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PHYSICAL, CHEMICAL AND ORGANOLEPTIC CHARACTERISTICS OF LACTOSE-FREE MILK-BASED ICE CREAM

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Abstract. *Lactose-intolerant individuals avoid consuming milk and dairy products, which may lead to deficiencies in essential nutrients naturally present in milk. Lactose-free milk, characterized by its higher sweetness compared to full-cream milk, serves as an ideal base for ice cream. This study aims to analyze the physical, chemical and organoleptic characteristics of lactose-free ice cream. Lactose-free milk was produced using 0.2% lactase enzyme. The evaluated parameters included viscosity, overrun, melting time, pH, sweetness level, total caloric content, lactose content, and organoleptic properties. Data were analyzed using a t-test by comparing ice cream made with whole milk and lactose-free milk. The results indicated that lactose-free ice cream exhibited a significantly higher overrun ($p < 0.05$), a sweeter taste, and lower total caloric content. However, it had a shorter melting time. No significant differences ($p > 0.05$) were observed in viscosity, pH, or organoleptic properties. These findings suggest that lactose-free ice cream demonstrates a comparable level of consumer acceptance to whole milk-based ice cream.*

Keywords : *Ice Cream, Lactase, Lactose Free Milk, Lactose Intolerant, Organoleptic*

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INTRODUCTION

Lactose intolerance is a condition in which the body is unable to properly digest or absorb lactose due to a deficiency of the enzyme lactase (Wicaksono *et al.*, 2022). Symptoms of this intolerance include bloating, diarrhea, and excessive gas production after consuming milk or dairy products containing lactose (National Digestive Diseases Information Clearinghouse, 2014). The prevalence of lactose intolerance is particularly high in Asia, with rates reaching 70–100% in East Asia and over 70% among Indonesian adolescents aged 12–14 years (Hegar & Widodo, 2015). As a result, many individuals are forced to avoid milk and dairy products, despite milk being a primary source of essential nutrients such as protein, calcium, and vitamins.

As a solution, lactose-free milk has been introduced to meet the nutritional needs of individuals who cannot consume regular milk. Lactose removal from milk can be achieved through two common methods namely enzymatic hydrolysis (Neves & de Oliveira, 2021), membrane filtration (Zhang *et al.* 2020), and fermentation (Rosolen *et al.*, 2015). Membrane filtration requires relatively higher costs compared to other methods, while fermentation takes a longer time compared to other methods. Enzymatic hydrolysis using β-galactosidase (*lactase*) being the most efficient and effective approach. This enzyme hydrolyzes lactose into glucose and galactose by breaking the glycosidic bond in lactose (Zhang *et al.*, 2025). Lactose-free milk not only benefits individuals with lactose intolerance but also possesses a higher natural sweet-ness compared to whole milk (Özdemir, 2018), making it an ideal base for various processed dairy products such as ice cream.

Ice cream, as one of the most popular dairy-based products, is appreciated for its sweet taste and distinctive texture. Utilizing lactose-free milk as a base allows ice cream to be consumed by lactose-intolerant individuals while also enabling a reduction in added sugar during production due to its naturally enhanced sweetness. Therefore, this study aims to investigate the physical, chemical and organoleptic characteristics of lactose-free milk-based ice cream. The findings of this research are expected to contribute to the development of more inclusive dairy products that cater to lactose-intolerant consumers while also expanding the range of healthy food options available.

MATERIALS AND METHODS

1. Materials

Cow's milk (Darul Fallah Farm), lactase enzyme (NOLATM Fit 5500, Denmark), cornstarch (Egafood), skim milk (Greenfields), sugar, and egg yolk. The primary equipment utilized included an ice cream maker (GEA ice-1530, China), a thermometer, a digital scale, a mixer, a pH meter (pH5S Ionix, China), a refractometer, a stopwatch, a refrigerator, and a freezer.

2. Methods

2.1 Lactose-Free Milk Production (Sudsaard *et al.*, 2014)

Fresh milk was heated to 50°C using a hotplate. Subsequently, lactase enzyme was added at a concentration of 0.20% of the milk volume. The mixture was then stirred thoroughly and left to stand at 50˚C for 60 minutes to allow enzymatic hydrolysis. Following this process, the milk underwent pasteurization using the High-Temperature Short-Time (HTST) method at 72.5˚C for 15 seconds.

2.2 Ice Cream Production (Özdemir *et al.*, 2018)

The produced lactose-free milk was then mixed with the ice cream base ingredients, including egg yolk, skim milk, whipping cream, cornstarch, and sugar, following the formulation presented in Table 1. The mixture was subsequently heated to 78˚C for 10 minutes while being continuously stir-red until fully homogenized. The next stage was the aging process, in which the mixture was stored at 5˚C for 24 hours. Once aging was complete, air incorporation was carried out by churning the aged mixture using an ice cream maker at temperatures ranging from -2.5˚C to -30˚C for 1 hour, resulting in the production of lactose-free milk-based ice cream.

2.3 Physical Characteristics Analysis of Ice Cream

A. Viscosity (AOAC, 2005)

Ice cream viscosity was measured using a viscometer. A 150 mL ice cream sample was placed in a container, and the viscometer was immersed to measure the sample's viscosity. The recorded reading from the viscometer was noted.

B. Overrun (Achmad *et al.*, 2012)

Overrun was measured by weighing the ice cream mixture before and after processing in an ice cream maker. Overrun was calculated using the following formula:

$$\%\text{Overrun} = \frac{\text{A} - \text{B}}{\text{B}} \times 100\%$$

A : weight of liquid mix
B : weight of frozen product

Table 1. Formulation of Lactose-Free Ice Cream with the Addition of Butterfly Pea Flower

Materials	Formulation (%)	
	Ice Cream -Whole Milk	Ice Cream - Lactose Free Milk
Whole Milk	58.8	0
Lactose Free Milk	0	58.8
Skim Milk	3.5	3.5
Whip cream	20	20
Cornstarch	2.4	2.4
Egg yolk	3.5	3.5
Sugar	11.8	11.8
Total	100	100

C. Melting Rate (Nurhuda, 2015)

A 10 g ice cream sample was placed in a container and stored at room temperature (25˚C). The melting rate was determined by measuring the time required for the ice cream to melt completely.

D. Melting Rate (Nurhuda, 2015)

A pH meter was calibrated using pH 4 and pH 7 buffer solutions before measurement. A 10 mL sample was taken, and the electrode of the pH meter was immersed in the sample. The pH value was recorded once the reading stabilized.

2.4 Chemical Characteristics Analysis of Ice Cream

A. Sweetness Level (Rahardjo *et al.*, 2021)

The sweetness level of the ice cream was analyzed using a refractometer, with the ice cream sample tested in liquid form at a temperature of 4˚C.

B. Total Caloric Content (Limbong, 2018)

The total caloric content of the ice cream was determined using an indirect method. The fat, carbohydrate, and protein contents of the ice cream were measured using different analytical techniques: fat content was determined via the gravimetric method, carbohydrates via the difference method, and protein via the titrimetric method. The energy value was calculated using the Atwater conversion factors, where protein contributes 4 kcal/g, fat 9 kcal/g, and carbohydrates 4 kcal/g.

C. Lactose Content (AOAC, 2005)

Lactose content in ice cream was analyzed using High-Performance Liquid Chromatography (HPLC). A six-point standard curve for lactose concentration was prepared in a 10 mL volumetric flask. A 2 mL test portion was pipetted into a 25 mL volumetric flask, and distilled water was added to half the flask's volume. Subsequently, 1 mL of Carrez I and II solutions were added and mixed thoroughly. The sample was sonicated for 15 minutes, after which distilled water was added up to the calibration mark and homogenized. The sample was filtered using a 0.45 µm syringe filter into a 2 mL vial and injected into the HPLC system.

2.5 Organoleptic Evaluation (Setyaningsih *et al.*, 2010)

The organoleptic evaluation consisted of hedonic and hedonic quality tests. A total of 30 semi-trained panelists participated in the study. The hedonic attributes assessed included color, taste, texture, and aroma, rated on a four-point scale: 1 (strongly dislike), 2 (dislike), 3 (like), and 4 (strongly like). The hedonic quality attributes evaluated color, taste, aroma, and texture, with the following specific scoring criteria: Color: Yellow, yellowish white, white, very white; Taste: Very sweet, sweet, not sweet, very not sweet; Aroma: Very milky aroma, milky aroma, no milky aroma, very no milky aroma; Texture: Very smooth, smooth, coarse, very coarse.

2.6 Data Analysis

Ice cream quality data were statistically analyzed using an independent two-sample ttest, comparing ice cream made from different base materials: lactose-free milk and whole milk. Each treatment was conducted in triplicate. The physical properties analyzed included viscosity, overrun, melting rate, and pH. The chemical properties evaluated were lactose content, total caloric content, and sweetness level. Sensory parameters assessed in the organoleptic test included color, aroma, mouthfeel, taste, and texture.

RESULTS AND DISCUSSION

1. Physical Characteristics of Ice Cream

The physical quality of ice cream can be assessed through viscosity, overrun, melting rate, and pH, as presented in Table 2. The viscosity test results showed no significant difference ($p>0.05$) between ice cream made from whole milk and lactose-free milk. This is because the hydrolysis of lactose into glucose and galactose does not significantly affect the viscosity of ice cream, as the lactose content in milk is approximately 4% (Asefa & Getenesh, 2019). Additionally, the total solids content in both whole milk and lactose-free milk is nearly identical since lactose hydrolysis does not alter the overall macronutrient composition of milk. The total solid content in milk is approximately 12.16% (Septiani *et al.*, 2023). The use of food additives such as stabilizers and emulsifiers in ice cream production may mask viscosity differences between ice cream made from different types of milk. The viscosity of ice cream in this study ranged from 7.11 to 7.33 dPas, whereas the study by Özdemir *et al.* (2018), which also used lactose-free milk in ice cream production, reported a viscosity of 2.32 dPas. The overrun results showed significant differences ($p<0.05$) , with lactose-free milk ice cream having a significantly higher overrun than whole milk ice cream. This is due to the higher monosaccharide content in lactose-free milk, which lowers the freezing point (Dekker *et al.*, 2019). The reduction in freezing point minimizes crystallization during freezing, leading to a more stable liquid phase that can retain air more effectively during the whipping process.

Glucose and galactose reduce surface tension, enhancing the mixture's ability to form and stabilize air bubbles during whipping. As a result, lactose-free milk ice cream exhibits a higher overrun compared to whole milk ice cream. Another study using lactose-free milk as an ice cream ingredient reported an overrun of 30.34% (Özdemir *et al.*, 2018).

Table 2. Physical Properties of Ice Cream

Treatment	Ice Cream Whole Milk	Ice Cream Lactose-Free Milk
Viscosity (dPas)	7.11±0.14 [a]	7.33±0.58 [a]
Overrun (%)	26.30±0.42[b]	49.71±7.42[a]
Melting Rate (minutes)	33.38±0.07[a]	25.67±1.92[b]
pH	6.55±0.01 [a]	6.48±0.04 [a]

Note: The average value in the row followed by different notations shows a significant difference ($P<0.05$).

The melting rate test showed that ice cream made from lactose-free milk melted significantly faster than that made from whole milk. This correlates with the high overrun value of lactose-free milk ice cream, indicating that more air is trapped within the ice cream structure, making it less dense and more susceptible to melting at warmer temperatures. Abbasi & Saeedabadian (2021) reported a faster melting time of 16.10 minutes. The pH values showed no significant differences ($p>0.05$) because lactose, glucose, and galactose are neutral carbohydrates that do not dissociate in water.

2. **Chemical Characteristics of Ice Cream**

The chemical characteristics evaluated in this study included sweetness level, total calorie content, and lactose content, as presented in Table 3. The sweetness test results showed significantly higher sweetness in lactose-free milk-based ice cream than in whole milk-based ice cream. This is due to lactose having a low sweetness level (Li *et al.*, 2023). The hydrolysis of 70% lactose in milk can increase sweetness to a level equivalent to adding 2% sugar (McCain *et al.*, 2018). Monosaccharides have a higher sweetness level than disaccharides due to differences in molecular structure. Glucose and galactose are smaller and more flexible, allowing them to interact more effectively with sweet taste receptors on the tongue compared to disaccharides such as lactose, which has a glycosidic bond that must be broken down by enzymes in saliva before interacting with taste receptors, making disaccharides taste less sweet than monosaccharides (Behr & Seidensticker, 2020). Additionally, monosaccharides dissolve in water more quickly than disaccharides, allowing them to spread and interact with taste receptors more efficiently. Based on relative sweetness values, lactose has a relative sweetness of 16, whereas glucose and galactose have relative sweetness values of 74 and 32, respectively (Winarno, 2008).

Lactose-free milk-based ice cream had significantly lower calorie values than whole milk-based ice cream. This aligns with the findings of Junior and Lannes (2011), who reported that ice cream made with a sucrosemonosaccharide sweetener combination had lower calories than those made with a sucrosedisaccharide combination. This is due to differences in carbohydrate structure.

Table 3. Chemical Properties of Ice Cream

Parameter	Ice Cream Whole Milk	Ice Cream Lactose-Free Milk
Sweetness (% Brix)	41.75±0.35[b]	57.53±0.84[a]
Total Calories	196.94±0.42[a]	188.93±0.66[b]
Lactose Content	2.64±0.01[a]	0.00±0.00[b]

Note: The average value in the row followed by different notations shows a significant difference ($P<0.05$).

A similar trend was observed when substituting sweeteners with 1% stevia, resulting in lower total calorie ice cream (Alizadeh *et al.*, 2014).

Lactose content in lactose-free milk-based ice cream was undetectable, indicating that the lactase enzyme had completely hydrolyzed lactose into glucose and galactose by breaking the glycosidic bond (Zhang *et al.*, 2025).

3. Organoleptic Characteristics of Ice Cream

The hedonic test results showed that whole milk-based and lactose-free milk-based ice cream had relatively similar preference scores across all sensory parameters, including color, aroma, mouthfeel, taste, and texture (Table 4). Although slight variations existed in average values, statistical analysis indicated no significant differences. Color perception can strongly influence consumer preferen-ce, with more visually appeal-ing food products being preferred (Ansari *et al.*, 2022). The similar color scores suggest that using lactose-free milk does not significantly impact the visual perception of ice cream. Aroma is influenced by the ingredients used (Alfadila *et al.*, 2020), and the results indicate equivalent aroma preferences. Aroma, a key sensory attribute of food products, is significantly influenced by the ingredients used in their formulation.

Table 4. Hedonic Test Results of Ice Cream

Parameter	Ice Cream Whole Milk	Ice Cream Lactose-Free Milk
Color	3.86±0.73	3.71±0.71
Aroma	3.54±0.74	3.74±0.66
Mouthfeel	3.63±0.91	3.77±0.86
Taste	3.80±0.83	3.86±0.77
Texture	3.69±0.80	4.31±0.63

Note: The hedonic test scale: 1 (very dislike), 2 (dislike), 3 (neutral), 4 (like), 5 (very like).

Table 5. Hedonic Quality Test Results of Ice Cream

Parameter	Whole Milk Ice Cream	Lactose-Free Milk Ice Cream
Color	1.00 ± 0.11	1.00 ± 0.09
Aroma	3.74 ± 0.82	3.71 ± 0.79
Mouthfeel	3.14 ± 0.91	3.23 ± 1.03
Taste	3.94 ± 0.73	4.09 ± 0.61
Texture	3.29 ± 0.79	4.090.66

Note: Sensory Scale Definitions: Color: (1) white, (2) yellowish white, (3) light yellow, (4) yellow, (5) brownish yellow; Aroma: (1) no milk aroma, (2) slightly milky aroma, (3) milky aroma, (4) very milky aroma; Mouthfeel: (1) very thin, (2) thin, (3) slightly thick, (4) thick, (5) very thick; Taste: (1) not sweet at all, (2) slightly sweet, (3) sweet, (4) very sweet; Texture: (1) very coarse, (2) slightly coarse, (3) smooth, (4) very smooth.

Each ingredient contributes specific volatile compounds that collectively define the product's overall aroma profile. This suggests that while ingredients distinctly influence aroma, the acceptance or preference for these aromas may remain consistent across different formulations. The texture assessment showed no significant differences, indicating that both ice creams were perceived similarly in terms of smoothness and homogeneity, which are crucial for high-quality ice cream (Ansari *et al.*, 2022).

The results of the hedonic quality test (Table 5) revealed no significant differences between the lactose-free and whole milk ice creams in terms of sensory parameters, including color, aroma, mouthfeel, taste, and texture ($p > 0.05$). The color scores indicated that both ice cream types had a white appearance. Both types also shared a milky aroma and a slightly thick mouthfeel. While the taste of lactose-free milk ice cream was not significantly different from whole milk ice cream, it tended to be slightly sweeter. Texture evaluation categorized both ice creams as smooth.

The absence of significant differences in organoleptic attributes may be attributed to the relatively small lactose content difference of only 2.64% between the two ice cream formulations.

CONCLUSION

Lactose-free milk-based ice cream shares similar organoleptic characteristics with whole milk-based ice cream, including taste, aroma, color, mouthfeel, and texture. However, lactose-free milk-based ice cream has a higher sweetness level and a lower total calorie content compared to whole milk-based ice cream.

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