding traditional product, with approximately 83% of energy content which suggests that the RDA for individual nutritional needs is not being met.

While developing a lactose-free product, it should be ensured that the nutritional profile of the product should not be reduced to such a level which may affect the health and RDA of a person. To ensure this, the sole solution is to include lactose hydrolysed products in their regular diet. The alternative sources (lactose hydrolysed milk, oat milk, etc.) can also be opted along with calcium and vitamin D supplements [8] regularly through other food sources or fortified with these nutrients to meet the RDA.

4.6. Economics

As per the available literature, adherence to a lactose-free diet leads to an economic burden on the patients because lactose-free products which are available in the market have prices much higher as compared to lactose containing products. Thiele [88] carried out a study for analyzing the price variation of the milk and milk products with and