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Full Length Research

Effect of processing technique on the proximate composition and sensory properties of tiger nut/dates dry milk substitutes

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ABSTRACT: This study examined the effect of different processing techniques on the proximate composition and sensory properties of powdered milk substitutes made from tiger nut tubers sweetened with dates, to offer an affordable and nutritious milk alternative for lactose-intolerant individuals, diabetics, and low-income populations. Four tiger nut/date milk substitutes were formulated using 70% tiger nut tubers and 30% dates, with the tubers processed by malting (MTMS), fermentation (FTMS), toasting (TTMS), and oven drying (OTMS). These products' nutritional content and sensory attributes were compared to a commercial powdered milk control. Results showed that fermentation yielded the highest protein content (7.01%), while toasting produced the highest fat content (15.42%) and the best sensory scores, especially in aroma and overall acceptability. The malted sample had the lowest protein content (5.38%) but the highest fibre content (2.98%). The oven-dried sample had the highest carbohydrate content (73.85%), and the fermented sample had the highest moisture content (3.92%). Sensory evaluation ranked the toasted sample as the most acceptable, with ratings similar to the commercial control. These findings highlight that processing methods significantly impact the nutritional and sensory qualities of tiger nut/date milk substitutes. Toasting enhances sensory appeal, while fermentation increases protein content, suggesting that these products, particularly the toasted version, can serve as nutritious, shelf-stable milk alternatives for individuals with dietary restrictions. The formulated products, if improved may substitute cow's milk.

Keywords: Date, milk substitute, processing technique, tiger nut.

INTRODUCTION

Milk, a nutrient-rich liquid produced by mammals, is a primary food source for young mammals and a key component of many global diets. In Africa, milk from domesticated animals plays a significant role in the diets of pastoral families, providing up to 30% of calorific needs (Ekechukwu, 2022). However, challenges in the dairy sector, such as poor nutrition and the limitations of local breeds, have restricted dairy farming to subsistence levels in many areas (Belewu and Belewu, 2007). This has reduced milk availability, increasing prices and the demand for plant-based alternatives from seeds and nuts, including soybeans, coconuts, walnuts, and tiger nuts.

The shift towards plant-based milk has gained attention due to its nutritional benefits and potential to alleviate malnutrition and micronutrient deficiencies, especially in countries like Nigeria. As noted by Belewu and Belewu (2007), vegetable milk offers an opportunity to combat hidden hunger and protein-energy malnutrition (PEM). Among these alternatives, tiger nut milk has gained prominence due to its rich nutritional profile, including high levels of carbohydrates (30.90–59.18%), fats 19.79–37.83%, proteins (6.08–9.70%), fibre (19.79–37.83%) (Nwosu *et al*., 2022, Gadanya *et al*., 2021, Nina *et al.*, 2019), and essential vitamins and minerals (Oluwakemi *et* *al.*, 2021). Research by Sánchez-Zapata *et al.* (2012) and Yeboah *et al.* (2012) highlighted the significant presence of unsaturated fatty acids, especially at the sn-2 position of triacylglycerols in tiger nut oil. This structural characteristic enhances its nutritional profile, contributing to its recognition as a heart-healthy edible oil. The oil's composition positively influences cholesterol metabolism, further supporting its role in promoting cardiovascular health.

As the high cost of animal-based milk products puts low-income populations at risk of PEM, especially among children under five, the development of affordable milk substitutes is crucial. Additionally, individuals with lactose intolerance or allergies to animal milk benefit from plant-based milk, such as tiger nuts, soy, and coconut. Tiger nut milk, in particular, contains more iron, magnesium, and carbohydrates than cow's milk (Bamishaiye and Bamishaiye, 2011), and has been found suitable for diabetics, those with cardiovascular issues, and lactose-intolerant individuals (Belewu and Abodunrin, 2006).

Despite their benefits, plant-based milk in liquid form faces challenges like short shelf life and difficulties in storage and transportation. Drying these products into powder forms can extend their shelf life, making them more accessible, especially in rural areas. This study focuses on developing a dry tiger nut milk substitute sweetened with dates, utilizing a waste valorization approach where dates—often discarded—serve as a natural sweetener.

Tiger nuts (*Cyperus esculentus*), an ancient crop dating back to 5000 BC in Egypt, are known for their nutritional density, containing proteins, carbohydrates, oils, and fibre (Adel *et al*., 2015). Their high content of digestive enzymes promotes digestion, though some antinutrients present in tiger nuts may inhibit nutrient absorption (Krichene *et al*., 2016). Nonetheless, tiger nuts are useful in producing milk, ice cream, and baked goods (Bamishaiye *et al*., 2014). Despite their benefits, tiger nut cultivation remains underexploited in Nigeria, largely due to a lack of awareness.

Dates, another underutilized food, are rich in iron, potassium, calcium, and fibre, making them a nutritious and natural sweetener. This study explores the impact of different processing methods, such as oven drying, toasting, fermentation, and malting, on the proximate composition and sensory properties of tiger nut-based dry milk substitutes sweetened with dates. The 70:30 ratio of processed tiger nut tubers to dried dates in the formulation likely reflects a balance of nutritional, sensory, and functional properties. Tiger nuts offer healthy fats and fibre, while dates provide energy from natural sugars. This ratio ensures a balanced macronutrient profile, combining sweetness and texture without overpowering flavours. The choice of processing methods like oven drying, toasting, fermentation, and malting for tiger nut-based dry milk substitutes is rooted in their potential to enhance the nutritional profile, improve sensory attributes, and increase shelf life.

MATERIALS AND METHODS

Source of materials

The tiger nut tubers and dates used in the study were bought from Eke Agbani market, Nkanu West Local Government Area of Enugu State, Nigeria. The chemicals were bought from Bio-organics Laboratory services Enugu and analyses were conducted in their laboratory.

Sample preparation

Three kilograms (3 kg) of tiger nut tubers were dried under the sun for 24 h, and sorted manually to remove dirt, stones, broken tubers, rotten tubers, and all debris. Out of the cleaned tubers, 500 g portions were divided equally into four separate groups.

Preparation of oven-dried/toasted tiger nuts tubers

The method reported by Ade-Omowaye *et al*. (2008) with minor modifications was used for the preparation of roasted tiger nut flour. Tiger nut flour is made by roasting and toasting tiger nuts and processing the roasted roots into fine powder. Tiger nut tubers (2 sets) (500 g) each were washed twice rinsed with potable water (30±2°C), and drained in a sieve. One set was dried in the oven (Gulfex scientific DHG 9202, England) at 55°C for 12 hours. The second set was toasted over an electric burner for I hour.

Preparation of fermented tiger nut tubers

The method reported by Ade-Omowaye *et al*. (2008) with minor modifications was used for the preparation of fermented tiger nut flour, Five hundred grams (500 g) of cleaned tiger nut tubers were washed with plenty of portable water (30±2°C) and soaked in water (1:3 $^{w}/v$) for 72 h to develop acidity, activate enzymes and indigenous microbial fermentative organisms. The water was changed every 24 hours. At the end of the fermentation period, the tubers were washed, drained and dried in the oven (Gulfex scientific DHG 9202, England) at 55°C for 1 hour and milled into flour.

Preparation of malted tiger nut tubers

The method reported by Ade-Omowaye *et al.* (2008) with

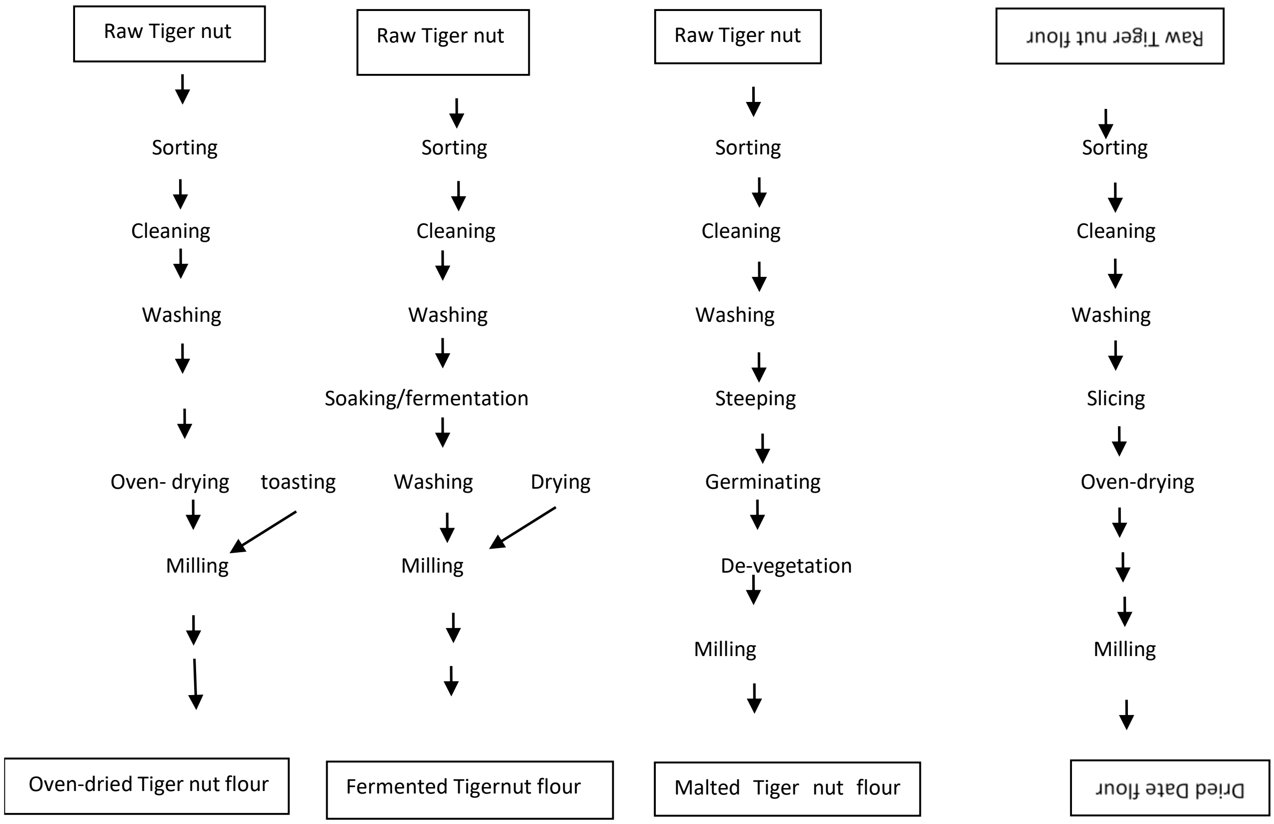

Figure 1. Production of oven-dried/toasted tiger nut flour, fermented tiger nut flour, malted tiger nut flour and dried date flour respectively (**Source:** Modified method of Ade-Omowaye (2008)).

minor modifications was used for the preparation of malted tiger nut flour. Cleaned tiger nut (500 g) was washed and steeped in water (1:3 ^{w}/v) for 12 hours at room temperature (30±2°C). A sterilized jute bag was used for germination. The jute bag was washed, oven-dried at 60°C and cooled. The jute bag was spread in a bench cupboard and the steeped tubers spread on it. The tubers were germinated for 3 days. They were turned and sprinkled with water twice a day for even distribution of air and to prevent the tubers from drying out or moulding. At the end of the germination period, the tubers were de-vegetated (removal of sprouts, shoots and roots). They were washed to reduce microbial load, drained and dried in an oven (Gulfex scientific DHG 9202, England) at 55°C for 1 hour.

Preparation of dried dates

Dry dates (500 g) were cleaned manually, washed with potable water (30±2°C), and oven-dried for 24 hours. The oven-dried dates were sliced thinly (1 mm thick) to ease further drying. The sliced dates were dried in the oven (Gulfex scientific DHG 9202, England) at 55°C for 3 hours and milled in flour.

Formulation of tiger nut/dates powdered milk substitutes

Samples were formulated with 70 g processed tiger nut tubers and 30 g dried dates, achieving a 70:30 ratio that balances nutritional, sensory, and functional properties. The first sample, OTMS (oven-dried tiger nut milk substitute), used oven-dried tiger nuts. A similar formulation with fermented tiger nuts was named FTMS (fermented tiger nut milk substitute). The third and fourth samples used malted and toasted tiger nuts, designated MTMS (malted tiger nut milk substitute) and TTMS (toasted tiger nut milk substitute), respectively. Each blend was milled with an electric grinder (Panasonic MX-AC 2105, Germany) and sieved through a 2 mm mesh into fine powder.

Determination of proximate composition

The proximate composition, including protein, moisture, fat, ash, and fibre content, was analyzed following the procedures outlined by the Association of Official Analytical Chemists (AOAC, 2010). Carbohydrate was determined by difference method as follows % CHO = 100 – (% protein + % moisture + % fat + % ash + % fibre). Energy (calorific value) was calculated using the Atwater method and expressed in kilocalories per gram of the sample. It was calculated as follows Energy kcal/ g = [(% CHO x 4) + (% protein x 4) + (% fat x 9)].

Sensory evaluation was conducted on all the samples, including OTMS (oven-dried tiger nut tubers and dates), STMS (fermented tiger nut tubers and dates), MTMS (malted tiger nut tubers and dates), TTMS (toasted tiger nut tubers and dates), and CPPM (commercial Peak powdered milk), which served as the control. Liquid milk was prepared by mixing each sample with 50 ml of water, boiled to 100°C and cooled to 85°C. A randomly selected panel of 10 untrained judges from the Faculty of Engineering and Technology, Madonna University, Akpugo Campus, evaluated the samples. The judges were asked to rate the products based on appearance, taste, aroma, and overall acceptability. The bread was provided to clear the palate, and the judges rinsed their mouths with water between samples. Ratings were recorded using a 9-point Hedonic scale (1 = dislike extremely to 9 = like extremely). Data were statistically analyzed using analysis of variance (ANOVA).

Statistical analysis

The data collected were analyzed using one-way analysis of variance (ANOVA) with SPSS version 18 (SPSS Inc., USA). Duncan's new multiple-range test was applied to separate the means, and statistical significance was determined at a 5% probability level ($p<0.05$). Results were reported as the mean ± standard deviation (SD) of three replicates.

RESULTS AND DISCUSSION

Table 1 presents the proximate composition of processed tiger nut milk substitutes. The sample made from fermented tiger nuts (FTMS) exhibited the highest protein content at 7.01%, while the malted tiger nut milk substitute (MTMS) had the lowest protein level at 5.38%. The differences in protein levels among the samples can be attributed to the distinct processing methods used for the tiger nuts. The reduced protein content in the MTMS (5.38%) may result from the malting process, which, according to Ijeomah (2015), tends to decrease overall protein quantity while enhancing its quality. During malting, protease enzymes break down complex proteins into simpler peptides and amino acids, which leads to a reduction in measurable total protein content. Some protein is hydrolyzed or utilized during germination, and although these simpler fragments are more easily digested and absorbed, they result in lower protein measurements in some analyses. In contrast, the fermentation process, recognized for its ability to boost the nutritional profile of foods, likely contributed to the increased protein content in the FTMS (7.01%). During fermentation, microorganisms break down carbohydrates and other compounds, leading to increased protein content through several mechanisms: microbial biomass (microbes contribute their proteins), enzymatic breakdown (proteins are broken into more bioavailable peptides and amino acids), nitrogen fixation (microbes incorporate nitrogen into proteins), and concentration of nutrients (non-protein components decrease, raising protein concentration). These processes enhance both protein quantity and quality, improving the nutritional profile of fermented foods. This aligns with the findings of Okorie and Nwanekezi (2014), who reported that the nutritional value of tiger nuts is influenced by the processing method used. The protein content of the milk substitutes showed significant variation ($p<0.05$), with the commercial control at 24.87%, while tiger nut flour contained 6.67% (Adejuyitan *et al*., 2009). Ndubuisi (2009) reported protein levels of 6.12% for dried non-malted and 5.92% for dried malted tiger nut tubers.

The variation in protein content among milk substitutes highlights the significant impact of processing methods and raw materials on protein levels. The commercial control had much higher protein (24.87%) compared to tiger nut-based products (around 6%), indicating that tiger nut milk substitutes are naturally low in protein and may require fortification. The slight reduction in protein during malting aligns with research showing that malting decreases total protein but enhances its quality. This emphasizes the need for careful processing to optimize the nutritional value of plant-based milk substitutes.

The ash content of the milk substitutes did not show significant differences ($p>0.05$) among the samples, though slight variations were noted: OTMS (1.92%), FTMS (1.94%), MTMS (1.90%), and TTMS (1.93%). These values were lower than the commercial control (2.97%) and higher than the 1.53% and 1.36% reported by Ndubuisi (2009) for non-malted and malted dried tiger nut tubers, respectively. The slight variations in ash content among the milk substitutes (OTMS, FTMS, MTMS, TTMS) are likely due to minor differences in processing methods and the inherent mineral composition of tiger nuts. These variations are expected, as fermentation, malting, and thermal treatments have minimal impact on mineral content. The lower ash content than the commercial control suggests fewer minerals in tiger nut-based substitutes, potentially due to a lack of fortification or differences in raw materials. The minor differences indicate a consistent mineral profile in tiger nuts across processing methods. Based on ash content, FTMS (1.94%) has the highest mineral content among the tiger nut milk substitutes, while MTMS (1.90%) has the lowest, though the differences are minimal. FTMS is preferable for

Table 1. Proximate composition of tiger nut milk substitute.

Parameters %	OTMS	FTMS	MTMS	TTMS	CPPM
Protein	5.68^{d}±0.10	7.01^{b}±0.01	5.38^{e}±0.01	6.41^{c}±0.01	24.87^{a}±0.01
Ash	1.92^{b}±0.01	1.94^{b}±0.02	1.90^{c}±0.00	1.93^{b}±0.06	2.97^{a}±0.01
Fibre	2.43^{b}±0.01	2.43^{b}±0.01	2.98^{a}±0.01	2.43^{b}±0.01	ND
Fat	2.43^{b}±0.01	14.29^{c}±0.02	14.29^{c}±0.01	15.42^{b}±0.02	17.14^{a}±0.01
Moisture	1.93^{d}±0.01	3.92^{a}±0.00	2.86^{b}±0.02	2.86^{b}±0.20	1.98^{c}±0.01
Carbohydrate	73.85^{a}±0.01	64.41^{d}±0.01	72.59^{b}±0.01	71.45^{c}±0.01	53.04^{e}±0.00
Energy kcal/g	446.40^{b}±0.20	414.29^{d}±0.01	440.49^{c}±0.01	447.40^{b}±0.01	466.34^{a}±0.00

Values are mean of triplicate determination ± standard deviation (SD) means with different superscripts on the same row are significantly different ($p<0.05$). OTMS = sample produced with oven-dried tiger nut tubers and dates, FTMS = sample produced with fermented tiger nut tubers and dates,

Table 2. Sensory properties of the tiger nut milk substitutes.

Attributes	OTMS	FTMS	MTMS	TTMS	CPPM
Appearance	7.50^{c}±0.71	8.00^{b}±1.33	7.90^{bc}±0.88	8.50^{ab}±0.53	9.00^{a}±0.94
Aroma	7.10^{b}±1.37	8.50^{a}±0.71	7.40^{b}±1.07	8.00^{ab} ±0.94	8.60^{a} ±0.52
Taste	7.30^{a}±0.82	7.50^{a}±0.97	7.60^{a}±1.17	8.10^{a} ±0.87	7.80^{a}±0.63
Overall acceptability	7.70^{b}±0.82	8.30^{ab}±0.67	7.85^{ab}±1.40	8.60^{a} ±0.70	8.60^{e}±0.52

Values are mean of triplicate determination ± standard deviation (SD) means with different superscripts on the same row are significantly different ($p<0.05$). Key: OTMS = sample produced with oven-dried tiger nut tubers and dates, FTMS = sample produced with fermented tiger nut tubers and dates, MTMS = sample produced with malted tiger nut tubers and dates, TTMS = sample produced with toasted tiger nut tubers and dates and CPPM = commercial powdered milk.

its slightly higher mineral content. Ash content reflects the mineral elements present in food.

All processed tiger nut milk substitutes had the same fibre content (2.43%), except for the sample made with malted tiger nuts, which showed a higher fibre content (2.98%) that varied significantly ($p<0.05$). The lower fibre values in the products are likely due to sieving, which removed much of the fibrous material. These findings contrast with the higher fibre values (7.48–13.97%) reported by Ndubuisi (2009) for non-malted and malted tiger nut tubers, and they are also higher than the 1.64–2.04% range noted by Adejuyitan *et al*. (2009) for fermented tiger nut flour.

The fat content of the tiger nut samples made from oven-dried, fermented, and malted tubers was uniform at 14.29%, which is lower than the fat content in the toasted sample (15.42%) and the commercial control (17.14%). The higher fat content in the toasted sample may be attributed to the elevated temperatures used during toasting, which can melt and extract more fat from the nuts. The toasted sample's fat content was significantly higher ($p<0.05$) than the 14.41 g reported by Adejuyitan *et al*. (2009) for tiger nut flour, but lower than the 32.06% and 19.80% noted by Ndubuisi (2009) for dried non-malted and malted tiger nut tubers, respectively.

Moisture levels varied among the samples, likely due to differences in drying methods and storage conditions. The malted (MTMS) and toasted (TTMS) samples showed similar moisture levels of 2.86%. The fermented sample (FTMS) had the highest moisture content at 3.92%, while the oven-dried sample (OTMS) had the lowest at 1.93%. Significant differences ($p<0.05$) were observed in the moisture contents across the samples.

Carbohydrate content ranged from 64.41% in the fermented sample (FTMS) to 73.83% in the oven-dried sample (OTMS). These variations can be attributed to differences in other proximate compositions. The energy values of the samples ranged from 414.29 to 466.34 kcal/g, reflecting the contributions of protein, fat, and carbohydrate contents to the overall energy value.

Sensory properties of tiger nut milk substitutes

The sensory evaluation scores for the samples are detailed in Table 2. All samples—oven-dried (OTMS), fermented (FTMS), malted (MTMS), toasted (TTMS), and the commercial control (CPPM)—performed well across various sensory attributes (appearance, taste, aroma, and overall acceptability). The toasted sample (TTMS) received the highest appearance score (8.50), making it visually appealing. The malted (MTMS) and fermented (FTMS) samples followed closely, suggesting that they also have good visual characteristics. In contrast, the oven-dried sample (OTMS) scored the lowest (7.50), which may make it less attractive to consumers. The taste scores highlight the appeal of FTMS (8.50) and TTMS (8.00), which are comparable to commercial control (CPPM, 8.60). These samples likely offer a more favourable flavour profile, making them more desirable. In contrast, OTMS (7.10) and MTMS (7.40) scored lower, indicating that their flavours may be less appealing or distinctive. This suggests that the fermentation and toasting processes enhance the taste, making FTMS and TTMS more liked (Shrestha and Noomhorm 2002; Sakai and Nakazawa 2012). The aroma scores were consistent across most samples but notably lower than TTMS (8.10).

The coffee-like aroma developed during toasting likely contributed to TTMS's higher score, making it more aromatic and appealing to consumers. The lower aroma scores for the other samples suggest they may lack the same complexity or richness, impacting their overall acceptability. TTMS is the best overall based on sensory attributes, while FTMS is recommended for its taste and health benefits. Both samples would be great choices, depending on the desired qualities—TTMS for visual and aromatic appeal and FTMS for flavour and nutritional value. Conclusively, further studies on the shelf life of FTMS are essential for ensuring safety, quality, and nutritional value, ultimately contributing to its success in the market

Appearance scores ranged from 7.50 to 9.00 on a 9-point hedonic scale, with the malted sample (7.90) showing comparable scores to the toasted (8.50) and fermented (8.00) samples, while being higher than the oven-dried sample (7.50). The taste scores for FTMS (8.50) and TTMS (8.00) were comparable to those of the commercial control (8.60). This aligns with findings by Sakai and Nakazawa (2012), who observed that fermentation releases amino acids and other flavor compounds, leading to improved flavor profiles and enhanced taste. In contrast, the taste scores for OTMS (7.10) and MTMS (7.40) did not show significant differences (p>0.05). Aroma scores were consistent across the samples and the commercial control (p>0.05) but were lower than the aroma score for the toasted sample (TTMS) at 8.10. This higher aroma score for TTMS is likely due to the coffee-like aroma developed during the toasting process. This is consistent with the findings of Shrestha and Noomhorm (2002), who examined flavor and aroma changes resulting from toasting processes and noted the development of a coffee-like aroma attributed to Maillard reactions.

Conclusion

This study demonstrates that different processing techniques significantly affect the nutritional composition and sensory properties of powdered tiger nut/date milk substitutes. Fermentation increased protein content, while toasting enhanced fat content and overall sensory acceptability, making it comparable to commercial powdered milk. Although the malted sample had the highest fibre content, it contained the lowest protein. The oven-dried sample was the richest in carbohydrates. These findings suggest that toasted tiger nut/date milk substitutes hold strong potential as a nutritious and appealing alternative for individuals with lactose intolerance, diabetes, or limited access to traditional dairy products. With additional improvements, these products could serve as viable substitutes for cow’s milk.

CONFLICT OF INTEREST

The authors declared that they have no conflict of interest.

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