Journal of Food Security, 2023, Vol. 11, No. 1, 8-15
Available online at http://pubs.sciepub.com/jfs/11/1/2
Published by Science and Education Publishing
DOI:10.12691/jfs-11-1-2

Heat Treatment by Boiling Conserved the Nutritional, Physical, Microbiological and Sensory Properties of Tigernut (*Cyperus esculentus*) Milk: Implication for Improving Rural Health in Nigeria

Paulina O. Adeniyi[1,*], Bassey E. Anam[2]

[1]Wageningen Center for Development Innovation, Wageningen University and Research, Netherlands
[2]Institute of Public Policy and Administration, University of Calabar, Nigeria
*Corresponding author: doyinadeniyi@yahoo.com

Received December 14, 2022; Revised January 22, 2023; Accepted February 05, 2023

Abstract The health and income of households is important to national development. Sequel to the inadequate and poor electricity supply especially in many low income countries, many small and medium scale enterprises are adversely affected and the household as well as commercial production and consumption of tigernut milk is not exempted. Also, the possibility of preserving the nutritional quality of tigernut milk after production using easy, safe, affordable, available, and cost effective measure other than refrigeration is yet to be ascertained. These are part of the limitations for the adequate utilization of the nutritious tuber towards improvement of public health nutrition among rural dwellers in Nigeria. This experimental study was therefore designed to determine the effect of boiling twice a day for three days after production on the nutritional, physical, microbiological and sensory properties of tigernut milk with a view of encouraging the household and commercial production and consumption of the imitation milk. Tigernut milk was prepared using appropriate method. Sample was taken on the day of production and designated TM0. On the first, second and third day after production the remaining portions of the milk was subjected to boiling (without fully covering the cooking pot) for 5 minutes twice a day and the samples were designated as TM1, TM2 and TM3 respectively. Samples were subjected to proximate, vitamins, minerals analyses while the physical, microbiological and sensory properties were assessed using standard procedures. Analysis of variance (ANOVA) was used to compare means at $p \leq 0.05$. The boiling sessions in the course of the 3-day ambient temperature storage of the tigernut milk samples did not adversely alter the proximate, vitamins, mineral composition, as well as the microbiological, physical and sensory properties. As the moisture content decreased significantly with storage period all other components increased. The nutritional quality, physical parameters, microbiological status and sensory properties of tigernut milk were conserved by boiling twice a day for three days and storage at ambient temperature. Household and commercial production and consumption of tigernut milk is hereby encouraged and unavailability of refrigeration facility is no longer a deterring factor.

Keywords: *tigernut milk, boiling, nutritional quality, physical properties, ambient storage*

Cite This Article: Paulina O. Adeniyi, and Bassey E. Anam, "Heat Treatment by Boiling Conserved the Nutritional, Physical, Microbiological and Sensory Properties of Tigernut (*Cyperus esculentus*) Milk: Implication for Improving Rural Health in Nigeria." *Journal of Food Security*, vol. 11, no. 1 (2023): 8-15. doi: 10.12691/jfs-11-1-2.

1. Introduction

Tigernut (*Cyperus esculentus*), an edible perennial grass-like plant, can be grown in different parts of the world. It grows best in mild climate with low temperature and shade while tuber development can be inhibited by high levels of light intensity, nitrogen and gibberellic acid [1]. Tigernut can tolerate many adverse soil conditions such as drought, flood, and can survive at soil temperature as low as -5°C (23°F) [1].

Tigernut contains all the essential amino acids except tryptophan [2]. The quantity of histidine, isoleucine, leucine, lysine, methionine, phenylalanine, threonine and valine in tigernut in mg/16g N are 4.43, 4.84, 8.03, 6.50, 11.83, 4.27, 3.59 and 5.93 respectively [2]. Even though still underutilized tigernut has potentials for both domestic and industrial uses. Tigernut is a valuable source of vegetable oil which is rich in unsaturated fatty acids, tocopherols and phytosterol. It also contains protein, carbohydrate, vitamins, minerals and bioactive compounds, hence, can be consumed domestically as source of nutrients and used as raw material industrially for oil production. Tigernut fiber (or waste after milk extraction) can be used in the industry

to produce biosurfactants which can be utilized to increase the bioavailability of hydrophobic substrates through solubilization or desorption as well as regulate the attachment and removal of microorganisms from surfaces [3]. Tigernut is also useful for oil, feed and food supplements [4] and can be processed into milk [5], flour may be used as emulsifier, shortening, binder in food processing [6] as well as added to carbohydrate-rich flour to complement the nutritional value [7]. Tigernut milk may be applicable in yoghurt production [8] amongst other uses.

Tigernut has also been reported to exert some medicinal effects. Complementing the diet of adult male and female rats with tigernut was reported to enhance sexual activities and performance such as sexual behavior, sex hormones levels and antioxidant activities [9], tigernut oil-based diet lowered predisposition to cardiovascular diseases or risks by lowering serum total cholesterol, triglycerides, low density lipoprotein and very low density lipoprotein while concomitantly increasing high density lipoprotein in male Wistar rats [10]. Methanolic extract of tigernut was observed to exert appreciable antioxidant activity and total phenolic content, hence, may exert antioxidant activity in human subjects [11]. Tigernut has also been reported to be aphrodisiac, curminative, diuretic, emmanogogue, stimulating and can be used to treat indigestion, diarrhea, dysentery and excessive thirst [12] and its protection against heart attacks, thrombosis and colonic cancer has also been documented [13]. It is of interest to note that the antioxidant property of tigernut was observed to reduce cell sickling in sickle cell anemia thus reducing vaso-occlusive crises in sickle cell anemia patients [14].

Many low income countries experience poor and low access to electricity supply which makes food preservation by refrigeration totally unreliable especially in rural communities [15]. The access and affordability of electricity in developing countries is low [16] and this has a negative impact on the productivity of manufacturing small and medium scale enterprises thus impairing the economic growth in such countries as well as lowering the economic power of the populace [17]. The production of tigernut milk is not a novel approach but the household consumption as well as small and medium scale enterprise has been impaired in areas where there is poor supply of electricity for refrigeration, hence, a feasible alternative to prevent spoilage of tigernut milk few days after production is a necessity and this may be achieved by boiling. However, there is need to assess the effect of this routine boiling sessions on the nutritional quality of the milk. This experimental study was therefore designed to determine how well boiling conserves the nutritional, physical, microbiological and sensory properties of tigernut milk few days after production.

2. Materials and Method

2.1. Collection of Tigernut

Fresh tigernut (at 41.23% moisture content) was purchased from Bodija market in Ibadan, Oyo State, Nigeria. This was cleaned manually to remove stones, damaged tigernut tubers and foreign seeds. This study was carried out in Ibadan, Nigeria.

2.2. Preparation of Tigernut Milk

Tigernut milk was prepared using method of Okyere and Odamtten, [18] with slight modification. A weighed quantity of fresh tigernut (500g) was washed and wet-milled by plate attrition mill with 1.4 liters of very clean water. This was sieved using a cheese cloth and bought to boil and allowed to boil for 10 minutes. A portion of the milk was taken and designated as TM0 as the control sample on the day of production. The remaining milk was allowed to cool in the pot and boiled for 5 minutes twice a day (morning and evening) subsequently for three days and samples were taken daily and designated as TM1, TM2 and TM3 respectively. The samples were subjected to the following analyses; proximate, physical properties (specific gravity, viscosity and pH), minerals, vitamins, microbial and sensory evaluation.

2.3. Moisture Content Determination

This was determined using the air oven method [19]. A known weight of the sample (3g) was put in a washed, dried and cooled crucible and this was dried at 103^{o}C until a constant weight was obtained. This was allowed to cool in a desiccator and the difference in weight was used to calculate the moisture content.

2.4. Protein Content Determination

The crude protein content was determined using the micro Kjeldahl method as described by Kirk and Sawyer, [19]. A tablet of Kjeldahl catalyst was added to a known weight of the sample (0.2077g) in a long necked Kjedahl flask. This was heated in a fume cupboard with 25cm^3 of concentrated H_2SO_4 until a clear solution was obtained. This was cooled, poured into a 10cm^3 volumetric flask and made up to mark with distilled water after which 10ml of this was measured into a distillation set. A measure (5cm^3) of boric acid was pipetted into a 100ml conical flask and placed at the receiving end of the distillation unit with the delivery tube completely dipped into the flask. Sodium hydroxide (40%) was used to liberate ammonia out of the digest into the boric acid under alkaline condition and this was titrated against 0.1N HCl. Blank sample was run through the procedure and the titre value was used to correct the titre value for the test samples. The protein content was calculated thus:

$$\%N = \frac{\left[\begin{array}{l} Molarity\ of\ HCl\ x\left(sample\ titre - blank\ titre\right) \\ x0.014\ x\ DF\ x100 \end{array}\right]}{Weight\ of\ sample}$$

%N was converted to the percentage crude protein by multiplying with 6.25
DF-Dilution Factor

2.5. Crude Fat Content Determination

The fat content was determined using Soxhlets extraction method as described by Kirk and Sawyer, [19]. A known weight of the sample (2g) was put into a weighed filter paper and folded neatly. This was put inside

a pre-weighed thimble (W_1). The thimble with the sample (W_2) was inserted into the soxhlets apparatus and extraction was carried out under reflux with petroleum ether (40°C – 60°C boiling range) or 6 hours. At the end of the extraction, the thimble was dried in the oven for about 30 minutes at 100°C to evaporate the solvent and thimble was cooled in a desiccator and later weighed (W_3). Crude fat content of the sample was calculated thus:

$$\% \, Fat = \frac{Loss \ in \ weight \ of \ sample}{Original \ weight \ of \ the \ sample} x100$$

$$= \frac{W_2 - W_3}{W_2 - W_1} x100$$

2.6. Ash Content Determination

The ash content denotes the total amount of minerals present in the products. This was determined using the method as described by Kirk and Sawyer, [19]. A known weight (1.5g) of finely ground sample was weighed into clean and dry previously weighed crucible with lid (W_1). The sample was ignited over a low flame to char the organic matter with lid removed. The crucible was then placed in muffle furnace at 600°C for 6 hours until it was turned to ash completely. This was then transferred directly to desiccators to cool and was later weighed (W_2).

$$\% \, Ash = \frac{W2 - W1}{Weight \ of \ sample} x100$$

2.7. Crude Fiber Determination

The crude fiber was determined using the method as described by Kirk and Sawyer, [19]. Two hundred milliliters (200ml) of freshly prepared 1.25%H2SO4 was added to a known weight (3g) of the residue obtained from fat extraction and this was boiled for 30 minutes and then filtered after which the residue was washed until it was free from acid. The residue was transferred quantitatively into a digestion flask and 1.25%NaOH was added after which this was boiled for 30 minutes. This was followed by filtration and the residue was then washed with methylated spirit and then petroleum ether to be free of alkali. This was then allowed to drain and the residue was transferred to a silica dish (previously ignited at 600°C and cooled). The dish and its content were dried to constant weight at 105°C. The organic matter of the residue was burnt by igniting for 30 minutes in a muffle furnace at 600°C). The residue was cooled and weighed while the loss on ignition was reported as crude fiber.

2.8. Carbohydrate Content Determination

This was calculated by difference of all other nutrients from 100 [19].

2.9. pH Determination

pH of the samples was measured directly using a pH meter (Cole-Parmer), U.S.A.

2.10. Specific Gravity Determination

The specific gravity was determined using Avogadro's Specific Gravity determination bottle, New Jersey, U.S.A.

2.11. Viscosity Determination

The viscosity of the samples was determined using Ostwald viscometer, Germany.

2.12. Thiamine, Riboflavin and Niacin Determination

These B vitamins content were determined using the method as described by Kirk and Sawyer, [19].

2.13. Thiamine Determination

Method as described by Kirk and Sawyer, [19] was used. Fifty milliliters (50ml) of 50% methanol and 50ml 0f 17% sodium carbonate was added to 1g of the sample in order to extract the vitamin. This was then filtered after which Folins-Denis reagent was added. This was allowed to cool until a bluish color was developed and absorbance was read in a spectrophotometer at 415nm. A standard curve was prepared using the data obtained with Tannic acid in place of the sample and the values for the sample were extrapolated from this curve.

2.14. Riboflavin Determination

The method as described by Kirk and Sawyer, [19] was used. To 0.5g of the sample 30ml of Dichloroethane and 30ml of 30% HCl were added. This was followed by the addition of 50ml of ammonium hydroxide solution after which filtration was carried out and later the absorbance was read at 415nm. A standard curve was constructed using the data obtained from the use of standard Riboflavin in place of the sample and the curve was used to extrapolate the values for the samples.

2.15. Niacin Determination

Method as described by Kirk and Sawyer, [19] was used. Niacin was extracted by autoclaving the sample (1g) with 0.75g calcium hydroxide and 20ml deionised water at 121°C for 30 minutes. The mixture was diluted with 30 ml of water, mixed thoroughly and allowed to cool after which it was centrifuged at 0°C and 2500 rpm for 15 minutes. A 15ml sample of the supernatant was adjusted to pH 7 with aqueous oxalic acid. The resulting suspension was centrifuged at 2500 rpm for 10 minutes to precipitate the calcium oxalate and the absorbance was measured at 650nm. A standard curve was constructed using the absorbance readings obtained from the reference niacin solutions in place of the sample and this was used to extrapolate the niacin content of the samples.

2.16. Vitamin C Determination

The method as described by Kirk and Sawyer, [19] was used. About 5g of the sample was weighed into a 50ml

volumetric flask and this was made up to the mark with distilled water after which it was filtered. A measure of the filtrate (10ml) was measured into a conical flask containing one drop of dilute acetic acid. This was then titrated against redox dye, 2:6 dichlorophenol indophenol solution in a burette. The volume of dye required to decolorize 10ml of the sample was noted. The titration was repeated using a standard ascorbic acid solution (1mg pure vitamin C per 100ml) in place of the sample.

2.17. Minerals Determination

The method as described by Kirk and Sawyer, [19] was used. A small quantity of the sample (0.2g) was weighed into a clean crucible and the organic content was burnt off in an open flame after which it was transferred into a muffle furnace and allowed to ash for 6 hours at 600^{o}C until the ash turned to white completely. This was then washed with 10ml 0.1N HCl into a 100ml volumetric flask and warmed on a heater for a few seconds to avoid frothing. This was filtered into another 100ml volumetric flask and distilled water was added to the filtrate to make it up to 100ml. This was then aspirated through the nebulizer into the air-acetylene flame where atomization took place. Using specific source of lamp (of an Atomic Absorption Spectrophotometer) for each element or mineral (e.g. calcium lamp for calcium assay) the amount of energy absorbed in the flame was proportional to the concentration of the mineral in the sample over a limited concentration range.

2.18. Microbial Analyses Using Pour Plate Method

The method of Harrigan and McCance, [20] was used. One (l) ml of the sample was aseptically dispensed into a sterile petri dish using a sterile pipette. A measured quantity (15 - 20ml) of sterile nutrient agar was added and the two mixed thoroughly by swirling gently. The dish was then incubated at 37°C for 18-24hours. For total viable count, the number of colonies growing in the agar plate was then counted.

For Coliform, MacConkey Agar was used.

For Anaerobes, MRS Agar (MRS = de Manns Rogosa and Sharpe) was used.

For Fungi, Potato Dextrose Agar was used.

For Aerobes, Nutrient Agar was used.

2.19. Sensory Evaluation

Mayonnaise samples were subjected to sensory evaluation with a total of 20 trained taste panelists using a 9 point hedonic scale with 1 denoting ‘dislike extremely’ and 9 denoting ‘like extremely’. The following sensory properties were evaluated: color, taste, mouth feel, aroma and overall acceptability [21].

2.20. Statistical Analysis

Data were analyzed with Statistical Package for the Social Science version 23.0 while mean data were compared using analysis of variance at $p \leq 0.05$

3. Result

Table 1 expresses the proximate composition of the tigernut milk samples. TM0 contains highest quantity of moisture while TM3 contains the least.

The protein, fat ash, crude fiber and carbohydrate content of the tigernut milk samples increased with increase in period of storage (Table 1).

Table 1. Proximate composition (%) of the tigernut milk samples

Samples	Moisture	Protein	Fat	Ash	Crude fiber	Carbohydrate
TM0	84.43±0.21	3.63±0.15	4.67±0.13	1.43±0.15	0.30±0.10	5.53±0.70
TM1	81.67*±0.23	3.90±0.10	4.77±0.15	1.53±0.20	0.33±0.06	7.80**±0.27
TM2	79.07*±0.21	4.17**±0.20	5.13**±0.15	1.63±0.16	0.40±0.10	9.60**±0.62
TM3	75.40*±0.20	4.97**±0.15	5.37**±0.17	1.93**±0.17	0.53**±0.06	11.76**±0.23

*-- significantly lower than the control at p<0.05 (data in same column)
**--significantly higher than the control at p<0.05 (data in same column)
TM0: Freshly produced tigernut milk sample (control)
TM1: Tigernut milk sample 1 day after production
TM2: Tigernut milk sample 2 days after production
TM3: Tigernut milk sample 3 days after production

The physical properties of the tigernut milk samples are expressed in Table 2.

Table 2. Physical properties of the tigernut milk samples

Samples	Specific gravity	Viscosity (Centistokes)	pH
TM0 (control)	1.2131±0.0003	284.20±0.60	6.23±0.05
TM1	1.2150**±0.0006	285.27**±0.31	6.60**±0.04
TM2	1.2170**±0.0005	290.57**±0.35	6.50**±0.03
TM3	1.2192**±0.0006	325.43**±0.15	6.30**±0.01

**--significantly higher than the control at p<0.05 (data in same column)
TM0: Freshly produced tigernut milk sample (control)
TM1:Tigernut milk sample 1 day after production
TM2: Tigernut milk sample 2 days after production
TM3: Tigernut milk sample 3 days after production

Table 3 shows the mineral composition of the tigernut milk samples.

Table 3. Mineral composition of the tigernut milk samples

Samples	Calcium	Magnesium	Potassium	Sodium	Phosphate	Zinc	Manganese
TM0	206.67±2.89	95.00±5.00	101.67±2.88	413.33±7.64	186.67±7.64	0.53±0.06	0.05±0.01
TM1	216.67±7.64	105.00**±5.00	110.00±5.00	421.67±2.89	190.00±5.00	0.60±0.10	0.06±0.01
TM2	226.67**±7.64	110.00**±5.03	120.00**±5.23	430.00**±5.00	195.00±5.23	0.83**±0.06	0.07**±0.02
TM3	264.33**±2.08	130.00**±5.63	165.00**±5.45	470.00**±5.43	203.33**±2.87	1.10**±0.10	0.08**±0.03

**--significantly higher than the control at p<0.05 (data in same column)
TM0: Freshly produced tigernut milk sample (control)
TM1: Tigernut milk sample 1 day after production
TM2: Tigernut milk sample 2 days after production
TM3: Tigernut milk sample 3 days after production.

Tigernut milk is exceptional high in calcium, sodium and phosphate but very low in zinc and manganese (Table 3). The vitamin composition of the tigernut milk samples are expressed in Table 4.

Table 4. Vitamin composition (in mg/100g) of the tigernut milk samples

Samples	Thiamine	Riboflavin	Niacin	Vitamin C
TM0	0.25±0.02	0.23±0.02	0.63±0.02	3.10±0.10
TM1	0.26±0.04	0.24±0.03	0.66±0.01	3.30±0.12
TM2	0.29**±0.03	0.26±0.01	0.76**±0.02	3.50**±0.14
TM3	0.32**±0.02	0.30**±0.01	0.93**±0.03	3.97**±0.15

**--significantly higher than the control at p<0.05 (data in same column).
TM0: Freshly produced tigernut milk sample (control).
TM1:Tigernut milk sample 1 day after production
TM2: Tigernut milk sample 2 days after production
TM3: Tigernut milk sample 3 days after production.

Table 5 shows the microbial load (CFU/ml) of the tigernut milk samples.

Table 5.

Samples	Total viable count	Total coliform count	Total fungal count
TM0	4.1×10^4	Nil	2.5×10^4
TM1	5.8×10^4**	Nil	5.1×10^4**
TM2	7.8×10^4**	Nil	5.9×10^4**
TM3	9.5×10^4**	Nil	7.4×10^4**

**--significantly higher than the control at p<0.05 (data in same column).
TM0: Freshly produced tigernut milk sample (control).
TM1:Tigernut milk sample 1 day after production
TM2: Tigernut milk sample 2 days after production
TM3: Tigernut milk sample 3 days after production.

The total viable count and total fungal count increased with increased in period of storage while the tigernut milk samples were completely void of coliform.

Table 6 shows the result of the sensory evaluation of the sensory properties of the tigernut milk samples

Table 6. Scores of the sensory properties of the tigernut milk samples

Samples	Color	Taste	Mouth feel	Favor/aroma	Ov Accept
TM0	7.93a±0.47	8.43a±0.55	8.40a±0.36	8.17ab±0.25	8.17a±0.25
TM1	7.93a±0.35	8.33a±0.67	8.10a±0.26	8.67a±0.15	8.27a±0.21
TM2	7.47a±0.25	8.37a±0.75	8.30a±0.56	8.10b±0.30	7.27b±0.67
TM3	7.57a±0.35	8.37a±0.51	6.47b±0.25	8.00b±0.36	6.23c±0.15

Mean data in same column with different alphabet are significantly different (p<0.05)
TM0: Freshly produced tigernut milk sample (control).
TM1:Tigernut milk sample 1 day after production
TM2: Tigernut milk sample 2 days after production
TM3: Tigernut milk sample 3 days after production.

4. Discussion

As expected the moisture content of the tigernut samples significantly reduced with increase in period of storage (Table 1). This may be as a result of loss of moisture during the boiling sessions which was carried out twice daily in the course of ambient temperature storage. The moisture content ranged from 75.40% in TM3 to 84.43% in TM0 (control). These values are in disparity with that reported by Eke-Ejiofor and Beleya, [22] who observed moisture content of 91.10 to 95.45% in fresh spiced tigernut milk but almost in agreement with that of roasted spiced tigernut milk samples which ranged from 74.57% to 82.42%. The difference in moisture content may be attributed to variation in tigernut milk preparation method as well as in moisture content of fresh tigernut used. However, the protein content tigernut milk samples observed in this study is markedly higher than that reported by Eke-Ejiofor and Beleya, [22] who observed a protein content range of 0.25% to 1.28% in fresh spiced tigernut milk drinks (using different spices). This disparity in protein content could be as a result of different varieties of tigernut used as well as well as preparation method engaged. Aside from the moisture content all other proximate composition of the tigernut milk samples increased with increase in period of storage (Table 1). This may be attributable to the loss of moisture content which concentrated the imitation milk samples thus increasing the total solid. In like fashion the fat and ash contents of tigernut milk observed in this study was notably higher than the observation of Eke-Ejiofor and Beleya, [22]. While the ash and fat in this study were 1.43 and 4.67% respectively, they reported the highest ash and fat content of 0.34 and 0.92% respectively. On the other hand the highest carbohydrate content of fresh spiced tigernut milk as observed by Eke-Ejiofor and Beleya, [22] is 11.50% while in this study the value observed was 5.53%. This disparity could be as a result of different varieties of tigernut used. The proximate composition of tigernut milk observed in this study is also in contrast with that reported by Adebayo-Oyetoro et al., [23] who observed (in %) moisture, protein, fat, ash, crude fiber and carbohydrate content of 92.90, 2.11, 2.54, 0.28, 0.12 and 2.07 respectively.

TM0 which is the control sample had the least specific gravity (1.213), viscosity (284.20 Centistokes) and pH (6.23) (Table 2) while the specific gravity and viscosity increased significantly with increase in period of ambient temperature storage. This could be as a result of the significant reduction in moisture content (Table 1) as a result of loss of moisture during the boiling process. On the other hand the pH increased significantly to 6.60 in TM1 and reduced in similar fashion till the 3rd day (Table 2). These changes in pH may be due to the microbial action which was inevitable at the ambient temperature at which the storage was maintained.

The mineral composition of the tigernut milk samples also increased with increase in period of storage (Table 3). For magnesium this increase was significant throughout the experimentation period while it was significant only at the last two days for calcium, potassium, sodium, zinc and manganese but was significant at the last day for phosphate (Table 3). This increasing trend in mineral composition could also be attributed to the concentration of the imitation milk samples as a result of loss of moisture during the boiling sessions in the course of the ambient temperature storage thus depicting that boiling of tigernut milk twice daily did not adversely affect the mineral composition of the milk. Freshly prepared tigernut milk in this study contained (in mg/100g) 206.67 calcium, 95.00 magnesium, 101.67 potassium, 413.83 sodium, 186.67 phosphates, 0.53 zinc and 0.05 manganese. These values are markedly higher (except for potassium) than that of the observation of Adebayo-Oyetoro et al., [23] who reported the magnesium, potassium, phosphorous, sodium and calcium content (in mg/100g) of tigernut milk as 49.68, 221.44, 131.50, 224.14 and 140.34 respectively. The disparity in these observations could be as a result of differences in the varieties of the tigernut used as well as variation in agricultural practices engaged during cultivation of the tuber crop (that is tigernut).

The vitamin content also increased with increase in period of storage (Table 4). Thiamine, riboflavin, niacin and vitamin C content (in mg/100g) increased from 0.25, 0.23, 0.63 and 3.10 respectively in TM0 to 0.32, 0.30, 0.93 and 3.97 respectively in TM3 (Table 4). This increase was significant in the last 2 days for thiamine, niacin and vitamin C while for riboflavin it was significant only on the last day (Table 4).

Table 5 shows the microbial load of the tigernut milk samples. The total viable count on the day of production was 4.1×10^4 CFU/ml and this increased to 9.5×10^4CFU/ml on the third day. This is still lesser than 1.5×10^5 CFU/ml which is the threshold for microbial load that poses a public health concern and can no longer be consumed [24], hence, the samples were still safe for consumption first, second and third days after production. The samples were completely free of coliforms depicting a satisfactory hygienic handling in the production process. In the same vein, the total fungal count in TM0 was 2.5×10^4 CFU/ml and this increased to 7.4×10^4 CFU/ml in TM3. This denotes satisfactory microbial load since it is less than 10^5 the threshold at which a food product or meal is no longer safe for consumption [24]. The total viable count observed in this study is in contrast with that of Ukwuru et al., [25] who reported a total viable count of 6.7×10^2 CFU/ml in tigernut milk. This disparity may be as a result of differences in the preparation method employed since they used dried tigernut tubers while in this study fresh tubers of tigernut was used to produce the imitation milk. On the other hand the microbial status or load observed in this study is comparable with that reported by da Costa Neto et al., [26] who observed a total viable count and fungal count of $<10^5$CFU/ml showing good microbial stability of the two tigernut milk samples.

Table 6 shows the scores of the sensory properties of the tigernut milk samples. The scores for color ranged from 7.47 to 7.93 which falls within an acceptable range (‘like moderately’) and there existed no significant difference among all the samples showing that the boiling sessions for the three days after production did not adversely alter the color perception of the tigernut milk samples, hence, the color was preserved. The situation was similar in the scores for taste though these were of higher values, 8.37 to 8.43, which was well acceptable (‘like very much’)- Table 6. The mouth feel property which depicts the texture of the tigernut milk samples the

scores for TM0, TM1 and TM2 were 8.40, 8.10 and 8.30 respectively also depicting a well acceptable food beverage which was liked very much. However there was a significant reduction in this scores to 6.47 in TM3 (Table 6) showing reduction in acceptability since this was 'liked slightly', hence, the mouth feel property of the tigernut milk samples was preserved by the boiling sessions only till the second day after production but was adversely altered on the last day. The scores for aroma ranged from 8.00 to 8.67 which also depicts 'liked very much'. This shows that the flavor of the tigernut milk samples was preserved throughout the experimentation period; hence, this property was not adversely affected by the boiling sessions. For the overall acceptability the scores for TM0, TM1, TM2 and TM3 were 8.17, 8.27, 7.27 and 6.23 respectively (Table 6). The scores for TM0 and TM1 were not significantly different and were 'liked very much' while at the second day of production (TM2) the value significantly reduced to 7.27 which depicts 'like moderately' which still falls within an acceptable range. On the other hand on the last day of experimentation the score for overall acceptability reduced significantly to 6.23 denoting 'like slightly' which is still acceptable. This shows that even though the scores for overall acceptability of the tigernut samples reduced significantly in the last two days of experimentation, the scores still fell within the acceptable range for likeness. Tigernut milk samples prepared in this study is more acceptable and liked than that produced by Ukwuru et al., [25] in taste, mouth feel, aroma or flavor and overall acceptability because it had higher scores in these sensory parameters. This could be as a result of variation in the processing methods. In the same vein the sensory scores for the tigernut milk samples observed in this study were markedly higher than the observation of Eke-Ejiofor and Beleya [22] who reported scores for aroma, color, flavor, sweetness, taste and overall acceptability of spiced fresh tigernut milk as 5.30, 5.70, 5.45, 5.40, 5.55 and 5.55 respectively. This difference in sensory scores could be attributable to the variation in tigernut milk preparation method since they did not subject the imitation milk to boiling and included spices. Furthermore, the dilution ratio of the tigernut paste could be a contributory factor.

5. Conclusion

The health of the nation is a key determinant of the productive sector of the nation. This is true of the rural sector. This study reveals the health value of tigernut milk to human health and that heat treatment by boiling indeed conserved the nutritional, physical, microbial and sensory qualities of tigernut milk for three days after production. Household and commercial production and consumption of tigernut milk is hereby recommended even in places where inadequate power supply does not make cold storage by refrigeration feasible.

References

[1] Ross M.A. and Lembi C.A. (2008). Applied weed science (3rd Edn). Prentice Hall, United States of America p 322.

[2] Gambo A. and Da'u A. (2014). Tigernut (*Cyperus esculentus*): composition, products, uses and health benefits: A review. *Bayero Journal of Pure and Applied Sciences*, 7(1): 56-61.

[3] Santos F., Freitas K., Costa Neto J., Fontes-Sant Ana G., Rocha-Leao M.H. and Amaran P. (2018). Tigernut (*Cyperus esculentus*) milk by product and corn steep liquor for biosurfactant production by *Yarrowia lipolytica*. *Chemical Engineering Transactions*, 65: 331-336.

[4] Mohdaly, A.A.R.A.A. (2019). Tigernut (Cyperus esculentus L.) oil . In M. Ramadan (Ed.), Fruit Oils: Chemistry and Functionality. Springer, Cham, Switzerland.

[5] Rubert J., Monfort A., Hurkova K., Perez-Martinez G., Blesa J., Navarro J.L., Stranka M., Soriano J.M. and Hajslova J.(2017). Untargeted metabolomics of fresh and heat treatment Tigernut (Cyperus esculentus L.) milks reveals further insight into food quality and nutrition. *Journal of Chromatography*, 1514: 80-87.

[6] Aguilar N., Albanell E., Minarro B. and Capellas M. (2015). Chickpea and tigernut flours as alternatives to emulsifier and shortening in gluten-free bread. *LWT-Food Science and Technology*, 62(1): 225-232.

[7] Awolu O.O., Omoba O.S., Olawoye O. and Dairo M. (2017). Optimization of production and quality evaluation of maize-based snack supplemented with soybean and tigernut (*Cyperus esculenta*) flour. *Food Science and Nutrition*, 5(1): 3-13.

[8] Wongnaa C.A., Adama F., Bannor R.K., Awunyo-Vitor D., Mahama I., Osei B.A., Owusu-Ansah Y. and Ackon A. (2019). Job creation and improved consumer health through commercialization of tigernut yoghurt: a willingness to pay analysis. *Journal of Global Entrepreneurship Research*; 9(4).

[9] Olabiyi A.A., Oboh G. and Adefegha S.A. (2016). Effect of dietary supplementation of tigernut (Cyperus esculentus L.) and walnut (*Tetracarpidium conophorum* mull. Arg) on sexual behavior, hormonal level and antioxidant status in male rats. *Journal of Food Biochemistry*, 41(3).

[10] Ibitoye O.B., Aliyu N.O. and Ajiboye T.O. (2018). Tigernut oil-based diet improves the lipid profile and anti oxidant status of male Wistar rats. *Journal of Food Biochemistry*, 42(5).

[11] Ogunlade I., Adeyemi B.A. and Aluko O.G. (2015). Chemical compositions, antioxidant capacity of Tigernut (*Cyperus esculentus*) and potential health benefits. *European Scientific Journal* (November 2015 special edition): 217-224.

[12] Adejuyitan J.A. (2011). Tigernut processing: Its food uses and health benefits. *American Journal of Food Technology*, 6: 197-201.

[13] Bamishaye E.I. and Bamishaye O.M. (2011). Tigernut as a plant, its derivative and benefits. *African Journal of Food, Agriculture, Nutrition and Development*, 11(5): 5257-5170.

[14] Jagpal C. (2017). . P29 The in vitro use of natural antioxidant oils (*Cyperus esculentus*, *Nigella sativa*) to reduce cell sickling in sickle cell anemia. *Biochemical Pharmacology*, 139(1): 134-140.

[15] Kanagawa M. and Nakata T. (2008). Assessment of access to electricity and the socio-economic impacts in rural areas of developing countries. *Energy Policy*, 36(6): 2016-2029.

[16] Winkler H., Simoes A.F., Lebre la Rovere E., Alam M., Rahman A. and Mwakasouda S. (2011). Access and affordability of electricity in developing countries. *World Development*, 39(6): 1037-1050.

[17] Scott A., Darko E.M. and Rud J.P. (2014). How does electricity insecurity affect businesses in low and middle income countries. In: L. Alberto and Rud J.P (Eds.), Shaping policy for development. Overseas Development Institute Report 2014, United Kingdom.

[18] Okyere A.A. and Odamtten G.T. (2014). Physico-chemical, functional and sensory attributes of milk prepared from irradiated tigernut (*Cyperus esculentus* L.). *Journal of Radiation Research and Applied Sciences*, 7(4): 583-588.

[19] Kirk R.S and Sawyer R. (2005). Pearson's Composition and Analyses of Foods, 9th edition, Longman, United Kingdom.

[20] Harrigan W.F and McCance M.E. (1976). Laboratory methods in food and dairy microbiology, Academic Press, London.

[21] Walfe K.A. (1979). Use of reference standards for sensory evaluation of product quality. *Food and Agriculture Organization of the United Nations*. Retrieved from www.agris.fao.org.

[22] Eke-Ejiofor J. and Beleya E.A. (2018). Chemical and sensory properties of spiced tigernut (*Cyperus esculentus*) drink. *International Journal of Biotechnology and Food Science*, 6(3): 52-58.

[23] Adebayo-Oyetoro A.O., Ogundipe O.O., Adeyeye S.A.O., Akande E.A. and Akinyele A.B. (2019). Production and evaluation of tigernut (*Cyperus esculentus*) milk flavoured with Moringa oleifera leaf extract. *Current Research in Nutrition and Food Science*.

[24] Chua S., Ng M., Craig D., Liu X., Chen S. and Ho P. (2014). Microbiological guidelines for food. Centre for Food Safety, Hong Kong.

[25] Ukwuru M.U., Ibeneme L.L. and Agbo G.I. (2011). New product development from tigernut (*Cyperus esculentus*) and their sensory, proximate and microbiological evaluation. *Pakistan Journal of Nutrition*, 10(2): 101-105.

[26] da Costa Neto J.J.G., Gomes T.L.M., Justo T.F., Pereira K.S., and Amaral P.F.F., Rocha Leao M.H.M. and Fontes Sant'Ana G.C. (2019). Microencapsulation of tigernut milk by lyophilization: Morphological characteristics, shelf life and microbiological stability. *Food Chemistry*, 284: 133-139.