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INFLUENCE OF PASTEURISATION ON THE BIOCHEMICAL PROPERTIES OF SWEET PEA MILK (*CYPERUS ESCULENTUS*) GROWN IN KORHOGO (CÔTE D'IVOIRE)

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ABSTRACT

Côte d'Ivoire is a country rich in significant agri-food resources, some of which are underutilized. This is the case with Cyperus esculentus L. (tiger nut, sweet pea). To better utilize its value, its nutritional potential should be understood through its milk. To this end, tiger nut milk was produced and divided into four parts. Three parts were pasteurized at 70°C for 10 minutes (LP10), 15 minutes (LP15), 20 minutes (LP20), and 25 minutes (LP25), and the remaining part was unpasteurized (LNP). Standard procedures were used to evaluate the nutritional characteristics of tiger nut milk. The results of this study revealed that tiger nut milk is rich in nutrients. The results of this study revealed that tiger nut milk contains carbohydrates (2.84 to 3.95%), lipids (1.76 to 2.64%), proteins (1.02 to 1.13%) and fibers (0.29%). Tiger nut milk also contains several minerals, the most prominent of which are potassium (154.47 to 398.70 mg/100g), phosphorus (158.31 to 341.32 mg/100g), magnesium (74.55 to 98.30 mg/100g), calcium (51.65 to 99.31 mg/100g), and sodium (24.26 to 88.70 mg/100g). Analysis of the results also showed that pasteurization time influenced the milk's properties. Generally, all parameters decreased after 20 minutes of pasteurization. This work paves the way for the potential use of tiger nuts (*Cyperus esculentus*).

Keywords: Polyphenols, Minerals, Valorization, Nutritional Parameters

1 INTRODUCTION

The growing popularity of plant-based milk is occurring at the expense of animal-based milk, in parallel with the rise of vegetarian diets and vegan lifestyles. Furthermore, lactose intolerance and milk protein allergies are other factors that have increased the consumption of plant-based milk. There are many milk substitutes on the market made from oats, soy, almonds, rice, and coconut [1]. In addition to milk made from legumes, almonds, cereals, and oilseeds, there is milk made from tubers such as tiger nuts.

Cyperus esculentus, commonly known as tiger nuts or sugar peas, from the Cyperaceae family [2], is cultivated for its tubers, which have good nutritional value, with high levels of fat, sugar, minerals, and vitamins [3]. It is widely used in various countries in Africa (Benin, Nigeria, Algeria, Kenya, Mali, Togo, and Morocco), Asia (Nepal, Iraq, and India), and South America (Brazil) [4].

In Côte d'Ivoire, the most common vernacular name for the tuber of *Cyperus esculentus* is "tchongon" and it is generally eaten fresh or dried as a treat. Rehydrated and ground sweet peas are used to produce a delicious beverage called "hortchata," consumed in Spain and some Mediterranean countries [5]. The chinese government promotes this sweet pea-based beverage as a substitute for soy due to its richness in oils, polysaccharides, proteins, and other nutrients [3].

Despite its interesting biochemical composition and nutritional properties, tiger nuts attract little interest from the general public and industry. This study aims to contribute to the development of tiger nuts in the food and dietary sectors.

2 MATERIAL

The biological material consists of tiger nut (*Cyperus esculentus*) tubers purchased from various markets in the city of Korhogo **(Figure 1).**

Figure 1: Tiger nut tubers

3 METHODS

3.1 Sampling

Sampling was carried out in three different markets in the city of Korhogo (northern Côte d'Ivoire) : the markets in the "disaster-stricken" neighborhood, "Petit Paris," and the main city market. Tiger nuts were purchased from three different women at each market, at a rate of 0.5 kg per woman. The tiger nuts were then mixed to create the sample.

3.2 Production of milk from tiger nuts

One (1) kg of dried tiger nuts was washed three times in distilled water and then soaked in distilled water for three days. After soaking, the tubers were ground using a grinder containing 500 mL of water. Once filtered through a white cloth, the resulting milk was divided into five batches. The first four batches were pasteurized at 72 °C for 10, 15, 20, and 25 minutes, respectively. The fifth batch was not pasteurized. **Figure 2** shows the production diagram of tiger nut milk.

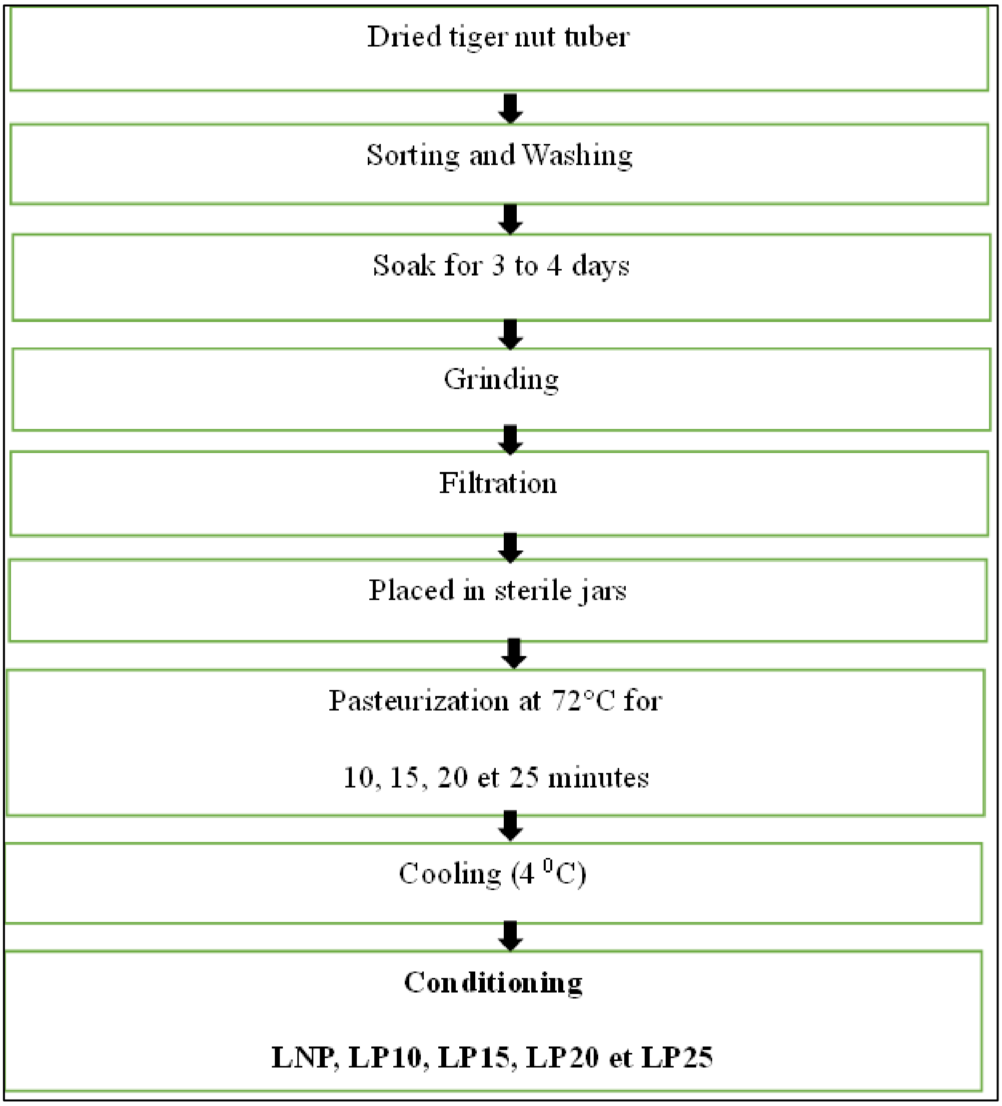

Figure 2: Diagram of milk production based on tiger nut tubers

Figure 3: Milk made from tiger nut tubers

3.3 Determination of nutritional properties

3.3.1 Moisture and dry matter content

The moisture content was determined according to the method (AOAC, 1984) [6]. The set (M1) of pre-tared porcelain crucibles containing 5 mL of milk (PE) was placed in an oven at 105 °C for 24 h. The crucibles were removed from the oven and placed in a desiccator for cooling before being weighed (M2).

$$TH\,(\%) = \frac{(M1 - M2)}{(M1 - M0)} \times 100$$

$$TMS\,(\%) = 100 - TH\,(\%)$$

3.3.1.1 pH and acidity

The procedure involved immersing the previously calibrated pH meter electrode in 50 mL of Laut. The displayed value was then read. Titratable acidity corresponds to the sum of free mineral and organic acids in fruit juices. It is determined according to the method described by Sadler and Murphy (2010) [7]. 10 mL of milk was titrated with a 0.1 N NaOH solution in the presence of phenolphthalein until a persistent pink color change was observed. The titratable acidity was calculated using the following formula:

$$TH\,(\%) = \frac{Vb\,(mL) \times 0{,}64}{10 \times d} \times 100$$

With:

AT: titratable acidity
VB: volume of NaOH added
d: milk density

The density of the juice is considered to be equal to 1, so the results are expressed in grams per liter (g/L).

3.3.1.2 Ash content

The AOAC method (1984) [8] was used to determine the ash content. Two grams of milk were weighed into a dried porcelain crucible of mass M1. The sample and crucible were then placed in a muffle furnace at 550 °C until white ash was obtained. After incineration, the crucible was placed in a desiccator for cooling and then weighed (M2).

$$TH\,(\%) = \frac{Vb\,(mL) \times 0{,}64}{10 \times d} \times 100$$

3.3.1.3 Lipid levels

Lipids were determined according to the AFNOR method (1996) [9]. Ten (10) mL of milk were added to 10 mL of concentrated sulfuric acid in a butyrometer. One mL of isoamyl alcohol was added to the mixture. After securely stoppering the butyrometer, it was shaken and inverted, then centrifuged at 1200 rpm for 5 minutes. After centrifugation, the butyrometer was placed in a water bath at 65°C for 5 minutes. After removing the butyrometer from the bath and with the stopper adjusted downwards, the value at the lower end of the fat column was recorded (A), and then the value at the upper end of the fat column was recorded (B). The fat content was determined using the following expression:

$$MG\,(g/L) = B - A$$

3.3.1.4 Total sugar levels

The techniques of Dubois *et al*. (1956) [10] and Martinez-Herrera *et al*. (2006) [11] were used to determine total sugars using phenol and concentrated sulfuric acid. To 1 g of milk, 10 mL of 80% ethanol, 2 mL of 10% zinc acetate, and 2 mL of 10% oxalic acid were added successively. After homogenization, the mixture was centrifuged at 1200 rpm for 10 min. The supernatant was transferred to a 50 mL volumetric flask, and the pellet was resuspended in 10 mL of ethanol and centrifuged again. The ethanol was evaporated, and the volume was adjusted to 50 mL. To 150 µL of the ethanol-soluble extract, 1 mL of 5% phenol and 1 mL of concentrated hydrogen sulfide (H_2SO_4) were added. After cooling, the reading is taken at 490 nm against the blank. The total sugar content was determined using a calibration curve established with glucose (2 mg/mL).

3.3.1.5 Reducing sugar levels

Reducing sugars were determined according to the Bernfeld method (1955) [12] using 3,5-dinitrosalycilic acid (DNS). The ethanosoluble extract (150 µL) was measured in a test tube. To this volume, 300 µL of the DNS solution was added. The mixture was heated in a boiling water bath for 5 min. After cooling for 5 min on the benchtop, 2 mL of distilled water were added to the reaction mixture. The optical density was measured at 540 nm using a spectrophotometer against a control containing 150 µL of distilled water and 300 µL of DNS. The optical density was converted to the amount of reducing sugars using the standard curve obtained from a glucose solution (2 mg/mL).

3.3.1.6 Protein levels

Protein levels were determined using the Kjeldahl method (AOAC, 1984) [6]. The determination was carried out in three stages : mineralization, distillation, and ammonia determination.

3.3.1.7 Fiber content

The fiber content was determined according to the AOAC method (2000) [8]. To 2 g of milk, 50 mL of sulfuric acid (0.25 N) was added. The mixture was boiled for 30 min, then 50 mL of NaOH (0.31 N) was added and boiled again for 30 min. The resulting solution was filtered, and the residue was washed several times with hot water until the alkalis were removed. The residue was dried at 105°C for 8 h and then incinerated at 550°C.

3.3.1.8 Vitamin C levels

The vitamin C content was determined according to the method of Pongracz (1971) [13]. 10 g of milk were added to 10 mL of 20% methaphosphoric acid-acetic acid. The mixture was titrated with a 0.5 g/L 2,6-DCPIP solution until a persistent pink color was observed.

3.3.1.9 Mineral element levels

Mineral elements were determined by atomic absorption spectrophotometry according to the AOAC (1984) [6] digestion method using strong acids. A 0.5 g ash sample was dissolved in 31 mL of a mixture of perchloric acid (11.80 mol/L), nitric acid (14.44 mol/L), and sulfuric acid (18.01 mol/L). The mixture was heated on a hot plate until thick white fumes appeared. After this heat treatment, the reaction mixture was cooled on the bench for 10 min and then diluted in 50 mL of distilled water. It was boiled again for 30 min and then cooled again under the same conditions. The mixture was then filtered through Whatman No. 4 filter paper. The resulting filtrate was made up to the calibration mark with distilled water. The mineral matter content was determined using a VARIAN AA.20 flame atomic spectrophotometer at a specific wavelength by comparison with standard solutions.

3.4 Characterization of organic acids by high-performance liquid chromatography (HPLC)

Chromatography was performed according to the (modified) technique of Ho et al. (1999) [14]. 50 mg of milk was placed in a 100 mL volumetric flask, and 75 mL of distilled water was added. The mixture was centrifuged at 12,000 rpm for 30 min. The collected supernatant was filtered through Wathman No. 4 filter paper and then through a 0.45 µm millipore filter. 20 µL of each solution obtained were injected into an HPLC system (Shimadzu Corporation, Japan) equipped with a binary pump (LC-6A) coupled to a UV-VIS detector (SPD-6A). Chromatographic separation of the organic acids was performed on an ICSep ICE ORH-801 column (30 cm long) at a temperature of 35 °C. The eluent consists of a mixture of a phosphate/methanol buffer solution (88:12 v/v) at an elution rate of 0.6 mL/min. The chromatograms obtained at 210 nm were compared to those obtained on organic acid standards (tannic acid, propionic acid, fumaric acid, tartaric acid, citric acid, lactic acid, acetic acid, formic acid, adipic acid, butyric acid, benzoic acid, salicylic acid, gluconic acid, ascorbic acid and malic acid).

3.5 Determination of antinutritional properties

3.5.1 Phytate levels

The phytate content was determined according to the method of Latta and Eskin (1980) [15]. 20 mL of 0.65 N hydrochloric acid was added to 0.5 g of milk. The resulting mixture was stirred for 12 h at room temperature and then centrifuged at 1200 rpm for 40 min. Next, 3 mL of Wade's reagent was added to 0.5 mL of the supernatant. The mixture was in the dark for 30 min. ODs were read spectrophotometrically at 490 nm against a blank. A calibration curve was prepared using a 10 mg/mL sodium phytate stock solution.

3.5.2 Oxalate level

The oxalate content was determined according to the method of Day and Underwood (1986) [16]. One (1) g of milk was homogenized in 75 mL of 3 M sulfuric acid. The mixture was stirred magnetically for 1 h. Then, 25 mL of the heady filtrate was hot-titized with a 0.05 M potassium permanganate solution until a persistent pink color was achieved.

3.6 Statistical analyses

Statistical analyses of the results were performed using STATISTICA 7 software. 1. The milk samples underwent analysis of variance (ANOVA) to determine the effect of pasteurization time on their properties. When a significant difference was observed, pairwise comparisons were made using the Tukey HSD test.

4 RESULTS

The biochemical composition of tiger nut milk is presented in **Table 1.** Statistical analysis of the results showed that the total sugar content, ranging from 3.95% to 2.84%, and the reducing sugar content, ranging from 0.06% to 0.03%, of unpasteurized milk (UPL) are significantly lower ($p < 0.05$) than those of pasteurized milk (PM). Conversely, the dry matter content, ranging from 3.57% to 3.29%, and the protein content, ranging from 1.13% to 1.02%, of UPL are significantly higher ($p < 0.05$) than those of PML. It should also be noted that there is no significant difference in fiber, total carbohydrate, or energy content between UPL and PML. The protein content of LNP was similar to that of milk pasteurized for 10 minutes (LP10), 15 minutes (LP15), and 20 minutes (LP20), but statistically ($p < 0.05$) different from that of milk pasteurized for 25 minutes (LP25). However, there was no significant difference between the different milk pasteurization times. Pasteurization time had no effect on the fiber, protein, or reducing sugar content. However, it did have a significant effect on the total sugar content.

Table 1: Macronutrients of the different types of tiger nut milk

Settings (%)	**MILK**				
	UPL	LP10	LP15	LP20	LP25
Dry matter content	3.57 ± 0.02 ^{b}	3.29 ± 0.01 ^{a}	3.30 ± 0.02^{a}	3.30 ± 0.02 ^{a}	3.296± 0.02 ^{a}
Protein levels	1.13 ± 0.06 ^{b}	1.08 ± 0.03 ^{ab}	1.07 ± 0.01 ^{ab}	1.05 ± 0.01 ^{ab}	1.02 ± 0.03 ^{a}
Lipid levels	1.76 ± 0.09^{a}	1.85 ± 0.15^{a}	2 ± 0.20^{ab}	2.30 ± 0.20^{bc}	2.64 ± 0.16^{c}
Fibers	0.29 ± 0.01 ^{a}	0.29 ± 0.01 ^{a}	0.29 ± 0.02 ^{a}	0.29 ± 0.01 ^{a}	0.29 ± 0.01 ^{a}
Total Sugars	0.47 ± 0.01 ^{a}	0.58 ± 0.08 ^{b}	0.65 ± 0.02 ^{b}	0.8 ± 0.02 ^{c}	0.92 ± 0.02 ^{d}
Reducing Sugars	0.03 ± 0.01 ^{a}	0.06 ± 0.01 ^{b}	0.06 ± 0.01 ^{b}	0.05 ± 0.01 ^{b}	0.06 ± 0.01^{b}
Total carbohydrates	3.26 ± 0.16 ^{a}	3.95 ± 1.05 ^{a}	2.84 ± 0.44 ^{a}	3.54 ± 0.24 ^{a}	2.91 ± 0.21 ^{a}
Energy (Kcal/100g)	33.4 ± 1.6 ^{a}	36.77 ± 3.23 ^{a}	33.64 ± 4.36 ^{a}	39.06 ± 2.94 ^{a}	39.48 ± 1.52 ^{a}

The physicochemical parameters of tiger nut milk are listed in **Table 2.** Analysis of the results in the table shows that the pH of UPL (3.57) is statistically different ($p < 0.05$) from the pH of LP (3.66–3.63). In contrast, pasteurization time had no effect on the pH of the different LP. The titratable acidity and moisture content of the different milks are all similar at the 0.05 threshold.

Table 2: Physico-chemical parameters of tiger nut milk

Settings (%)	MILK				
	UPL	LP10	LP15	LP20	LP25
pH	3.57 ± 0.02 [a]	3.65 ± 0.01 [b]	3.63 ± 0.01 [b]	3.66 ± 0.01 [b]	3.63 ± 0.04 [b]
Titratable acidity (%)	2.33 ± 0.52[a]	2.67 ± 0.30 [a]	2.33 ± 0.30 [a]	2.31 ± 0.4 [a]	2.67 ± 0.31 [a]
Humidity level	96.43 ± 0.23 [a]	96.71 ± 0.1 [a]	96.69 ± 0.02 [a]	96.70 ± 0.02 [a]	96.71 ± 0.02 [a]

The mineral composition of tiger nut milks is presented in **Table 3**. Analysis of the results shows that tiger nut milk contains several minerals, the most prevalent being potassium, phosphorus, magnesium, calcium, and sodium. The potassium (154.47 mg/100g) and calcium (51.65 mg/100g) levels of UPL are significantly lower ($p < 0.05$) than those of LP (200.28 to 398.70 mg/100g). Pasteurization time has no significant effect on the ash content, which is similar for all the milks. However, the phosphorus, sodium, magnesium, iron, and zinc levels of tiger nut milk are statistically different from one another. The results show that, among the pasteurization times, the mineral levels of LP25 are all lower than the levels of the other LP milks.

Table 3: Mineral composition of the different parts of tiger nut milk

Settings (mg/100g)	MILK				
	UPL	LP10	LP15	LP20	LP25
Ash (%)	0.42 ± 0.02 [a]	0.41 ± 0.01 [a]	0.40 ± 0.03 [a]	0.41 ± 0.06 [a]	0.42± 0.03 [a]
Potassium	154.47 ± 0.53 [a]	278.61 ± 1.39 [c]	398.70 ± 3.70 [e]	311.46 ± 8.54 [d]	200.28 ± 0.28 [b]
Phosphorus	189.31 ± 0.69 [c]	217.90 ± 2.10 [d]	341.32 ± 1.32 [e]	176.61 ± 1.39 [b]	158.31 ± 0.69 [a]
Calcium	51.65 ± 0.41 [a]	87.58 ± 1.58 [d]	99.31 ± 2.31 [e]	69.32 ± 0.69 [c]	58.31 ± 0.69 [b]
Sodium	49.18 ± 0.82 [c]	88.70 ± 1.30 [d]	38.48 ± 1.52 [b]	26.58 ± 0.42 [a]	24.26 ± 2.26 [a]
Magnesium	74.55 ± 0.45 [b]	68.50 ± 0.5 [a]	98.30 ± 0.7 [e]	92.31 ± 0.31 [d]	79.32 ± 0.68 [c]
Iron	5.58 ± 0.15 [b]	5.90 ± 0.10 [c]	7.61 ± 0.39 [d]	5.31 ± 0.69 [b]	4.58 ± 0.02 [a]
Zinc	5.61 ± 0.39 [b]	8.31 ± 0.69 [c]	1.36 ± 0.14 [a]	0.60 ± 0.10 [a]	0.60 ± 0.10 [a]

4.1 Composition in organic acids

The organic acid composition varies according to the different pasteurization times (**Table 4**). Analyses showed that the fumaric and salicylic acid content of LNP (0.82% and 0.18%, respectively), LP10 (0.76% and 0.18%, respectively), and LP15 (0.94% and 0.16%, respectively) is significantly higher ($p < 0.05$) than that of LP20 (0.57% and 0.11%, respectively) and LP25 (0.57% and 0.09%, respectively). In contrast, no significant difference was observed in the citric and adipic acid content of the different milks. The propionic acid content of LP20 is statistically different from that of LP25 but similar to that of LNP, LP10, and LP15. The results also showed that the benzoic and lactic acid levels of UPL are significantly higher ($p < 0.05$) than those of pasteurized milks where no significant difference was observed.

Table 4: Composition in organic acids

Settings (%)	MILK				
	UPL	LP10	LP15	LP20	LP25
Fumaric acid	0.82 ± 0.08 [b]	0.76 ± 0.01 [b]	0.94 ± 0.02 [c]	0.57 ± 0.03 [a]	0.57 ± 0.05 [a]
Citric acid	0.66 ± 0.04 [a]	0.48 ± 0.04 [a]	0.49 ± 0.12 [a]	0.56 ± 0.04 [a]	0.49 ± 0.03 [a]
Lactic acid	0.86 ± 0.08 [b]	0.54 ± 0.06 [a]	0.53 ± 0.06 [a]	0.58± 0.021 [a]	0.57 ± 0.03 [a]
Adipic acid	0.17± 0.05 [a]	0.21 ± 0.02 [a]	0.14± 0.02 [a]	0.57 ± 0.41 [a]	0.08 ± 0.02 [a]
Propionic acid	0.08 ± 0.02 [ab]	0.05 ± 0.01 [ab]	0.1 ± 0.01 [ab]	0.5 ± 0.34 [b]	0.03± 0.01 [a]
Benzoic acid	0.30 ± 0.10[b]	0.17 ± 0.01 [a]	0.15 ± 0.02 [a]	0.18 ± 0.02 [a]	0.18 ± 0.01 [a]

Salicylic acid	0.18 ± 0.01 b	0.18 ± 0.02 b	0.16 ± 0.02 b	0.11 ± 0.02 a	0.09 ± 0.02a

Means assigned a different letter on the same line are significantly different at $p < 0.05$. UPL: Unpasteurized milk, LP10, LP15, LP20 and LP25: Milk pasteurized for 10, 15, 20 and 25 minutes respectively. **Figure 4** shows the content of anti-nutritional factors in tiger nut milk. The analysis shows that the oxalate levels of UPL, LP10, LP15 and LP20 (0.07 ± 0.06; 0.05 ± 0.04, 0.06 ± 0.03 and 0.06 ± 0.02 mg/100mL respectively) are higher than those of LP25 (0.03 ± 0.01 mg/100mL). However, the phytate levels in UPL and LP10 (1.45 ± 0.05 and 1.46 ± 0.20 mg/100 mL, respectively) are statistically higher than those in LP15 (1.29 ± 0.06 mg/100 mL), LP20 (1.25 ± 0.11 mg/100 mL), and LP25 (1.33 ± 0.04 mg/100 mL), where there was no difference. It should be noted that these levels of antinutritional factors decrease with increasing pasteurization time. The lowest levels were recorded in LP25.

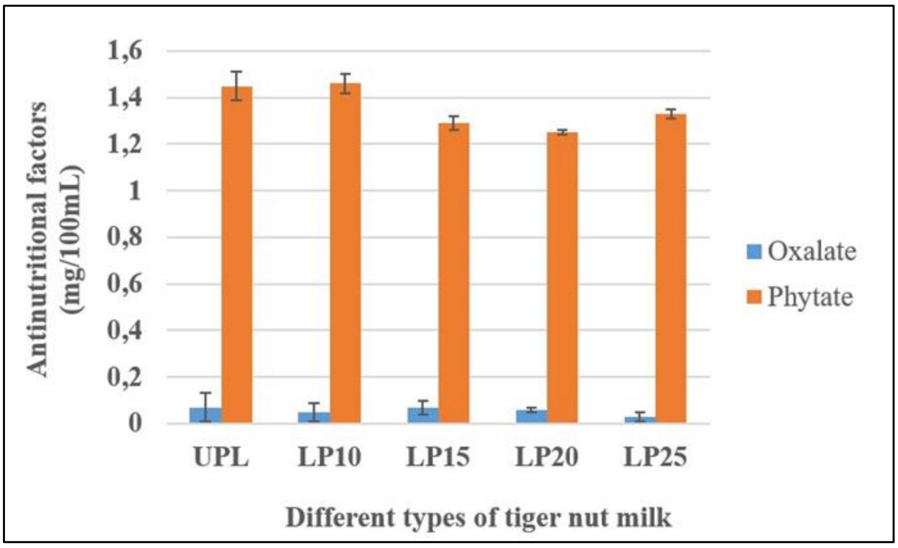

Figure 4: Antinutritional factors in tiger nut milk

5 DISCUSSION

The lipid content of the tiger nut milk samples is lower than that found by Opeyemi and Smart (2020) [17] but similar to that of rice milk (Drewnowski, 2022) [18]. Belewu and Belewu (2007) [19] report that tiger nut lipids are rich in beneficial fatty acids such as oleic acid. Tiger nut oil, with its inherent nutritional and therapeutic benefits, could serve as a good alternative to imported vegetable oils in food products [20].

The fiber content of tiger nut milk is 0.29% (290 mg/100 g). This is lower than the levels reported by Kouame *et al*. (2022) [21] for tiger nuts purchased in Bondoukou (7.68 to 8.57%). This difference is likely due to the tiger nut variety. The recommended daily intake (RDI) of crude fiber in foods is ≥ 4.0 mg/100 g [22]. Dietary fiber is an essential nutrient for the body, and a high intake enhances health benefits, primarily related to its positive impact on the gut microbiota [23].

Carbohydrates are the primary source of energy [24]. They provide 50 to 70% of the energy intake [25]. Cyperus esculentus milk is a source of carbohydrates.

The pH value helps interpret certain results of biological activities. The pH of vegetable juices is very important, especially for juices intended for preservation. In this case, a pH value between 3 and 4.5 is recommended for juices intended for preservation. The pH values obtained are within the recommended pH range. An acidic pH helps protect fruit juices against microbiological spoilage and better preserves vitamin C.

The titratable acidity values of tiger nut milk obtained in this study are lower than those obtained by Ogori *et al*. (2022) [26]. Acidity is a factor that also contributes to the preservation of plant-based beverages.

Several minerals were identified during this study. Some of them were significantly affected ($p<0.05$) by pasteurization time. These results are consistent with those of Karimian et al. (2016), who observed a significant variation in mineral levels between raw and cooked tiger nut (Oncorhynchus mykiss) flesh after different heat processes. These results are also consistent with those of Cifelli *et al*. (2010) [27], who observed minimal mineral loss after milk pasteurization.

Tiger nut milk contains reasonable amounts of potassium, phosphorus, calcium, sodium, magnesium, iron, and zinc. These results corroborate those of Maduka *et al*. (2022) [28], who showed that tiger nut milk is rich in minerals. The recommended daily intake is more than 100 mg for macro-minerals (Na, Mg, K, Ca, and P) and less than 100 mg for micro-minerals (Fe, Cu, and Zn) [29]. Based on the results of this study, consuming tiger nut milk would cover the requirements for P, K, Fe, and Zn, and partially for the other minerals.

The polyphenol content of the tiger nut milk in this study is higher than that of the tiger nut milk powder obtained by Kadjo et al. (2023) [30] but lower than that found in the aqueous extract of tiger nut flour [31]. Consuming foods rich in polyphenols reduces the risk of developing numerous diseases such as cancer, atherosclerosis, and hypertension [32]. The average human intake of flavonoids is between 25 mg/day and 1 g/day [33]. Flavonoids have antifungal, antiviral, and antibacterial activities [34]. Regarding vitamin C, its content decreases as the pasteurization time increases. This could be explained by its heat sensitivity. Vitamin C is a reducing agent involved in antioxidant defenses [35].

Regarding the tannin content in this study, it is lower than that found by Ayo *et al*. (2016) [36] in Nigeria on fermented tiger nuts. Consuming vegetables rich in tannins and flavonoids is thought to be quite beneficial, as these phytochemicals are believed to have numerous therapeutic effects [37].

Regarding organic acids, citric acid, propionic acid, lactic acid, fumaric acid, benzoic acid, adipic acid, and salicylic acid were detected in the tiger nut milk in this study. These acids improved mineral absorption [38]. Furthermore, their presence acidifies the beverage, enhances its flavor, and increases its antimicrobial preservation effectiveness [39].

The antinutritional compounds in tiger nut milk, namely phytates and oxalates, are present in lower concentrations than in cooked tiger nuts [40]. Antinutritional compounds are undesirable due to their harmful effects on the human body by chelating essential minerals. According to Sanz and Reig (1992) [41], the minimum lethal dose of oxalate in adults is 4 to 5 g. The minimum lethal dose of phytate is greater than 50 mg/100 g [42]. Given these low levels of antinutritional factors, the consumption of tiger nut flour would be safe for consumers.

6 CONCLUSION

This study on tiger nut milk has highlighted its numerous potential uses. Indeed, sweet pea milk contains many minerals, secondary metabolites, vitamins, and organic acids. Like soy milk, the milk from Cyperus esculentus tubers could be used by the food industry. This will help increase the income of local tiger nut producers.

STATEMENTS ON COMPLIANCE WITH ETHICAL STANDARDS

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Disclosure of conflict of interest

The authors declare that they have no conflicts of interest related to this article.

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