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TIGER NUT TUBER MILK: USING DAIRY BYPRODUCTS AND PROBIOTIC BACTERIA

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ABSTRACT

Background. Tiger nut milk is an underused food product in Europe, Africa, and a number of developing countries. This milk has been suggested as a substitute for bovine milk to reduce malnutrition in poor parts of the world. Hence, this study aimed to prepare tiger nut tuber milk using milk permeate or cheese whey as an extraction medium. A novel probiotic fermented tiger nut milk was also developed using probiotic culture of *Lactobacillus helveticus* Lh-B02.
Materials and methods. The physico-chemical, color, sensory, and microbiological properties of the tiger nut milk were determined.
Results. Our results showed that substituting water for permeate or whey led to an enhancement of the nutritional, physico-chemical, and viscosity properties of tiger nut milk. No differences were observed in the sensory properties between water-tiger nut milk and permeate- or whey-tiger nut milk. As for fermentation of tiger nut milk, fermented permeate- and whey-tiger nut milk had the highest values of viscosity and *L. helveticus* Lh-B02 count. Also, the color parameters (a^*, b^*, and L^*) were enhanced in fermented permeate- and whey-tiger nut milk. Regarding the sensory properties, all fermented tiger nut milk types were acceptable, and the panelists preferred the flavor of fermented whey-tiger nut milk. During cold storage (20 days), fermented water-tiger nut milk exhibited the lowest values of chroma, *L. helveticus* Lh-B02 count, and appearance compared to other fermented tiger nut milk types. The storage period revealed a negative effect on the viscosity and a positive effect on the luminosity values (L^*) of all fermented tiger nut milk types.
Conclusion. It is possible to substitute water with milk permeate or cheese whey to prepare tiger nut tuber milk with high nutritional and organoleptic properties.

Keywords: tiger nut milk, fermentation, probiotic bacteria, milk permeate, cheese whey

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INTRODUCTION

The lack of distribution and processing of plant food sources in all parts of the world has led to human suffering from malnutrition. Despite great progress in food provision, malnutrition remains a real problem and one of the main public health problems in the world, particularly in Africa. Nowadays, the development of functional food products that have potential health effects is one of the main topics in the field of food sciences (Ndiaye et al., 2019). The tiger nut, which is underused as a food source, is a sweet, edible almond-like tuber native to southern Europe and West Africa. In Egypt, it is a plant of early domestication grown in the Nile Valley, and it is utilized as a source of medicine, perfume, and food products (Sánchez-Zapata et al., 2012).

It has been recognized as a functional food which can prevent the risk of cardiovascular disease and colon cancer, and activate blood circulation (Adejuyitan et al., 2009). Alegría-Toran and Farré-Rovira (2003) reported that tiger nut tuber consists of starch (29.90%), lipids (24.49%), carbohydrates (43.30%), protein (5.04%), and ash (1.70%). Tiger nut tuber is known a rich source of high-quality oil and some beneficial minerals and vitamins, including calcium, phosphorus, potassium, and vitamins C and E (Belewu and Belewu, 2007; Yeboah et al., 2011). Tiger nut tubers have been reported to be effective in the prevention of many disorders, such as cardiovascular diseases, gastrointestinal disorders, obesity, diabetes, and some types of cancers (Anderson et al., 2009; Borges et al., 2008; Chukwuma et al., 2010).

The development of a variety of tiger nut-based products allows global populations to benefit from its properties. Tiger nut tubers can be utilized in raw, baked, or dried form, or as an aqueous extract called "tiger nut milk". Tiger nut-based products are prepared using a broad number of preparation methods. One well-known application of tiger nut tubers in the food industry is the manufacturing of tiger nut milk, "horchata de chufa" (Sánchez-Zapata et al., 2012). "Horchata" is a sweetened beverage of milky appearance made from tiger nut tubers blended with water and sugar. It is used as an aroma agent in ice cream (Mosquera et al., 1996). Tiger nut milk is an energizing and nutritive beverage rich in minerals and vitamins. It has been reported to be a good alternative to bovine milk, with a natural sweet flavor, particularly for lactose-intolerant individuals who avoid cow's milk and other dairy products (Adejuyitan, 2011).

The valorization of dairy byproducts, such as cheese whey, buttermilk, and permeate, has become a main topic of research in the development of a sustainable food chain. Furthermore, the utilization of dairy byproducts is a waste reduction measure; it would enhance sustainability and increase industrial profitability. Therefore, these byproducts can be used as new technologies for the preparation of tiger nut milk. Similar to bovine milk, tiger nut milk can be fermented with lactic acid bacteria to produce sweet-sour, lactose-free fermented products that could act as a substantial source of food nutrients (Wakil et al., 2014). Intense interest in fermented tiger nut milk has arisen because of its nutritional, sensory, and probiotic potentials, and because fermentation could be a convenient way to produce microbially steady agents with an extended shelf-life (Kizzie-Hayford et al., 2016).

There is no evidence from previous studies regarding the utilization of dairy byproducts for the preparation of tiger nut milk. Therefore, the objective of this study was to use cheese whey and milk permeate as an extraction medium for the preparation of tiger nut milk instead of water. Moreover, the development of fermented tiger nut milk with probiotic *Lactobacillus helveticus* Lh-B02 was studied.

MATERIALS AND METHODS

Materials

Dried tiger nut tubers (*Cyperus esculentus* L.) were purchased from a local market in Cairo, Egypt, in November 2019, and it contained 8.80, 4.10, 21.90, 6.80, and 56.70% of moisture, crude protein, crude fat, crude fiber, and carbohydrates, respectively. The mineral content of the dried tiger nut tubers comprised 4.25, 2.80, 2.07, 0.37, 0.08, and 0.036 g/kg of potassium, manganese, sodium, calcium, iron, and zinc, respectively. Sweet whey (6.71% total solids, 0.95% protein, 0.1% fat, 5.13% lactose, and 0.5% ash) was obtained from the Dairy Technology Unit of the Faculty of Agriculture, Cairo University, in Giza, Egypt. Milk permeate (5.7% total solids, 5.0% lactose, and 0.3% ash) was obtained from the Dairy Technology Unit of Animal Production Research Institutes in Dokki, Cairo, Egypt.

Lacta 133/14 stabilizer and the direct vat inoculation (DVI) commercial probiotic *L. helveticus* Lh-B02 were gifted from MIFAD Company in Cairo, Egypt. Nutrient agar (NCM0033), malt extract agar (LAB 550), MacConkey agar (NCM0017A), and de Man, Rogosa, and Sharpe (MRS) broth (NCM0190) were obtained from Lab M Ltd. Company (Heywood, Lancashire, UK).

Tiger nut milk preparation

In this study, water, milk permeate, and cheese whey were utilized as extraction media to prepare tiger nut milk at laboratory scale. Dried tiger nut tubers (3 kg) were sorted, washed, and drained, then boiled in water for 10 min, followed by drainage. Subsequently, the tiger nut tubers were divided into three portions (1 kg for each portion) and soaked in distilled water, permeate, and whey, respectively for 24 h. Thereafter, the tiger nut tubers were drained, washed, and mixed with 3 L of distilled water, permeate, and whey, respectively. The mixture of each portion was filtered through cheese cloth and homogenized at two stages (1500 and 500 psi), before Lacta 133/14 stabilizer was added at 0.5%. Finally, the obtained tiger nut milk (water-, permeate-, and whey-tiger nut milk) was heat-treated at 70°C for 2 min and packaged in sterilized glass bottles and kept at 4°C until analysis.

Fermented tiger nut milk manufacturing

The probiotic *L. helveticus* Lh-B02 was pre-cultured (0.02%, w/v) in sterilized skimmed milk and incubated at 37°C for 12 h. Three different treatments of fermented tiger nut milk were manufactured at laboratory scale. The three types of tiger nut milk were warmed to 37°C and inoculated with 2% *L. helveticus* Lh-B02, before being incubated at 37°C until the acidity reached about 0.5%. Thereafter, all treatments of fermented tiger nut milk were stored at 4°C for 20 days.

Physico-chemical properties

Gross composition of the tiger nut tubers was determined according to the methods of AOAC (Horwitz and Latimer, 1990). Moisture was estimated by drying a 5 g ground tiger nut tuber at 105°C to a stable weight and the total solids were determined. Crude protein content was determined using the Kjeldahl method. Crude fat was evaluated using the Soxhlet method. Ash content was obtained by burning the product in a muffle at 550–600°C for 6–8 h. Carbohydrate content was obtained by difference between one hundred and sum of protein, fat, and ash percentages. Mineral content of the tiger nut tubers was determined using inductively coupled plasma atomic emission spectrometry (ICP-AES) using iCAP 6000 Series; Thermo Scientific. Acidity, total solids, total protein, fat, ash, and crude fiber contents of the tiger nut milk were determined according to the methods described in AOAC (Horwitz and Latimer, 1990). Specific gravity was determined according to the method of Ghatak and Bandyopadhyay (2007).

Apparent viscosity

The apparent viscosity of each sample was measured using a Brookfield viscometer (model DV-II+, Brookfield Engineering Laboratories Inc., Middleboro, MA, USA) at 100 rpm. The spindle was rotated in the sample for 1 min at 25ºC. The apparent viscosity readings in centipoises (cp) were observed from the digital output of the viscometer.

Color measurement

The color parameters of the samples were measured according to the CIE (Commission Internationale de l'Eclairage) system, as described by Pathare et al. (2013). The color was determined based on CIE Lab: a^* (−green / +red color), b^* (−blue / +yellow color), and L^* (lightness). The chroma (C) was calculated using the following equation:

$$C = [(\Delta a^*)^2 + (\Delta b^*)^2]^{0.5}$$

where the calculation supposes that $L^* = 100$, $a^* = 0$, and $b^* = 0$.

Microbiological examination

Total aerobic bacterial, total molds and yeasts, coliform bacteria, and *L. helveticus* Lh-B02 counts were enumerated using nutrient, malt extract, MacConkey, and MRS agar media, respectively. The petri dishes of total aerobic bacteria, total molds and yeasts, coliform bacteria, and *L. helveticus* Lh-B02 were incubated at 32 ±1°C/48 h, 25 ±1°C/5 days, 37 ±1°C/24–48 h, and 37 ±1°C/48 h, respectively, and the colonies formed were presented as log CFU mL^{-1} (APHA, 2004).

Sensory evaluation

The tiger nut milk samples were analyzed for appearance, aroma, taste, texture, and overall acceptability according to Shah and Prajapati (2014). All the samples were judged by fifteen staff members of the Dairy Department, Faculty of Agriculture, Cairo University. The staff members were given a 9-point hedonic scale (1 – extremely undesirable and 9 – extremely desirable).

Statistical analysis

Three replicates from each parameter were statistically analyzed, and the data were recorded as the mean ±standard deviation (SD). Mstat-C software (Michigan State University, USA) was used to carry out both the randomized complete block design and the analysis of variance of factorial methods. The calculation of least significant differences (LSD) at $P \leq 0.05$ was used to compare the significant differences between the mean of triplicate treatments.

RESULTS AND DISCUSSION

Physico-chemical properties of tiger nut milk

The physico-chemical properties found in the tiger nut milk that was extracted in water, milk permeate, and cheese whey are presented in Table 1. The results show that the total solids content of the water-tiger nut milk was 8.22%, which constituted 0.584% protein, 2.43% fat, 0.263% ash, and 0.556% fiber. In a different study, Kizzie-Hayford et al. (2016) found that tiger nut milk contained 10.40% total solids, 1.02% protein, 2.23% fat, 0.28% ash, and 6.87% total carbohydrate. Compared to water-tiger nut milk, permeate- and whey-tiger nut milk had significantly higher percentages of total solids, protein, and ash, while the fat and fiber contents had the opposite trend. These results are due to the fact that permeate and whey contain high contents of protein, ash, and total solids, whilst tiger nut tubers have high contents of fat and fiber. Our results in Table 1 revealed that the tiger nut tubers contained 4.10, 21.90, 6.80, and 1.70% of crude protein, crude fat, crude fiber, and ash, respectively. Sánchez-Zapata et al. (2012) found that tiger nuts contained 24.49% fat and 8.91% fiber. Moreover, El-Batawy et al. (2018) found that the total solids, protein, and ash percentages of whey were 7.15, 0.94, and 0.46%, respectively, while they were 6.15, 0.14, and 0.5%, respectively in permeate.

Regarding physical properties (Table 1), utilization of permeate or whey to produce tiger nut milk significantly increased the acidity and viscosity compared to water-tiger nut milk. The protein and lactose contents of permeate and whey are most likely responsible for this result. However, there is not a significant difference in the specific gravity of water-, permeate-, and whey-tiger nut milk.

Microbiological and sensory properties of tiger nut milk

Molds and yeasts and coliform bacteria were not detected in any of the tiger nut milk types. The total aerobic bacterial count of the whey-tiger nut milk (1.57 log CFU mL^{-1}) was significantly higher than that of the permeate-tiger nut milk (1.41 log CFU mL^{-1}) and the water-tiger nut milk (1.25 log CFU mL^{-1}).

Table 1. Physico-chemical properties of different tiger nut milk types

Treatments	Total solids %	Protein %	Fat %	Ash %	Fiber %	Acidity %	Specific gravity	Viscosity (cp)
WTM	8.22 ±0.076[c]	0.583 ±0.026[b]	2.43 ±0.075[a]	0.263 ±0.005[c]	0.5563 ±0.00057[b]	0.077 ±0.005[c]	1.013 ±0.501[a]	3.60 ±0.163[c]
PTM	11.50 ±0.079[b]	1.20 ±0.1[a]	1.82 ±0.058[c]	0.397 ±0.01[b]	1.281 ±0.012[a]	0.123 ±0.005[b]	1.032 ±0.055[a]	4.31 ±0.12[b]
WHTM	13.01 ±0.054[a]	1.38 ±0.029[a]	1.96 ±0.064[b]	0.473 ±0.037[a]	0.741 ±0.103[b]	0.173 ±0.004[a]	1.040 ±0.053[a]	10.37 ±0.052[a]

Values are the mean ±standard deviation of at least three determinations ($n = 3$). Values in the same column with different superscript letters differ significantly.
WTM – water-tiger nut milk, PTM – permeate-tiger nut milk, WHTM – whey-tiger nut milk.

The results of the 9-point estimation indicated insignificant differences in appearance (9.0), taste (8.83–9.0), aroma (8.53–8.67), and texture (8.50–8.67) of the tiger nut milk prepared in water, permeate, and cheese whey. In this regard, Sady et al. (2013) reported that the supplementation of orange beverages with whey led to a significant decline in all evaluated sensory properties, except color features.

The characteristics of fermented tiger nut milk

Acidity. It was stated that the acidity (Fig. 2A) significantly differed among the fermented tiger nut milk treatments, where the fermented permeate- and whey-tiger nut milk had significantly higher acidity than the fermented-water tiger nut milk on day 1 of the storage period. This result may be attributed to the fact that permeate and whey contain lactose and whey proteins,

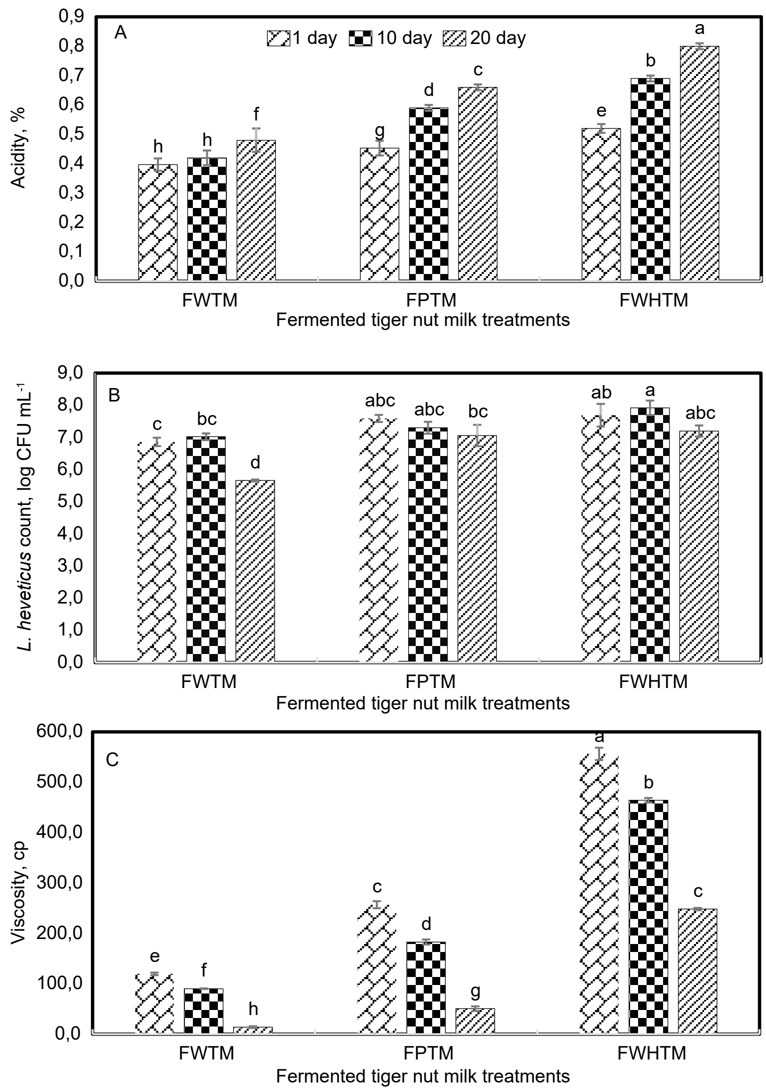

Fig. 1. Acidity percentage (A), *L. helveticus* counts (B), and viscosity (C) of different fermented tiger nut milk types during storage period: FWTM – fermented water-tiger nut milk, FPTM – fermented permeate-tiger nut milk, FWHTM – fermented whey-tiger nut milk

which encourage the growth of *L. helveticus* Lh-B02 and increase lactic acid. Also, cheese whey contains whey proteins which have a low buffering capacity (Abd El-Fattah et al., 2018).

During the storage period, the acidity significantly increased in all the fermented tiger nut treatments. In this regard, Kizzie-Hayford et al. (2017) found that storage of fermented water-tiger nut milk did not significantly affected pH or acidity, while fortification with sodium caseinate or whey proteins significantly reduced the pH and increased the acidity of fermented tiger nut milk after 15 days.

Microbiological analysis. All the fermented tiger nut milk types were free from molds and yeasts and coliform bacteria during the storage period. As shown in Figure 2B, all fermented tiger nut milk types allowed the growth of lactic acid bacteria to differing extents. On day 1, the range of viable counts of *L. helveticus* Lh-B02 for fermented water- and permeate-tiger nut milk were log 6.86–7.59 CFU mL^{-1} and were significantly lower than those of the fermented whey-tiger nut milk (log 7.69 CFU mL^{-1}).

This result is supported by Bury et al. (1998), who noted that the addition of whey proteins to a fermentation medium stimulated the growth of lactic acid bacteria. Kizzie-Hayford et al. (2017) reported that the enrichment of fermented tiger nut milk with whey proteins or sodium caseinate led to an increase in the viable counts of yogurt starter. After 20 days of storage, the *L. helveticus* Lh-B02 count exhibited a drastic decline in the fermented water-tiger nut milk compared to that of the fermented permeate- or whey-tiger nut milk, which showed an insignificant reduction in the viable counts. El-Shenawy et al. (2019) observed that the viable counts of *L. plantarum*, *L. acidophilus*, and *Bifidobacterium breve* in fermented permeate-tiger nut beverages slightly increased until day 3 of storage and reduced thereafter.

Apparent viscosity. The results in Figure 2C show that the fermented whey-tiger nut milk had the highest viscosity by far, followed by the fermented permeate-tiger nut milk, and finally, the water-tiger nut milk on day 1 or after 20 days of the storage period. The enhancement in viscosity observed in the fermented whey-tiger nut milk could have resulted from the soluble protein aggregates or the protein gels from the thermal denaturation of whey proteins (Kizzie-Hayford et al., 2016). Also, Akalin et al. (2012) observed an increase in yogurt viscosity when it was supplemented with whey protein concentrate.

Our results show that storage of the fermented tiger nut milk had a negative effect on viscosity. In this respect, Mohan et al. (2020) observed that the apparent viscosity of yogurt significantly reduced at the end of the storage period. Aryana and McGrew (2007) attributed the decrease in the viscosity of yogurt during storage to the starter culture enzyme activity on the micelle structure of casein.

Color analysis. The change in color parameters of the fermented tiger nut milk was examined as food color is one of the most remarkable and distinctive features of consumer appreciation which affects their product purchasing decisions. The color analysis was divided into three essential parameters including a^*, b^*, and L^*. The positive values of parameter a^* are considered for reddish colors and negative values for greenish ones, while the positive values of parameter b^* are considered for yellowish colors and negative values for blueish ones. The values of the L^* parameter express the shine or luminosity of the product color. According to this feature, each color can be deemed as equivalent to a part of grayscale (Granato and Masson, 2010). Chroma (*C*) represents the quantitative property of colorfulness, with the higher values of chroma being assigned to a higher intensity of color (Pathare et al., 2013).

The change in color parameters of the fermented tiger nut milk during the storage period are listed in Table 2. Our results revealed that parameter a^* of all the fermented tiger nut milk treatments had negative values as they were partially green in color. However, parameter b^* had positive values, appearing partially yellow in color. Furthermore, using permeate or whey to prepare tiger nut milk significantly decreased the b^* values of the fermented tiger nut milk. As for luminosity (L^*), utilization of permeate significantly increased the L^* value, while using whey had the opposite effect. The chroma C value of the fermented water-tiger nut milk was significantly higher than that of the fermented permeate- and whey-tiger nut milk. In this regard, Sady et al. (2013) found that the addition of whey to orange beverages resulted in a significant decrease in

Table 2. Color parameters of fermented tiger nut milk during storage

Attributes	Storage, day	Treatments		
		FWTM	FPTM	FWHTM
*a**	1	–11.81 ±0.19[cd]	–11.76 ±0.081[bc]	–12.55 ±0.157[e]
	10	–11.51 ±0.09[b]	–12.05 ±0.07[d]	–13.02 ±0.075[f]
	20	–10.77 ±0.12[a]	–12.49 ±0.07[e]	–13.63 ±0.076[g]
*b**	1	11.19 ±0.04[a]	8.057 ±0.046[g]	9.143 ±0.049[b]
	10	8.56 ±0.04[e]	8.64 ±0.057[d]	8.29 ±0.026[f]
	20	8.73 ±0.025[c]	8.66 ±0.04[cd]	7.863 ±0.032[f]
*L**	1	69.59 ±0.455[d]	72.73 ±0.238[b]	67.19 ±0.299[e]
	10	73.02 ±0.206[b]	74.97 ±0.11[a]	71.54 ±0.135[c]
	20	73.08 ±0.047[b]	75.00 ±0.21[a]	71.80 ±0.263[c]
Chroma	1	16.54 ±0.446[a]	14.67 ±0.216[d]	15.42 ±0.012[bc]
	10	14.33 ±0.111[e]	14.87 ±0.11[d]	15.58 ±0.172[bc]
	20	13.89 ±0.084[e]	15.19 ±0.05[cd]	15.69 ±0.032[b]

Values are the mean ±standard deviation of at least three determinations ($n = 3$). Values in the same column or row for each parameter with different superscript letters differ significantly.

The positive values of parameter *a** are considered for reddish colors and negative values for greenish ones. The positive values of parameter *b** are considered for yellowish colors and negative values for blueish ones. The values of *L** parameter express shine or luminosity of the product color.

FWTM – fermented water-tiger nut milk, FPTM – fermented permeate-tiger nut milk, FWHTM – fermented whey-tiger nut milk.

the *L** value. The differences in color parameter values were related to the utilization of whey, which was characterized by muddiness because of the presence of colloidal protein and a yellow-green tint originating from the riboflavin dissolved in it.

During the cold storage period (20 days), the *a** values significantly increased in the fermented water-tiger nut milk and significantly decreased in the fermented permeate- and whey-tiger nut milk. However, the *b** values significantly reduced in the fermented water- and whey-tiger nut milk and significantly increased in the fermented permeate-tiger nut milk. The storage period had a significantly positive effect on the levels of *L** parameter in the different types of fermented-tiger nut milk. On the other hand, a 20-day storage had no significant influence on the values of the *C* parameter, except in the fermented water-tiger nut milk, which showed a significant decline in *C* value.

Alterations in the values of the color parameters of the fermented tiger nut milk occurring during the storage period may be due to the interaction of tiger nut, permeate, and whey components and the sedimentation of precipitate. Permeate and whey included significant amounts of lactose, protein, and minerals, as well as components that tend towards coagulation, precipitation, and interactive processes (Sady et al., 2013). El-Shenawy et al. (2019) found that the whiteness degree decreased and the redness degree increased in the permeate-tiger nut milk (without probiotic bacteria) during the storage period (10 days), whilst these parameters were more stable in all the fermented permeate-tiger nut beverages.

Sensory evaluation. Sensory evaluation plays an important role in the quality control and marketing of food products; thus, it is essential for assessing the development of novel food products. The 9-point

Table 3. Sensory evaluation of fermented tiger nut milk during storage

Properties	Storage day	Treatments		
		FWTM	FPTM	FWHTM
Appearance	1	8.0 ±1.732[ab]	9.0 ±0.0[a]	9.0 ±0.0[a]
	10	8.0 ±0.0[ab]	8.0 ±0.0[ab]	7.67 ±0.577[ab]
	20	6.33 ±1.155[b]	8.0 ±0.0[ab]	7.0 ±0.0[b]
Taste	1	7.33 ±0.577[ab]	7.67 ±0.577[ab]	8.0 ±1.0[ab]
	10	7.0 ±1.0[ab]	7.33 ±0.577[ab]	8.33 ±0.577[a]
	20	6.67 ±1.528[b]	7.67 ±1.528[ab]	8.0 ±1.0[ab]
Aroma	1	7.67 ±0.577[a]	7.67 ±0.577[a]	8.67 ±0.577[a]
	10	7.33 ±0.577[a]	7.67 ±0.577[a]	8.0 ±0.0[a]
	20	7.0 ±1.0[a]	7.67 ±1.155[a]	8.33 ±0.577[a]
Texture	1	7.33 ±1.155[ab]	8.0 ±0.0[a]	8.0 ±0.0[a]
	10	7.0 ±1.732[ab]	8.0 ±0.0[a]	7.33 ±0.577[ab]
	20	5.67 ±0.577[b]	7.67 ±1.528[ab]	7.33 ±0.577[ab]
Overall acceptability	1	7.67 ±0.577[a]	7.67 ±0.577[a]	8.33 ±0.577[a]
	10	7.67 ±1.528[a]	7.67 ±1.155[a]	8.0 ±1.0[a]
	20	6.67 ±1.528[a]	7.67 ±1.528[a]	8.33 ±0.577[a]

Values are the mean ±standard deviation of at least three determinations ($n = 3$). Values in the same column or row for each parameter with different superscript letters differ significantly.
FWTM – fermented water-tiger nut milk, FPTM – fermented permeate-tiger nut milk, FWHTM – fermented whey-tiger nut milk.

hedonic method was used to assess the fermented tiger nut milk, and the results are presented in Table 3.

On day 1 of the storage period, it was noted that there were no significant differences in any of the sensory attributes among the different types of fermented tiger nut milk. The storage period did not significantly affect the sensory properties, except the appearance of the fermented water-tiger nut milk, which showed a significant decrease after 20 days of cold storage. Consumers stated that the flavor of the fermented whey-tiger nut milk was enhanced and became like the flavor of Rayeb on day 20 of storage. This note may be attributed to an increase in the protein content of the fermented whey-tiger nut milk, which might have improved the release of microbial metabolites and byproducts such as amino or fatty acids, which affect flavor characteristics (Sadler and Murphy, 2014).

Our results are compatible with those of El-Shenawy et al. (2019), who revealed that there were no significant differences in the sensory attributes of probiotic-permeate-tiger nut beverages during the storage period (10 days).

CONCLUSION

Tiger nut milk is reported to be a wholesome food. The utilization of milk permeate and cheese whey to prepare tiger nut milk improved its nutritional and organoleptic properties. The fermentation of tiger nut milk prepared using milk permeate and cheese whey resulted in products with a high viscosity and probiotic *L. helveticus* Lh-B02 count.

Color parameters (a^*, b^* and L^*) were improved in the fermented permeate- and whey-tiger nut milk compared to the fermented water-tiger nut milk. In terms of sensorial properties, all the fermented tiger nut milk types were acceptable.

After 20 days of cold storage, the chroma value, *L. helveticus* Lh-B02 count, and appearance of the fermented water-tiger nut milk decreased. The storage period (20 days) had a negative effect on the viscosity and a positive effect on the luminosity parameter (L^*) of the different fermented tiger nut milk types.

In conclusion, our results show that it is possible for the food industry to use milk permeate and cheese whey to develop novel food products, enhance the sustainability of the food chain, and increase industrial profitability through waste reduction.

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