Journal of Sohag Agriscience (JSAS) 2025, 10(1): 147-157

ISSN 2357-0725
https://jsasj.journals.ekb.eg
JSAS 2025; 10(1): 147-157

Received: 03-06-2025
Accepted: 08-06-2025

Effect of Adding Tiger Nut Milk on Rheological, Physicochemical, Nutritional and Organoleptic Properties of Ice Cream

Ateteallah H. Ateteallah, Mohamed F. Y. Hassan, Amna A. A. Osman and Naglaa Abd-Elkarim

Ateteallah H. Ateteallah
Dairy Science Department
Faculty of Agriculture
Sohag University
Sohag
Egypt

Mohamed F. Y. Hassan
Food Science and Human Nutrition Department
College of Agriculture and Food
Qassim University
Buraydah 51452
Saudi Arabia

Amna A. A. Osman
Food Science and Technology Department
Faculty of Agriculture and Natural Resources
Aswan University
Egypt

Naglaa Abd-Elkarim
Dairy and Food Science Department
Faculty of Agriculture
South Valley University
Egypt

Corresponding author:
Ateteallah H. Ateteallah
ateteallah@agr.sohag.edu.eg

Abstract

Tiger Nuts (TN) are an excellent food choice due to their rich mineral and bioactive components. Ice cream formulations (10% fat,11% SNF,16% sugar,0.5% gelatin and 0.5% vanilla) using TN milk instead of cow milk with a partial replacement, six ice cream samples were produced and marked as TNIC-0: control ice cream, TNIC-10: ice cream with10% of its cow milk content partially replaced with TN milk, TNIC-20: ice cream with 20% of its cow milk content partially replaced with TN milk, TNIC-30: ice cream with 30% of its cow milk content partially replaced with TN milk, TNIC-40: ice cream with 40% of its cow milk content partially replaced with TN milk, TNIC-50: ice cream with 50% of its cow milk content partially replaced with TN milk, respectively. The impact of substituting cow's milk with TN milk on ice cream's physicochemical, rheological, and organoleptic properties was examined. Adding TN milk in a combination resulted in ice cream mixes with more total antioxidant activity, total phenol levels, and ash content compared to the control (100% cow milk). Titratable acidity value% increased with increasing TN milk levels in ice cream samples, which ranged from 0.33 to 0.41. All functional ice cream formulations with tiger nut milk showed higher viscosity, melting resistance, and overrun percentages than the control. Regarding taste, color, texture, and melting quality in the mouth, there is no appreciable difference between control and ice cream incorporated with tiger nut milk at different ratios. Therefore, cow's milk can be replaced with TN milk up to 50% in the ice cream industry to raise nutritional value and functional properties.

Key words: Tiger nuts, Ice cream, Functional food, additives.

INTRODUCTION

Ice cream is a sweetened frozen dairy product preferred as a snack or dessert made of milk and milk products, which is often added with fruits (raw and/or dried form) and other essential ingredients like flavors, colors, etc. Over the past ten years, customers now view ice cream as a functional food with health advantages rather than a simple snack or dessert. Several communities worldwide and research institutes have shown keen interest and need for ice creams that are fortified with extra nutrients or bioactive ingredients. By adding probiotics, attempts have been made to develop ice cream as functional food with several benefits, including improved ice cream characteristics and increased consumer health and nutritional value. (Patil and Banerjee, 2017). Over the years, attempts have been made to find cheaper replacement for cow's milk, due to the increasing the cost of cow's milk and its products, irrespective of its abundant nutritional quality in terms of proteins (Umelo *et al*., 2014). Scientific development in understanding the relationship between nutrition and health has a rising profound impact on consumers' approach to nutrition, resulting in the concept of functional foods (Bhat and Bhat, 2011). Functional foods can be defined as foods containing significant levels of biologically active components that provide specific health benefits beyond the traditional nutrients they contain (Drozen and Harrison, 1998). Globally, the demand for functional foods is rising quickly as consumers become more conscious of how food affects their health. Functional foods comprise conventional foods containing naturally occurring bioactive alternative (e.g., dietary fiber) or food fortified with bioactive alternative (e.g., probiotics and antioxidants) or synthesized food additives introduced to conventional foods (e.g., prebiotics) (Sloan, 2002). Prebiotics like insulin and Fructo-oligosaccharides are frequently used as sugar replacements and have been proven to improve digestive health. As an additive to ice cream, Spirulina powder helps replace stabilizers and gives a natural light green colour to ice cream. The increasing concerns about the effects of diet on health have increased demand for ice cream with less fat. For this reason, whey protein, dietary fibers, and modified starch have been used in ice cream recipes. Vegetable oils derived from soy and other sources are used to make ice cream, which has health benefits such as reducing the risk of cardiovascular disease and cancer. (Patil and Banerjee, 2017). Ice cream and frozen desserts are the most suitable carriers of prebiotics (Homayouni *et al*., 2008). Tiger nut (*Cyperus esculentus*) is one of the underutilized crops and commonly known as "earth almond", "chufa", and "zula" nuts (Umelo *et al*.,2014). Some scholars believe that tiger nuts originated in Africa and tropical Asia, while others think they are endemic to tropical and subtropical locations worldwide. tiger nuts are used primarily in raw form (gluten-free flour, ice cream milk type extract) and as a valuable source of vegetable oils. In addition, they have numerous medicinal benefits (lowering the risk of colon cancer, acting as a heart stimulant, effectively treating diarrhea, and reducing inflammation) and are used as high-value compounds like protein, glucose, and starch, as well as vital minerals like potassium, phosphorus, and vitamins E and C. (Bazine& Arslanoğlu, 2020). In addition, considering the nutritive and health benefits of tiger nut, which is believed to be one of the underutilized tubers, its incorporation in ice cream production can enrich its utilization and associated health benefits. Thus, this study aimed to evaluate the physicochemical, rheological, and organoleptic properties of ice cream made using tiger nut milk at different ratios.

MATERIALS AND METHODS

1. Materials

Fresh raw cow's milk 3% fat, 8.5% total solids, and fresh cream 60% fat were got from the herd of animal production, Faculty of Agriculture, Sohag University, Egypt. Dried skim milk, gelatin, sugar, and vanilla were purchased from the local market, Sohag governorate. In contrast, TN seeds used in this research were obtained from the local Qena governorate, Egypt market. After screening, TNs were selected and cleaned to remove stones, foreign materials, dirt, and infestations. Milk was extracted from the soaked and milled TN by filtration using a clean muslin cloth. All reagents and chemicals used were purchased from Sigma.

2. Methods

2.1. Preparation of TN milk and Formulations:

TN seeds were washed and soaked in warm tap water for 24 hr to soften the fiber. After that, mixed with distilled water (1:5 w/v), the TN was added to the TN, then blended in the domestic blender. The mash was filtered through a clean muslin cloth to obtain the milk according to El-Shenawy et al. (2019). The diagram for the extraction of TN milk. (Table 1). six ice cream samples were produced and marked as TNIC-0: control ice cream, TNIC-10: ice cream with10% of its cow milk content partially replaced with TN milk, TNIC-20: ice cream with 20% of its cow milk content partially replaced with TN milk, TNIC-30: ice cream with 30% of its cow milk content partially replaced with TN milk, TNIC-40: ice cream with 40% of its cow milk content partially replaced with TN milk, TNIC-50: ice cream with 50% of its cow milk content partially replaced with TN milk.

Table 1. Chemical composition of TN milk

TS%	Moisture %	Crude Protein	Crude fats	Crude ash	Crude fiber	Carbohydrates	Total phenols	Activity IC_{50}	Acidity	PH
21.2	78.8	5.82	3.95	2.36	2.23	6.87	79.5	115.33	0.08	6.9

2.2. Preparation of TNIC:

According to Arbuckle (2013), The ingredients indicated in Table 2 were used to create six different ice cream formulations. In a mixing vat, liquid ingredients were combined and heated to around 43 °C. After adding the dry ingredients to the heated mixture, it was thoroughly mixed. Following the addition of 0.5% vanilla powder, the ingredients were whipped-freezed in an Italian Taylor-Male ice cream machine (Model 156). The resulting ice cream was put into 100 g cups and stored in a freezing cabinet at -18°C for at least 24 hours prior to evaluation. For every treatment, three copies were done.

Table 2. Ingredients of different ice cream formulations incorporating TN milk

Formula	Cream 60%	Milk 3% fat	Dried skim milk	Sugar	Gelatin	Vanilla	TN milk	total
TNIC-0	13.5	64.5	5	16	0.5	0.5	0	100
TNIC-10	13.4	55.6	4	16	0.5	0.5	10	100
TNIC-20	13.2	46.7	3.1	16	0.5	0.5	20	100
TNIC-30	12.95	37.9	2.15	16	0.5	0.5	30	100
TNIC-40	12.7	29.1	1.2	16	0.5	0.5	40	100
TNIC-50	12.5	20.2	0.3	16	0.5	0.5	50	100

TNIC-0: typical control, TNIC-10: 10% replacement of cow milk by TN milk; TNIC-20: 20% replacement of cow milk by TN milk; TNIC-30: 30% replacement of cow milk by TN milk; TNIC-40: 40% replacement of cow milk by TN milk; TNIC-50: 50% replacement of cow milk by TN milk.

2.3. Physicochemical Analysis:

Total solids, Moisture, protein, ash, available carbohydrates, and acidity were measured according to AOAC (2005). The pH value was determined using Orion mode 1410A, Boston, MA, and Crude fibers were determined according to AOAC (2005).

2.4. Determination of Bioactive Components:

Total phenolic compounds (TPC):

The total phenolic content of TN milk extracted and ice cream mixtures that contain different ratios of TN milk was determined using the Folin-Ciocalteu as milligrams of gallic acid equivalents according to Beskow *et al*. (2015).

Antioxidant activity:

Brand Williams et al. (1995) described the method with some modification to determine the antioxidant activity. The stable 1, 1-diphenyl-2-picrylhydrazyl (DPPH) radical was used. Absorbance was measured at 517 nm. The IC50 was the concentration of an antioxidant required to quench 50% of the initial DPPH radical under the experimental conditions. Radical scavenging activity (%) was calculated as follows: Radical scavenging activity (%) = (1-absorbance of sample /absorbance of control) x 100.

2.5. Overrun

The overrun of different ice cream samples was measured. The weight of the freshly made and unfrozen ice cream mix was compared to the weight of the ice cream itself to calculate the overrun percentage. Hassan and Barakat, 2018, using the following formula:

$$\text{Overrun (\%)} = \frac{\text{weight of ice cream mix} - \text{weight of ice cream}}{\text{weight of ice cream}} \times 100 \qquad (1)$$

2.6. Melting resistance:

Typical control ice cream (TC-ice cream), as well as formulated ice cream incorporating tiger nut milk, were produced for the melting resistance assessment according to Muse et al. (2004)

2.7. Instrumental Color Measurements

The color of each sample was measured with a chromameter CR-400 (Konica Minolta Co., Ltd., Osaka, Japan) by applying the CIELAB scale (L*, a*, and b*) against a standard white plate (Y=85.6; x=0.3149; y=0.3213). L* (lightness), a* (+a*=redness, -a*=greenness), and b* (+b*=yellowness, -b*=blueness) were measured using a D65 light source and a 2° observer angle. Then, in comparison to the control values, the hue angle (H°), chroma (C), color changes (ΔE), and browning index (BI) were calculated according to Lavelli et al. (2011) using continuity Equations (2–5):

$$C=(a^{*2}+b^{*2})^{0.5} \qquad (2)$$

$$H^{\circ}=\tan^{-1}\left(\frac{b^*}{a^*}\right) \qquad (3)$$

$$BI=\frac{\left[100\left(\frac{(a^*+1.75L^*)}{(5.645L^*+a^*-3.012b^*)}\right)-0.31\right]}{0.17} \qquad (4)$$

$$\Delta E^*=[(\Delta L^*)^2+(\Delta a^*)^2+(\Delta b^*)^2]^{0.5} \qquad (5)$$

2.8. Rheological Properties

The Texture Analyzer (TA-TX Plus, Stable Micro Systems, UK) was used to test the samples' hardness. Plastic rings were used to create samples of the same volume. The samples measured 60 mm in diameter and 25 mm in height. For a minimum of twenty-four hours, the samples were kept in a freezer at -20°C. A climate chamber was attached to the Texture Analyzer prior to the measurement in order to keep the temperature at -20°C. A cylindrical cutting tool was used to extract the samples from the plastic rings, and they were then promptly placed to the climate chamber. The samples were then measured using a 10-mm-diameter aluminum cylinder probe that was fastened to a 50 kg load cell and penetrated to a 50% strain at a rate of 2 mm/s. The highest peak force experienced during sample penetration was used to define instrumental hardness, according to Liu et al. (2023).

2.9. Ice cream Viscosity

The viscometer was used to measure the viscosity of ice cream mixtures that contain different ratios of TN milk instead of cow's milk was operated at various shear rates using spindle 4 (Digital viscometer model MFDVIS) and the data were directly recorded from instrument after one minute of spindle was rotated in the sample for 1 min at 25ºC and filled in 150 mL containers, the apparent viscosity readings in centipoises (cp) were observed from the digital output of the viscometer(Atallah and Barakat, 2017).

2.10. Organoleptic properties:

Organoleptic properties of formulas were measured after 24 hours of frozen storage. The prepared TNIC was to be evaluated by 21 panelists who were employees of the Faculty of Agriculture, Dairy Science and Food Science Department, Sohag University. The following parameters, such as taste (50), body and texture (30), color (10), melting quality (10), and overall acceptability (100), according to Arbuckle, (2013).

2.11. Statistical analysis

Analysis of Variance (ANOVA) was performed using SAS 9.4 software. The means were compared using Duncan's multiple range tests at $p < 0.05$ (Duncan, 1955).

RESULT AND DISCUSSION

1. Chemical compositions:

The chemical composition of adding TN milk to the ice cream mixture in place of cow's milk is displayed in Table 2. Total Solids ranged from 36.53 % to 40.65%. TNIC-0 had the lowest total solids content (36.53%) compared with formulated ice cream. Ash levels of some formulations with TN milk were higher when compared to the control, and these values considerably declined as the TN milk addition ratio increased. Total protein decreased significantly ($P < 0.05$) with increasing TN milk concentration in formulated ice cream. Fat content (10%) in formulated ice cream was constant according to the formula. Titratable acidity value% rose with increasing the amount of TN milk added to the formulations; these results agreed with Ismail *et al*. (2024).

Table 3. Chemical compositions of formulated ice cream incorporating TN milk.

Formulations*	T. S%	Moisture %	T. P%	Fat%	Ash%	Acidity%
TNIC-0	36.53^{b}	63.47^{a}	6.13^{a}	10.00	1.19^{b}	0.33^{c}
TNIC-10	36.94^{b}	63.06^{a}	5.95^{b}	10.00	2.44^{ab}	0.34^{c}
TNIC-20	40.65^{a}	59.35^{b}	5.76^{c}	10.00	3.33^{a}	0.36^{bc}
TNIC-30	40.65^{a}	59.35^{b}	5.52^{d}	10.00	2.49^{ab}	0.39^{ab}
TNIC-40	38.24^{ab}	61.76^{ab}	5.35^{e}	10.00	2.36^{ab}	0.40^{ab}
TNIC-50	39.45^{ab}	60.55^{ab}	5.21^{f}	10.00	1.07^{b}	0.41^{a}

*: See Table 2 for details.
Means that have the same superscripted letters within the same row do not differ statistically at $p > 0.05$.

2. Bioactive components:

The total phenol contents and antioxidant activity of TNIC treatments that contain different ratios of TN milk instead of cow's milk are shown in Table 4. These results showed a strong correlation between total phenol content and antioxidant activity; total phenol levels of enol increased, and the IC_{50} DPPH inhibition increased. The results showed that with an increase in the different ratios of TN milk instead of cow's milk, the ice cream treatments' antioxidant and total phenolic contents increased significantly. The control treatment, which contained only 100 % cow's milk, had lower antioxidant and total phenolic contents than the other treatments. It was 87.75 mg/100 g of Gallic acid and 102.49µ/g IC_{50} DPPH. While TNIC-50 recorded the highest value in total phenol and antioxidant activity, it was 128.97mg/100 g of gallic acid and 58.64 µ/g IC50 DPPH. Total phenolic content increased with increasing TN milk; these findings agreed with Shalabi (2023). The phenolic content and antioxidant activity of the TN milk can make it a potential functional food that can help prevent oxidative stress and lower the incidence of cardiovascular and other age-related disorders (Djikeng *et al*., 2022).

Table 4. The effect of cow milk substitution with TN milk on the DPPH inhibition (%) and total phenolic content (TPC) of TNIC (Mean ±SE), n = 3.

Formulations *	Total phenols (mg/100 g Gallic)	DPPH IC_{50}
TNIC-0	87.75^{c}	102.49^{a}
TNIC-10	107.12^{b}	87.32^{b}
TNIC-20	118.82^{ab}	70.95^{c}
TNIC-30	122.89^{a}	63.39^{d}
TNIC-40	125.33^{a}	62.07^{de}
TNIC-50	128.97^{a}	58.64^{e}

*: See Table (2) for details.
Means that have the same superscripted letters within the same row do not differ statistically at $p > 0.05$.

3. Viscosity of ice cream:

The presented data show the viscosity measurements of ice cream mixes prepared with different TN and cow milk ratios, tested at two spindle speeds (30 rpm and 60 rpm). The results indicate non-Newtonian and shear-thinning behavior, with viscosity decreasing as shear rate increases. Additionally, viscosity increases with higher ratios of tiger nut milk incorporation, suggesting interactions between plant-based and dairy components. The data show that viscosity decreases at 60 rpm compared to 30 rpm for all samples. This is characteristic of pseudoplastic (shear-thinning) fluids, which is typical for ice cream mixes due to "Structural breakdown of fat globules and casein micelles under shear and Fat globule destabilization differences due to plant-based lipids vs. dairy fat (Goff & Hartel, 2013). Plant-based milks often increase mix viscosity due to their high polysaccharide content, which enhances water retention and structural rigidity" (Roselló-Soto *et al.,* 2019). The shear-thinning behavior confirms that TN milk–cow milk blends are pseudoplastic, similar to conventional ice cream. Increasing TN milk content raises viscosity, likely due to fiber, protein, and fat interactions.

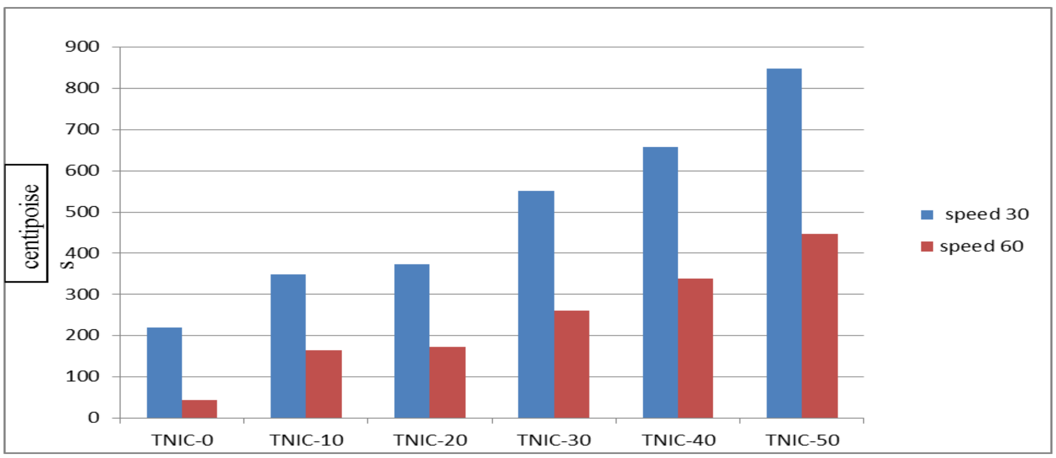

Fig 1. Viscosity of formulated ice cream incorporating TN milk, TNIC-0: typical control, TNIC-10: 10% replacement of cow milk by TN milk; TNIC-20: 20% replacement of cow milk by TN milk; TNIC-30: 30% replacement of cow milk by TN milk; TNIC-40: 40% replacement of cow milk by TN milk; TNIC-50: 50% replacement of cow milk by TN milk.

4. Overrun

Figure 2 depicts the overrun% of ice cream formulations. Adding TN milk increased the overrun % in formulated ice cream. As the amount of TN milk in the final ice cream grew, the overrun increased more and more. Overrun% ranged from 14.89% to 35.69%; all formulations had a higher overrun% % than the control (14.89%), which had the lowest overrun%. El-Shenawy *et al*. (2016) found in a previous study that as the TN extract concentration increased, there was little decrease in ice cream overrun (P > 0.05). Moreover, Shalabi (2023) indicates that the overrun of ice milk treatments significantly decreased (P<0.05) when the variable ratios of TN milk instead of cow's skim milk increased.

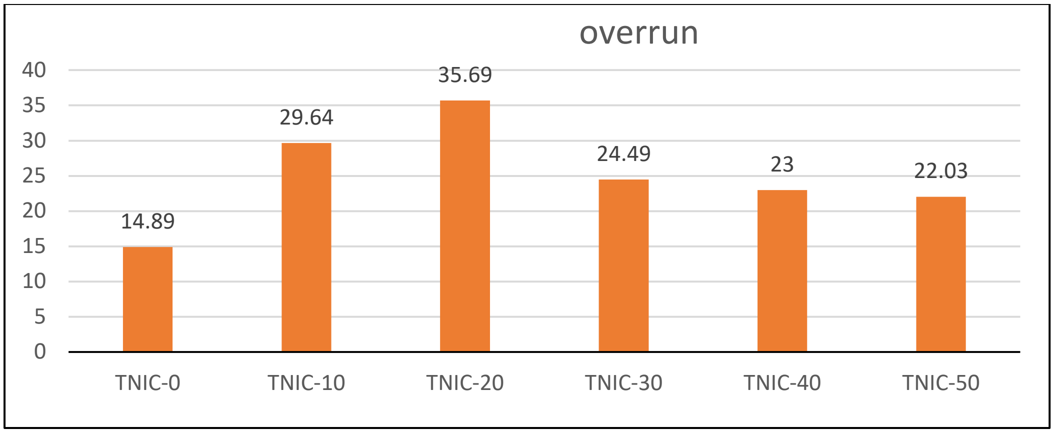

Fig 2. Overrun of formulated ice cream incorporating TN milk, TNIC-0: typical control, TNIC-10: 10% replacement of cow milk by TN milk; TNIC-20: 20% replacement of cow milk by TN milk; TNIC-30: 30% replacement of cow milk by TN milk; TNIC-40: 40% replacement of cow milk by TN milk; TNIC-50: 50% replacement of cow milk by TN milk.

5. Melting resistance of different ice cream formulations.

The melting resistance of ice cream samples was recorded in Figure 3. After 45 minutes, TNIC-0 had the lowest significant percentage of melting resistance compared to ice cream incorporated with TN milk. Also, there was an enormous loss after 60 minutes for the TNIC-40 sample compared to other samples. The result showed an increase in the melting resistance % of the ice cream as the inclusion level of TN increased, which indicates a higher melting resistance. These findings agreed with Shalabi (2023).

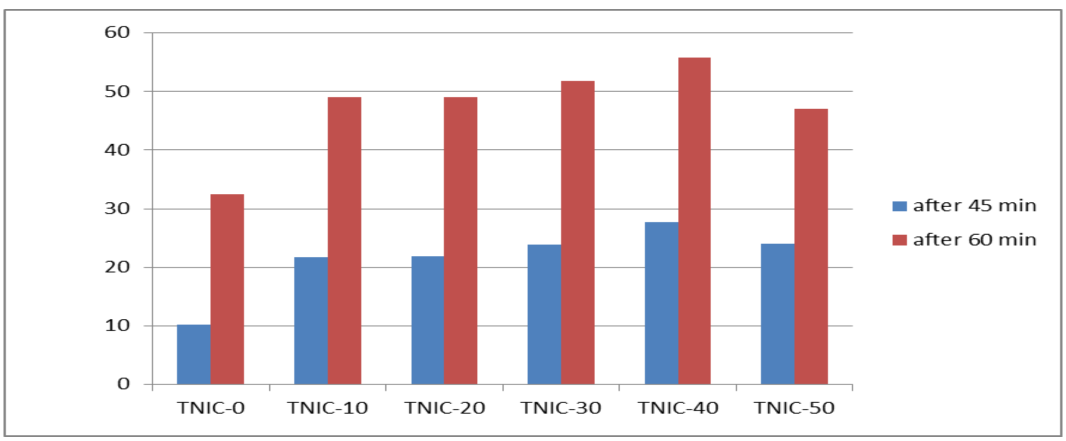

Fig 3. Melting resistance of formulated ice cream incorporating TN milk, NIC-0: typical control, TNIC-10: 10% replacement of cow milk by TN milk; TNIC-20: 20% replacement of cow milk by TN milk; TNIC-30: 30% replacement of cow milk by TN milk; TNIC-40: 40% replacement of cow milk by TN milk; TNIC-50: 50% replacement of cow milk by TN milk.

6. Instrumental Color

Colour characteristics of food and food products are one of the most critical quality attributes of food and its acceptability. Therefore, they directly affect consumers' preferences and are related to the degree of food freshness and flavour expectations. Incorporating TN milk into ice cream formulations leads to apparent changes in the color of ice cream samples, as shown in Table 5, the a* scale goes from negative (green hue) to positive (red hue); the b* scale goes from negative blue to positive yellow; and the L* scale goes from 0 black to 100 white. TN milk typically has creamy, off-white to light L*, lower than in ice cream samples, and higher values of a*, b*, and BI. This dark color might be due to its natural pigments and suspended solids. When TN milk is used to replace or supplement cow's milk in ice cream, the final product is likely to exhibit a slightly darker, more beige or creamy hue compared to the bright white of standard cow milk ice cream, L* and a* values of the ice cream samples were significantly decreased however b* values were significantly increased by increasing the level of TN milk replacement as well as resulted in more yellowish and redness of ice cream samples. The hue angle (H°) and chroma (C) values increased significantly with the increase in TN milk levels (-80.8 and 11.08 respectively), and the highest values of browning index (BI) and color changes (ΔE) were when replacing 50% of cow milk by TN milk in ice cream samples (13.60 and 4.0 respectively). These results agree with Sakr *et al.* (2023).

Table 5. Color changes of ice cream samples incorporating TN milk.

Sample*	L*	a*	b*	C	H°	BI	ΔE
TN Milk	73.8 e	0.53 e	14.10 [a]	14.10 a	87.91 a	21.23 a	0.00
TNIC-0	83.5 b	-3.5 a	8.4 d	9.1 d	-67.6 b	7.2 f	0.0
TNIC-10	84.6 a	-2.5 b	9.6 c	9.9 d	-75.3 c	9.5 e	3.5b
TNIC-20	81.7 bc	-2.5 b	9.7 c	10.0 c	-75.7 c	10.0 d	1.8c
TNIC-30	81.3 cd	-2.1 c	11.3 b	11.5 b	-79.3 d	12.7c	3.3b
TNIC-40	79.5 d	-2.2 c	11.5 b	11.7 b	-79.1 d	13.2 b	4.0a
TNIC-50	80.1 cd	-1.9 d	11.6 b	11.8 b	-80.8 e	13.6 b	4.0a

Means that have the same superscripted letters within the same row do not differ statistically at $p > 0.05$.
*: See Table 2 for details.

7. Textural properties

The textural properties of ice cream incorporating TN milk at varying concentrations were evaluated, and the results was presented in Table 6. The hardness of the ice cream increased with higher TNM incorporation, peaking at TNIC-30 (42.80 N), followed by a sharp decline in TNIC-40 (9.60 N) and TNIC-50 (11.50 N). Adhesiveness, represented as negative values, showed a similar trend, with the highest adhesion observed in TNIC-20 (-7.40 N). Springiness exhibited a gradual increase from TNIC-0 (0.50 mm) to TNIC-30 (0.56 mm), with a notable rise in TNIC-40 (0.79 mm). Cohesiveness decreased with higher TNM levels, dropping from 0.25 (TNIC-0) to 0.16 (TNIC-30), before rebounding in TNIC-40 (0.34) and TNIC-50 (0.33). Gumminess and chewiness followed a pattern similar to hardness, with peaks at TNIC-30 (6.78 N and 3.79 N·mm, respectively) and lower values at higher TNM concentrations.

Table 6. Textural properties of resultant ice cream incorporating tiger nuts milk.

Treatments *	Character assessed					
	Hardness (N)	**Adhesiveness (N)**	**Springiness (mm)**	**Cohesiveness**	**Gumminess (N)**	**Chewiness (N*mm)**
TNIC-0	15.70	-4.00	0.50	0.25	3.85	1.91
TNIC-10	20.40	-5.00	0.51	0.24	4.83	2.44
TNIC-20	35.30	-7.40	0.54	0.18	6.23	3.40
TNIC-30	42.80	-6.30	0.56	0.16	6.78	3.79
TNIC-40	9.60	-2.1	0.79	0.34	3.24	2.58
TNIC-50	11.50	-2.90	0.71	0.33	3.77	2.67

*: See Table 2 for details.

The textural properties of ice cream are critical determinants of consumer acceptability, and the incorporation of TNM significantly influenced these attributes. The observed increase in hardness up to TNIC-30 suggests that moderate TNM levels enhance structural integrity, possibly due to the higher protein and fiber content in TNM, which can stabilize the ice cream matrix (Benichou et al., 2000). However, the sharp decline in hardness at TNIC-40 and TNIC-50 may indicate a disruption of the fat-protein network at excessive TNM concentrations, aligning with findings by Leahu *et al.* (2022), who reported similar effects in plant-based ice creams. The adhesiveness results, reflecting the force required to overcome attractive forces between the ice cream and surfaces, peaked at TNIC-20 (-7.40 N). This could be attributed to the interaction of TNM polysaccharides with water molecules, increasing surface stickiness (Bazán et al., 2012). The subsequent reduction in adhesiveness at higher TNM levels might result from altered water-binding capacity, as excessive TNM could lead to phase separation (Bullock, 2021). Springiness, an indicator of elastic recovery, improved with TNM incorporation, particularly in TNIC-40 (0.79 mm). This suggests that TNM contributes to a more resilient structure, likely due to its high fiber content, which enhances air cell stability (Tomczyńska-Mleko, 2024). The cohesiveness trend—decreasing up to TNIC-30 before rebounding—implies that TNM initially weakens internal bonds but may form new interactions at higher concentrations, possibly through fiber-fat interactions (Buchko, 2024). Gumminess and chewiness derived from hardness and cohesiveness mirrored the hardness trend, peaking at TNIC-30. This indicates that moderate TNM levels optimize the balance between firmness and chewability, which is critical for sensory appeal. The decline at higher TNM levels suggests a threshold beyond which textural quality deteriorates, consistent with studies on other plant-based dairy alternatives (Devalekar and Udachan, 2021). Finally, TNM incorporation up to 30% enhances the textural properties of ice cream, but exceeding this level may compromise quality. Future research should explore optimizing TNM formulations with emulsifiers or stabilizers to mitigate textural declines at higher concentrations.

8. Organoleptic properties:

Organoleptic acceptance of ice cream with TN milk was shown in Table 7. The panelists' evaluations of all the sensorial parameters tended to be accepted. With the increase in the percentage of TN milk incorporated up to 50%, all sensory property ratings declined relative to the control. The scores of total acceptability of ice cream samples ranged from 93.9% to 83.2%. Control had the highest overall acceptability compared to formulated ice cream, which indicates that an increase in the TN milk content alters the normal parameters of control ice cream. Color and melting quality decreased insignificantly ($P > 0.05$) among all formulated ice creams. Insignificant differences in overall acceptability between TNIC-0, TNIC-10, and TNIC-20 were observed between TNIC-40 and TNIC-50. These findings mimic Shalabi's (2023) and El-Shenawy et al. (2016) findings.

Table 7. The effect of cow milk substitution with TN milk on the organoleptic properties of TNIC

	Treatments *					
Components	TNIC-0	TNIC-10	TNIC-20	TNIC-30	TNIC-40	TNIC-50
Color (10%)	9.6[a]	9.3[a]	9.1[a]	9.1[a]	8.8[a]	8.8[a]
Taste (50%)	47.1[a]	47.1[a]	47[a]	43[b]	42.1[bc]	41.6[c]
Body and texture (30%)	28.1[a]	27.8[ab]	27[ab]	26.6[bc]	25.3[cd]	24.5[d]
Melting quality (10%)	9.1[a]	8.8[a]	8.8[a]	8.7[a]	8.5[a]	8.3[a]
Total (100%)	93.9[a]	93[a]	91.8[a]	87.6[b]	84.7[c]	83.2[c]

*: See Table (2) for details.
Means that have the same superscripted letters within the same row do not differ statistically at $p > 0.05$.

CONCLUSION

The study demonstrated that incorporating TN milk as a partial substitute for cow milk in ice cream formulations significantly enhanced the nutritional and functional properties of the product. TN milk increased the total phenolic content and antioxidant activity, with the highest values observed in the 50% substitution sample (TNIC-50). Additionally, TN milk improved rheological properties such as viscosity, overrun, and melting resistance, while maintaining acceptable sensory attributes up to 50% substitution. Notably, the ice cream formulations with TN milk exhibited higher ash content and titratable acidity, further underscoring their potential as functional foods. Despite these benefits, textural properties such as hardness and adhesiveness peaked at 30% TN milk substitution (TNIC-30), suggesting an optimal threshold for maintaining desirable texture. Sensory evaluations indicated that while higher TN milk concentrations (up to 50%) were acceptable, the control and lower substitution levels (TNIC-10 and TNIC-20) were preferred regarding overall acceptability. TN milk presents a promising alternative for developing functional ice cream with enhanced nutritional value and acceptable quality. Further research should aim to optimize formulations and validate health benefits, paving the way for innovative dairy products in the functional food market.

REFERENCES

AOAC (2005): Association of Official Analytical Chemists. Official methods of analysis of (18th Ed.). Gaithersburg, M.D, USA.

Arbuckle, W.S. (2013). Ice Cream. Springer, New York, USA.

Atallah, A.A., Barakat, H., 2017. Preparation of non-dairy soft ice milk with soy milk. Adv. Dairy Res. 5, 1000172. https://doi.org/10.4172/2329-888X.1000172

Bazine, T., & Arslanoğlu, F. (2020). Tiger nut (Cyperus esculentus): morphology, products, uses, and health benefits. Black Sea Journal of Agriculture, 3(4), 324-328.

Benichou, A., Aserin, A., & Garti, N. (2002). Protein-Polysaccharide Interactions for Stabilization of Food Emulsions. Journal of Dispersion Science and Technology, 23(1–3), 93–123.

Beskow, G. T.; Hoffmann, J. F.; Teixeira, A. M.; Fachinello, J. C.; Chaves, F. C. and Rombaldi, C. V. (2015): Bioactive and yield potential of jelly palms (Butia odorata Barb. Rodr.). Food Chem.,172:699 704.

Bhat, Z.F. and H. Bhat, 2011. Milk and dairy products as functional foods: A review. Int. J. Dairy Sci., 6: 1-12. 2.

Brand-Williams, W.; Cuvelier, M. and Berset, C. (1995): Use of a free radical method to evaluate antioxidant activity. LWT - Food Science and Tech.,28:25 30.

Buchko, A. L. (2024). Impact of protein, starch, and dietary fiber on functionality and protein matrix of faba bean and pea Texturized Vegetable Protein (TVP).

Bullock, Y. (2021). Instrumental Analysis, Sensory Analysis and Consumer Acceptance of Strained Yogurt in Frozen Desserts (Doctoral dissertation, University of Missouri-Columbia).

Drozen, M. and T. Harrison, 1998. Structure/function claims for functional foods and nutraceuticals. Nutraceuticals World, 1: 18-18.

Duncan. (1955). Multiple Range and Multiple F-test. Biometrics,11:142.

El-Shenawy, M., Abd El-Aziz, M., Elkholy, W., & Fouad, M. T. (2016). Research article: probiotic ice cream made with tiger-nut (Cyperus esculentus) extract. American Journal of Food Technology, 11(5), 204-212.

El-Shenawy, M., Fouad, M.T., Hassan, L.K., Seleet, F.L., El-Aziz, M.A., 2019. A probiotic beverage made from tiger-nut extract and milk permeate. Pak. J. Biol. Sci. 22, 180–187. https://doi.org/10.3923/pjbs.2019.180.187.

Goff, H.D., Hartel, R.W. (2013): Ice cream Structure. In: Ice Cream, 7th edition. H.D. Goff, R.W. Hartel (Eds.). Springer New York, US. https://doi.org/10.1007/978-1-4614-6096-1.

Hassan, M. F., & Barakat, H. (2018). Effect of carrot and pumpkin pulps adding on chemical, rheological, nutritional and organoleptic properties of ice cream. Food and Nutrition Sciences, 9(8), 969-982.

Homayouni, A., Azizi, A., Ehsani, M. R., Yarmand, M. S., & Razavi, S. H. (2008). Effect of microencapsulation and resistant starch on the probiotic survival and sensory properties of synbiotic ice cream. Food chemistry, 111(1), 50-55.

Ismail, H. A., Salama, W. M., Ali, A. A., & Awad, R. A. (2024). Impact of tiger nut milk as a substitute for cow milk on the rheological, physiochemical, and organoleptic properties of functional ice cream. Journal of Food Science and Technology, 1-10.

Lavelli, V., Corey, M., Kerr, W., & Vantaggi, C. (2011). Stability and anti-glycation properties of intermediate moisture apple products fortified with green tea. *Food Chemistry*, *127*(2), 589-595. https://doi.org/10.1016/j.foodchem.2011.01.047.

Leahu, A., Ropciuc, S., & Ghinea, C. (2022). Plant-based milks: Alternatives to the manufacture and characterization of ice cream. Applied Sciences, 12(3), 1754.

Liu, X., Sala, G., & Scholten, E. (2023). Structural and functional differences between ice crystal-dominated and fat network-dominated ice cream. Food Hydrocolloids, 138, 108466.

Muse, M. and Hartel, R.W., (2004). Ice Cream Structural Elements That Affect Melting Rate and Hardness. Journal of Dairy Science, 87, 1-10.

Patil, A. G., & Banerjee, S. (2017). Variants of ice creams and their health effects. MOJ Food Process. Technol, 4(2), 58-64.

Roselló-Soto, E.; Garcia, C.; Fessard, A.; Barba, F.J.; Munekata, P.E.S.; Lorenzo, J.M.; Remize, F. Nutritional and microbiological quality of tiger nut tubers (*Cyperus esculentus*), derived plant-based and lactic fermented beverages. Fermentation 2019, 5, 3. doi:10.3390/fermentation5010003

Sakr, S.S., Mohamed, S.H.S., Ali, A.A., Ahmed,W.E, Algheshairy, R.M. Almujaydil, M.S, Al-Hassan. A.A., H. Barakat, Hassan, M.F.Y. (2023) Nutritional, physicochemical, microstructural, rheological, and organoleptical characteristics of ice cream incorporating Adansonia digitata pulp flour. Foods, 12 (3) https://doi.org/10.3390/foods12030533

Shalabi, O. M. (2023). Utilizing tiger nut milk to make a novel, healthy, functional ice milk. Annals of Agricultural Sciences, 68(2), 118-125.

Sloan, A.E., (2002). The top 10 functional food trends: The next generation. Food Technol., 56: 32-57.

Tomczyńska-Mleko, M., Mykhalevych, A., Sapiga, V., Polishchuk, G., Terpiłowski, K., Mleko, S., ... & Pérez-Huertas, S. (2024). Influence of plant-based structuring ingredients on physicochemical properties of whey ice creams. Applied Sciences, 14(6), 2465.

Umelo, M. C., Uzoukwu, A. E., Odimegwu, E. N., Agunwah, I. M., Njoku, N. E., & Alagbaoso, S. (2014). Proximate, physicochemical and sensory evaluation of ice cream from blends of cow milk and tigernut (Cyperus esculentus) milk. Int. J. Sci. Res. Innov. Technol, 1(4), 63-76.

Devalekar, S. K., & Udachan, I. S. (2025). Process optimization of vegan prebiotic ice cream by response surface methodology. Discover Food, 5(1), 1-13.

Bazán, M. A., Carrillo, A., Saldaña, N., Martínez, M., Flores, Y. L., Hernández, E., ... & Guadarrama, Z. B. (2012). Characteristics of textural evaluation and the stability to a low-calorie ice cream, for optimize a mixture of stabilizers.