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Production of Flavored Low Lactose Milk Powder with a Small Spray Dryer

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Abstract: In the present study, after preparing low lactose milk using lactase enzyme (0.15%), it was flavored with banana extract (5%) and cocoa powder (0.7%), separately. The ready mass was dried in spray dryer which designed and made with the dimension of 2.27 m height and 2 m width. The spray dryer was a co-current model. The physico-chemical, bacteriological and organoleptic properties of the flavored (banana puree and cocoa powder) low lactose milk powder were examined also. The flavored low lactose milk powder after being dissolved in water becomes a very pleasant beverage with 0.5% lactose. As a result, lactose intolerant people could consume it easily obtaining the useful properties of the dairy products. The above mentioned types of milk can also be consumed by lactose non-sensitive people.

Key words: Milk · Low Lactose · Spray Dryer · Powder · Lactose Intolerance

INTRODUCTION

Many people suffer from lactose intolerance, an inherited characteristic, making them unable to consume milk and milk-based products. Lactose or milk sugar is a disaccharide with relatively low sweetness intensity which accounts for about 5% of whole milk [1-3].

Lactose is normally digested in the small intestine by the lactase enzyme. People with lactose intolerance have an insufficient amount of this enzyme and are therefore unable to digest lactose in food [4-7].

The maldigestion of lactose can cause them intestinal disorders like flatulence, bloating and abdominal pain. As a result, many people can't usage milk and milk products and profit the nutritional matters of milk. As they are lactose intolerant, refuge to consume milk products and ultimately given some diseases like "Osteoporosis" [8, 9].

Lactose-hydrolysed and lactose-free dairy products should be considered as important physiologically functional dairy foods.

Their rapidly expanding availability will mean not only more satisfied milk drinkers world-wide, but will lead to improved nutritional status due to increased availability of dairy calcium and ultimately, to reduction of health-related societal expenses [10-13].

The aim of this study was to produce flavored (Banana and cocoa powder) hydrolyzed-lactose milk powder with a small spray dryer and investigation of its physico-chemical and organoleptic characteristics.

MATERIALS AND METHODS

Milk: A standard cow's milk was obtained from Mazandshir dairy company with characteristics of 1.5 % fat, 3.1% protein, lactose, 4.7%.

Enzyme: Hydrolysis of lactose was used by lactase enzyme (Lactozym 3000 L HP G, novozymes, Denmark). The dosage was 0.15 %.

Flavoring Agents: Cocoa powder and banana concentrate which used as flavoring agents of milk were purchased from commercial corporations, ELCAFE, Turkey and Chiquita brands, Inc. Malaysia, respectively.

Solvents and Reagents: All reagents and solvents for experiments except enzyme were purchased from Merck (Germany) and were of analytical grade.

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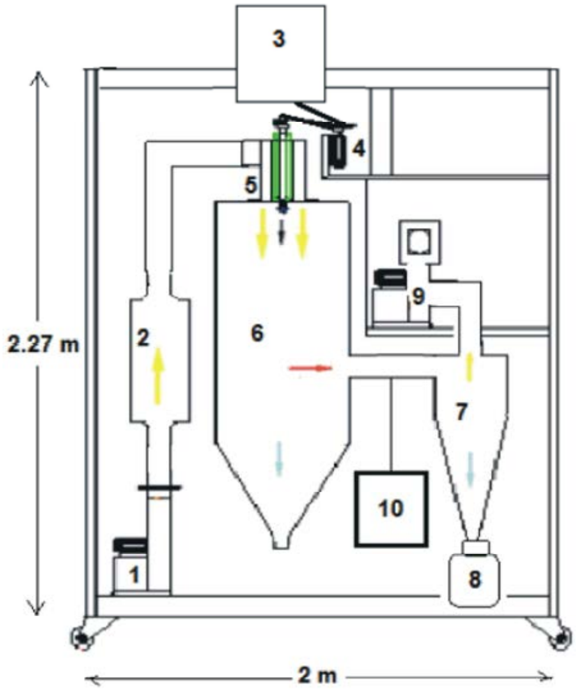


1. Blower	6. Chamber
2. Heater	7. cyclone
3. Feed tank	8. Powder collector
4. Pump	9. Fan
5. Atomizer (Nozzle)	10. Control box

Fig. 1: Spray dryer

Production of Low Lactose Milk: After purification and standardization of milk fat to 1.5%, milk was pasteurized (72°C/15 sec.) and cooled back to the incubation temperature (37°C), then put into the hydrolysis tank. 0.15% lactase enzyme was added to milk while stirring. Through this process, lactose was hydrolyzed to D-glucose and D-galactose. After hydrolysis, the milk pasteurized again, followed by cooled.

For flavoring the milk, cocoa powder (0.7%) and banana concentrate (5%) were mixed to low lactose milk, separately.

Finally, flavored low lactose milk powder was produced by spray drying of these mixtures. Produced samples were packed in amber-coloured glass flasks and stored in ambient condition for further analysis.

Co-Current Spray Dryer: For producing of flavored low lactose milk powder, a spray dryer (Fig. 1) was designed [14] in a factory in north of Iran and tested in a dairy company. The spray dryer used in this research project was a co-current spray dryer. The characteristics of spray dryer chamber of this study are as follows:

- Diameter: 60 cm
- Height: 150 cm

The characteristics of air heating system are as follows:

- Diameter: 30 cm
- Height: 50 cm
- Number of elements: 5

The characteristics of cyclone was as follows:

- Material: stainless steel
- Height: 70 cm
- Diameter: 35 cm (Fig. 1).

In this study the ambient air is filtered, heated and introduced into the drying chamber. Air cleaning is performed by dry filters.

Electric air heaters were used in this research. These heaters are common on laboratory and pilot plant spray dryers. The heater has low investment costs, but it is expensive in operation and therefore not used in industrial scale plants.

Different spray drying temperatures (145, 155, 165 and 175°C) were used to find the optimum drying temperature; finally, experiments were performed at 145°C. The outlet temperature was fixed at 75°C.

Milk Analysis: Chemical analyses were carried out by standard methods. Fat content, protein (Micro Kjeldahl , N × 6.37), acidity, carbohydrates and total solids were estimated according to ISIRI No. 93. [15]. Lactose determined using lactostar analyzer (Lactostar, Labortechnik 12105 berlin, Article No. 3510, Germany). pH measurements were performed using a Metrohm model 744 pH meter (Switzerland).

Powder Analysis: For moisture content, the sample was dried to a constant weight at 103±2°C and the loss in weight reported as moisture content [9]. Protein of samples was done with Micro Kjeldahl (N × 6.37) (Gerhard, Germany) [16]. For fat analysis, 1 gram of powder weighed in a Mojonnier flask and 9 ml of warm distilled water was added. After shaking, 1.25 ml of ammonia solution was added, shake well and proceed as per Rose Gottleib method [17].

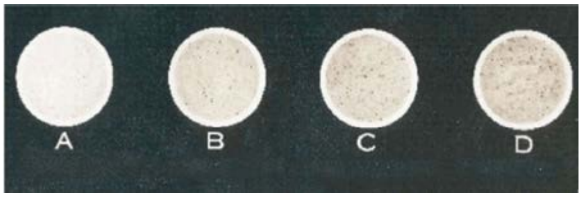


Fig. 2: Standard chart for scorched particles of milk powder

Determination of scorched particles involves filtering a hydrated milk powder solution through a disc and comparing the color of the mass on the dried disc with standard discs [18].

25±0.1 gram of powder was weighed and blended with 250 ml water. After 60 seconds mixing, the solution filtered through the filter. Filters were dried for 2 hours at approximately 35°C. The results compared with the original standard chart (Fig. 2). The comparison is visual. The standard chart is divided into a scale from A-D.

Particle size distribution of produced powders was determined using the method described by Farral [19]. A sample of powder (100 g) was used. A suitable sieve shaker (AU MEDIA, Iran) and designated sizes of 500, 180 and 125 mesh and a balance of accuracy ±0.01 g (Sartorius LP 1200s, Germany) were used. The sample was poured onto the top sieve of the shaker and after shaking for 5 min. (200 rpm), the particles remained in each sieve were weighed by an accurate balance and the weight per cent calculated.

For ash content, 2 gram sample was weighed into a porcelain crucible and placed in muffle furnace at 600°C for 2 hr. The crucible was removed from the furnace and placed in a desiccator, cooled and weighed. The residue is the ash and represents the inorganic constituents of the sample. Values were reported as ash percentage [20].

Sugar analysis was determined using enzyme test kits (R-Biopharm, Darmstadt, Germany) and Gas Chromatography Mass (Agilent 7000A, USA). Microbiological analysis of powders was determined according to ISIRI 2406 [21].

Samples were weighed and diluted with buffered peptone water (BPW) (Oxoid, Unipath, Hampshire, UK). The homogenate from the sample preparation was used for the plating and incubation procedures. Four 10-fold dilutions were made with each samples, 1 ml of each step was inoculated in duplicate plate count agar standard (PCA) (Oxoid, Unipath, Hampshire, UK) at 30°C for 72 h to determine the number of mesophilic aerobic plate counts [22].

Coliform bacteria were determined using duplicate pour plates with 1 ml of each dilution in violet red bile glucose (VRBG) agar (Oxoid, Unipath, Hampshire, UK), over-layered with a further 10-15 ml of VRBG agar. The plates were incubated at 37°C for 24 h. Typical colonies were counted on all plates [23]. To isolate *E. coli*, the previous BPW tubes were inoculated into Lauryl Suifate Tryptose Broth (Oxoid, Unipath, Hampshire, UK) at 37°C for 48 h. Tubes with gas production inoculated to Escherichia Coli broth (EC Broth) (Oxoid, Unipath, Hampshire, UK) and confirmed test was done by indole reaction [24].

A volume of 0.1 ml of previous BPW was surface plated on Baird-Parker agar containing egg-yolk tellurite emulsion (Oxoid) and incubated at 37°C for 24 h to enumerate *S.aureus*. Colonies with typical *S. aureus* morphology (i.e., black, convex and with or without halo on BP agar) were examined microscopically, Gram stained, tested for catalase reaction and confirmed with an agglutination Staphytect Plus test (Oxoid) [25].

Statistical Analysis: Total solids, acidity, protein, lactose and pH of initial milk were measured in duplicate repeats. Protein, Moisture content, carbohydrates, ash, fat, pH, particle size distribution and scorched particles of powders were made in triplicate repeats for each sample.

All values are reported as means of determinations. Average and standard deviation values were calculated using the Microsoft Excel data sheet (Microsoft Co., Seattle, WA).

Analysis of variance was calculated using the standard ANOVA procedure. Significant differences between the means were estimated using Duncan's multiple range tests. Significant differences were determined at $\alpha = 0.05$ level of significance.

Sensory Evaluation: All the powder samples were reconstituted and then sensory evaluation was performed. All the reconstituted samples were evaluated for sensorial acceptability by pairing a preference test.

The panel participating in the sensory evaluation included 30 volunteers who were staff members of the Institute of standard and industrial researches of Iran. These panelists were randomly selected based on availability and interest.

The reconstituted samples were prepared at room temperature prior to sensory evaluation.

As well as reconstituted samples a sample produced with this formula: flavored (Cocoa) low lactose milk powder+water+saccharose.

In this trial, 2% succharose was added to flavored (Cocoa) low lactose milk powder and then reconstituted with water. Organoleptic analysis was done for this new product, also.

Each panelist received the reconstituted sample in a random order and a glass of water for consumption between tests was supplied.

Each panelist was served with 50 ml of reconstituted samples in clear plastic containers, which were randomly coded.

Five different descriptions were employed to grade the overall quality in terms of color, odor and taste: extremely dislike, dislike, like, neither like nor dislike and extremely like. Extremely dislike corresponded to 1 and extremely like to 5 [26].

RESULTS AND DISCUSSION

After regulating of milk fat to 1.5%, it was tested for some chemical and microbial analysis. Results were according to National standard of Iran. The objective of standardization is to adjust the ratio of milk fat and total solids to the level required in the final product.

With the desire to consume milk and milk-based products growing throughout the world, it makes sense to implement an effective and natural solution that breaks down lactose and enables everyone to consume and benefit from these products.

Enzymatic method was used in this research for producing of low lactose milk with the help of beta-galactosidase, commonly named lactase [27]. This enzyme breaks down (Hydrolyses) the disaccharide lactose to the sweeter-tasting monosaccharides glucose and galactose.

To determine the influence of temperature and time on the enzymatic hydrolysis of lactose, experiments were performed at 37, 41 and 45°C and two time (3 and 4 hour) at an initial lactose content of milk. The results of experiments revealed that the activity of enzyme decreased with the increasing of temperature and the optimum activity of enzyme was at 37°C (For both incubation times).

Due to the results, with increasing of incubation time, enzymatic hydrolysis increased at all incubation temperatures but there wasn't any significant difference between the times 3h 20 min to 4 hours of incubation. As a result, the time of 3h 20 min was preferred for incubation time.

The remaining lactose in milk incubated at 37°C for 3h 20 min was 12% of initial content.

Table 1: Chemical analysis of flavored low lactose milk powder

	Value (%)	
Characteristic	With banana flavor	With cocoa powder flavor
Humidity	2.3 ± 0.24	2.6 ± 0.24
Total carbohydrate	44.3 ± 0.23	41.7 ± 0.13
Lactose	4.6±0.10	5.3±0.12
Protein	36.0 ± 0.31	35.1 ± 0.22
Fat	12.6 ± 0.22	15.5 ± 0.14
Ash	4.8 ± 0.03	5.1 ± 0.02

After hydrolyzing of lactose in milk, chemical analysis was performed. No significant difference was seen in chemical analysis data of milk and hydrolyzed milk except it's lactose that decreased to 0.5%.

Microbiological analysis of low lactose milk was performed and just the total plate count of low lactose milk was increased to 35000 cfu/ml. However with this change, results confirm to national standard of Iran. The pilot plant spray dryer was used to produce free flowing hydrolyzed milk powder. There was no powder stickiness on the chamber wall surface. In spray drying, stickiness occurs when particles are insufficiently dry collide with one another or with the dryer walls and become stuck.

Chemical analysis of flavored (Banana puree and cocoa powder) low lactose milk powder was performed and results indicated in Tables 1.

There appears to be critical level around 5% moisture and every effort should be made to maintain a level not exceeding 4%. Moisture content of produced powders in this study was below these ranges.

All kinds of milk powders absorb moisture very readily from the atmosphere and if packed in materials which are not impermeable to moisture, such as plain paper sacks, cardboard cartons, etc., it may develop large hard lumps or severe caking during storage.

Masters [28] and Pisecky [29] showed that the moisture content of a dairy powder is related to the outlet air temperature, the moisture content decreasing when the outlet air temperature increases.

Due to the importance of carbohydrates in produced powders, sugars of total carbohydrates of flavored (Banana puree) low lactose milk powder are showed in Fig. 3.

As the sugars of flavored (Banana puree) low lactose milk powder included glucose, saccharose, fructose, galactose and a low amount of lactose, it can be concluded that with reconstituting of this powder with water and consumption of this flavored milk doesn't have any side effect on lactose intolerance people.

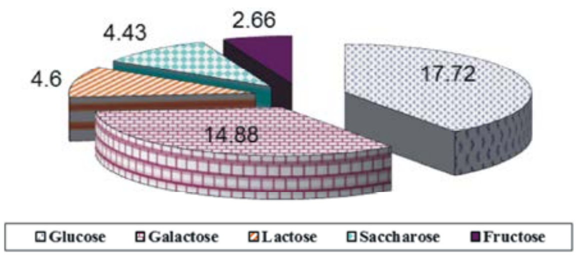


Fig. 3: Main carbohydrates (g) of flavored (Banana puree) low lactose milk powder

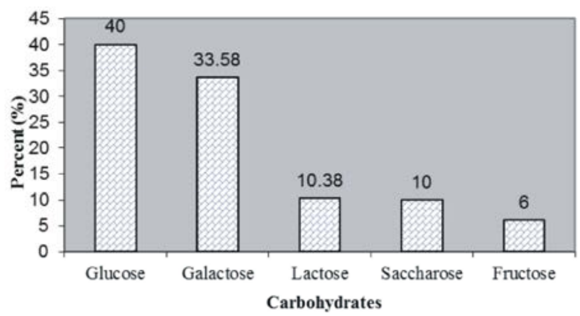


Fig. 4: Main carbohydrates (%) of flavored (Banana puree) low lactose milk powder

In Fig. 4, the percentage of each carbohydrate which exists in flavored (Banana puree) low lactose milk powder displayed.

Together with flavored (Banana puree) low lactose milk powder, flavored (Cocoa powder) low lactose milk powder is bare of harmful sugars for lactose intolerance people (Fig. 5). Consumption of this product is suitable for lactose intolerant.

In Fig. 6, the percentage of each carbohydrate which exists in flavored (Cocoa powder) low lactose milk powder displayed.

All these studies illustrated that production of flavored low lactose milk is a good way to introduce new generation of products for lactose intolerance people.

A comparison of milk powder with flavored (Banana and cocoa) low lactose milk powder was performed from lactose point of view (Fig. 7).

As a result, this figure denoted that application of enzyme for producing low lactose milk and then mixing with other flavoring matters followed by drying with spray dryer is a successful way for creating different kinds of flavored low lactose milk powders.

These are products that lactose intolerance people can use them by reconstituting by water at any time.

Microbiological analysis of powders was performed for confidence of healthy aspects of these powders and results recorded in Table 2.

Table 2: Microbiological analysis of low lactose milk powder

Characteristic	Value With banana flavor	With cocoa powder flavor
Total plate count (cfu/g)	12000	9000
Coliform (cfu/g)	<10	<10
E. coli (cfu/g)	Absent	Absent
S. aureus (cfu/g)	Absent	Absent

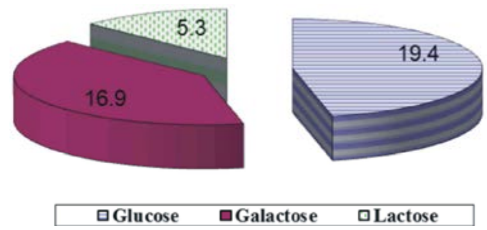


Fig. 5: Main carbohydrates (g) of flavored (Cocoa powder) low lactose milk powder

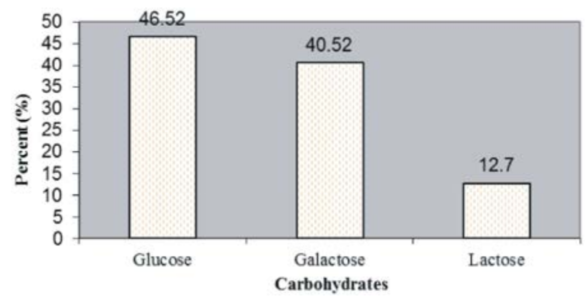
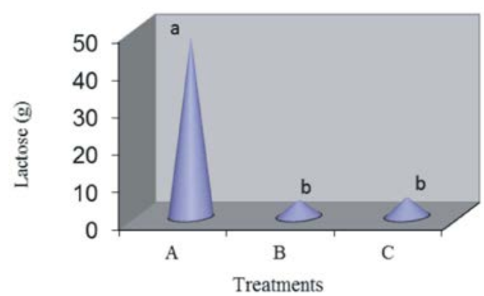


Fig. 6: Main carbohydrates (%) of flavored (Cocoa) low lactose milk powder

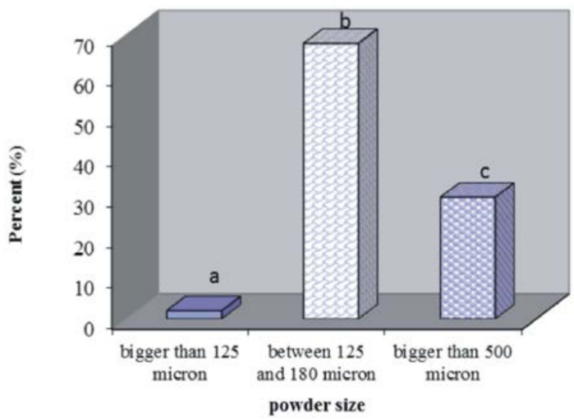


There Was Significant Difference Between The Groups ($P<0.05$).

Fig. 7: Comparison of Lactose Content;
Common milk powder (A); flavored (banana puree) low lactose milk powder (B); flavored (cocoa powder) low lactose milk powder (C)

The size of the particles produced from the liquid droplet depends on the solids content in the liquid feed, inlet air temperature and the plasticity of the moist solid phase [30].

Sieves were used for measuring powders size distribution in this research. Fig. 8, shows that the particle size distribution was as follows: 68% of powders were



There was significant difference between the groups ($p<0.05$)

Fig. 8: The size of flavored low lactose powders

Fig. 9: Scorched particles of flavored (cocoa (a) and (banana)(b)) low lactose milk powder

bigger than 180 micron and smaller than 500 micron, 30% of powders were bigger than 500 micron and 2% of powders were bigger than 125 micron and smaller than 180 micron.

The average droplet size and distribution is fairly constant for a given method of atomization, but the average particle size can be in the range of 10-300 microns.

Scorched particles of flavored (Banana) low lactose milk powder and flavored (Cocoa) low lactose milk powder was determined. As illustrated before, powders reconstituted with water and then passed through a filter. After drying the filter in oven, it was investigated visually with standard discs. As it is observable in Fig. 9 (A and b), scorched particles measurement showed that it is conforms to (A) disk (Fig. 2). The reason of dark color of disc (Fig. 9a) is existence of cocoa in this production. This good quality is because of well designing of spray dryer, method of powders production and using of optimum conditions for production.

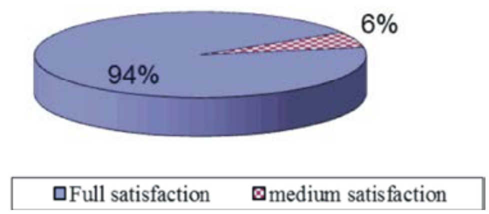


Fig. 10: Investigation of the color of reconstituted flavored (banana) low lactose milk powder with water

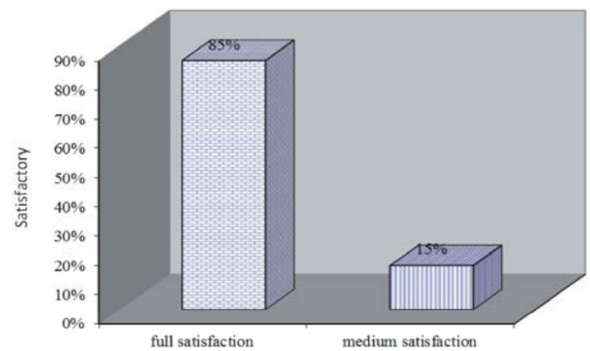


Fig. 11: Investigation of the taste of reconstituted flavored (Banana) low lactose milk

For organoleptic analysis, first reconstituted flavored low lactose milk was prepared with dissolving powders in water and then organoleptic analysis was done.

The panelists evaluated sensory properties of color, aroma and flavor of samples by using of five points hedonic scale. In that scale, 1 to 5 refers as follows:

1= extremely dislike; 2= dislike; 3= neither like nor dislike; 4= like and 5= extremely like.

As it displayed in Fig. 10, 94% of panelists had full satisfaction from color quality of mixed flavored (banana) low lactose milk powder with water and only 6% of panelists had a moderate satisfaction.

As well, panelists evaluated the taste of reconstituted flavored (Banana) low lactose milk that the analysis of this evaluation displayed in Fig. 11.

Another evaluation for sensory characteristics was the analysis of reconstituted flavored (cocoa) low lactose milk by panelists. All the panelists had full satisfaction for the color quality of reconstituted flavored (Cocoa) low lactose milk. In another words, this powder showed the highest score for color. All the reconstituted samples had a satisfactory smell and showed the highest score in assessment forms.

Fig. 12, displays the satisfaction rate of reconstituted flavored (cocoa) low lactose milk from flavor point of view. The score of this test was not very good and this product couldn't satisfactory the panelists.

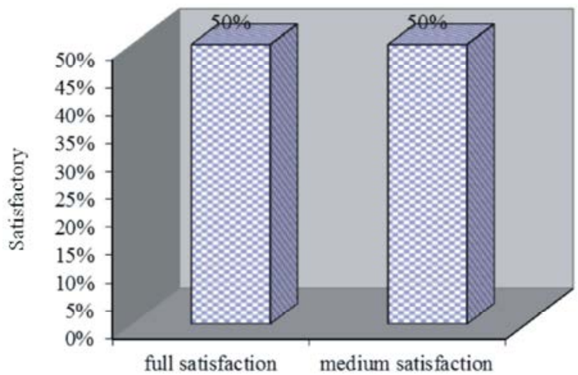


Fig. 12: Investigation of the taste of reconstituted flavored (cocoa) low lactose milk

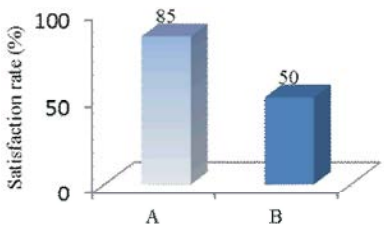


Fig. 13: Comparison of the taste of reconstituted flavored low lactose milk. A: with banana flavor and B: with cocoa flavor

In Fig. 13, the satisfaction rate of the taste of reconstituted flavored (Cocoa) low lactose milk compared with reconstituted flavored (Banana) low lactose milk.

As it was expected, samples that contain banana puree had higher acceptance. This is related to higher sweet taste. The reason of higher sweetness of this product is related to higher carbohydrate and the composition of sugars that present in banana puree which used for production of this product.

Although the panelists hadn't good satisfaction from the sweetness of reconstituted flavored (Cocoa) low lactose milk and the taste of flavored (Cocoa) low lactose milk accepted in 50% as full satisfaction, but they satisfied by giving them the reconstituted product with flavored powder and 2% sugar. Results showed that the score was changed and satisfaction was reached to 83%.

One of the important advantages of these powders is the absence or low percent of saccharose.

With due to hydrolysis of lactose to glucose and fructose and also application of natural banana puree, the sweetness of reconstituted flavored (Banana) low lactose milk was good and there wasn't need to adding sugar. One of the advantages of this product in comparison with common flavored milk is the added sugar that for reconstituted flavored (Cocoa) low lactose milk, only 2% saccharose was added that in comparison is very low.

The amount of sugar in common flavored milk is about 6-7% that is not good nutritionally. Sucrose is notorious for its adverse health effects such as the development of dental cavities, diabetes, insulin resistance, obesity and elevated triglycerides, which are a risk factor for the development of atherosclerosis (Hardening of the arteries).

On the other hand, some of the disadvantages of low lactose milk expressed follow:

Low shelf life; high requirement of space for storage; need to refrigeration and low satisfaction of consumers because of its taste. As a result conversion of low lactose milk to low lactose milk powder is a beneficial method to conquest these problems [31].

Transformation form flavored low lactose milk to flavored low lactose milk powder help increasing the shelf life of the product and reduction of transportation cost to distant market [31, 32].

This is important especially for places that located in impassable places. There is no need to transmit these types of powders by vehicles with refrigeration system.

Another preference of flavored low lactose milk powder is that the sweetness of these products were mixed with flavoring agents and represent as flavored milk after reconstitution but in low lactose milk, this sweetness changes the original taste of milk that was not accepted by consumers [33].

These powders have the ability of packaging in sachet and distribute as instant powders [34]. These products can be used in any time and places.

CONCLUSION

Flavored low lactose milk powder can be part of an eating plan that supports healthy life. It is a good strategy for preventing the refuge of dairy products. Next to the medical aspect of lactose intolerance, the production of self-sweetening products or products with less sucrose addition would be possible by using lactose hydrolyzed milk.

Offering low lactose flavored milk powder encourages increased milk consumption and adequate calcium intake. These types of products are natural sources of high quality protein and essential nutrients including calcium and minerals, which can help lactose intolerant people maintains their milk-drinking habits. The consumption of these new products will surely be a good prophylaxis against different diseases that the treatment of which demands high expenses.

The removal of nearly all the water content of flavored low lactose milk yields a compact product which is easily transported and stored. It may be stored for very long periods and reconstituted again in water when required. Produced powders have the ability of packaging in sachet and have long storage life without needing of refrigerator. Transportation costs can be reduced when shipping this product to distant markets. With the presence of modern technologies, this research gives many advantages to food industry and human life.

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