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EVALUATION OF QUALITY AND SHELF-STABILITY OF YOGHURT-LIKE PRODUCTS FROM OSMO-CONCENTRATED TIGERNUT (*Cyperus esculentus*) MILK

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ABSTRACT

The quality assurance, safety and shelf-stability of processed foods are crucial questions to food nutrition and security of consumers. The objective of this study was to evaluate the quality, storage stability and predict the shelf-life of tigernut milk yoghurt-like products with storage at 5°C. The methodology was based on the analysis of the effects of storage time, osmotic concentration of Single Strength Tigernut Milk (SSTM), supplementation of fructose and Non-Fat Dry Milk (NFDM) on physicochemical, microbiological, sensory and shelf-life of Tigernut Milk Yoghurts during storage on 0, 7, 14 and 21 days. Results were analyzed with SPSS 24 commands for descriptive analyses, One-Way ANOVA and Post Hoc Tests. Pure starter cultures (*Streptococcus thermophilus* and *Lactobacillus bulgaricus*) and five tigernut milk-based premixes from Osmo-concentrated Tigernut Milk (OCTM) and SSTM were produced. Total solids (TS), lactic acid and viscosity values of initial yoghurts increased ($p<0.05$) with osmotic concentration and increasing levels of fructose supplementation, and then the values and pH decreased as storage time was prolonged. The initial moisture values of all yoghurts increased significantly ($p<0.05$) on 21 days storage. After 14 days of storage *Streptococcus thermophilus* and *Lactobacillus bulgaricus* counts increased on 7 and 14 days after storage and then declined 21 days in all yoghurts. The SSTM + NFDM had the highest growth of lactic acid bacteria (LAB) while OCTM + 0% fructose had the lowest growth on 14 days storage. Yeasts and molds were absent at the beginning and end of storage of tigernut milk yoghurt-like products. Osmotic concentration and increasing levels of fructose supplementation significantly ($p<0.05$) increased appearance, mouthfeel, flavor and acceptability scores for OCTM + 0% fructose, OCTM + 0.2% fructose, and OCTM + 0.4% fructose. The SSTM + NDFM and OCTM + 0.6% fructose yoghurts had the lowest scores in sensory properties. Also, the shelf-life values in OCTM yoghurts were significantly ($p<0.05$) higher than for SSTM + NFDM yoghurts. Hence, OCTM + 0.2% fructose had the highest average shelf-life value of 36.85 days followed by OCTM + 0.4% fructose (35.03 days) and OCTM + 0% fructose (32.70 days) while SSTM + NFDM yoghurt recorded the lowest average shelf-life value of 21.84 days. Results were confirmed to the standards for sanitary quality and safety for yoghurt that is healthy, shelf-stable and favorable for human consumption. The scaling-up of results could therefore improve quality nutrition and health security, and products competitiveness. Investigating the nutritional and health benefits of the tigernut milk yoghurts could be useful for fighting against food insecurity, malnutrition and micronutrients deficiencies in Niger.

Key words: Tigernut milk, osmotic concentration, *Streptococcus thermophilus, Lactobacillus bulgaricus*, yoghurt, quality, shelf-stability, Niger

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INTRODUCTION

Efforts have been made over the years to develop alternative milk-like products from vegetable sources [1, 2]. Researchers have shown interest in processing bigger and yellow tigernut variety into purely natural tigernut milk and its yoghurt-like products because of their economic, nutritional and health benefits [3, 4, 5] and to enhance utilization and processing of available tubers in producing countries like Niger Republic and Nigeria. Yoghurt is a fermented milk product by *Streptococcus thermophilus* and *Lactobacillus bulgaricus* [6, 7, 8]. It is a perishable drink and hardly lasts for 48 hours if not refrigerated due to its nutritive quality which aids the growth of microorganisms [9, 10]. Food products usually undergo spoilage and deterioration during storage as a result of growth and activities of microorganisms, and food enzymes; chemical reactions within the food; infestation by pests; effect of storage temperatures, moisture, pH, oxygen, light and physical stress or abuse [11]. Undesirable microbes that can cause spoilage of dairy products include Gram-negative psychrotrophs, coliforms, LAB, yeasts, and molds [6]. The shelf-life of a food product depends on the processing method, packaging and storage conditions [12]. In many cases shelf-life is taken as the time within which a product remains stable. Methods of prediction are particularly useful for new food products which do not have a history of distribution [11]. The deterioration in sensory quality as well as microbiological counts have been used as indices for the end of shelf-life of dairy products and the alternative methods to achieve texture and flavor improvements of yoghurts have been of interest in recent years [13]. Milk is concentrated to increase the total and non-fat milk solids for yoghurt manufacture by various water removal technologies, such as use of fortifiers, osmotic concentration, reverse osmosis, evaporation, freeze concentration and osmotic dehydration [14, 15]. The use of traditional yoghurt fortifiers such as NFDM, Whey Protein Concentrate (WPC) and Evaporated Milks (EM) to increase the TS of milk for yoghurt manufacture were reported by previous researchers [16, 17]. These traditional fortifiers are very expensive and unavailable especially in developing countries [15, 17]. Therefore, osmotic concentration of tigernut milk may serve the dual purpose of improving the flavor and increasing the TS content of the tigernut yoghurt prior to lactic acid fermentation by *Streptococcus thermophilus* and *Lactobacillus bulgaricus*.

The compositional, chemical and sensory aspects of tigernut milk and yoghurt-composites using milk of animal origin were studied by earlier workers [2, 5, 18]. The quality assurance, safety and shelf-stability of foods is a crucial question to food nutrition, health and security of consumers. Foods even of excellent nutritional quality, may be harmful to health if their qualities did not meet the sanitary safety standards [19]. Information is scanty on the use of osmotic concentration technique for the development of OCTM and its yoghurts and the accompanying changes that might affect physicochemical and microbial properties, sensory characteristics and the prediction of shelf-life of tigernut yoghurt-like products during storage. Therefore, the aim of this study is to evaluate the quality, storage stability and predict the shelf-life of tigernut milk yoghurt-like products with storage at 5°C.

MATERIALS AND METHODS

Materials

The vegetative materials were composed of matured dried yellow tigernut. Fifteen kilograms were purchased from Maradi central market, Maradi region, Niger Republic. They were properly manually sorted and cleaned to remove infected nuts and other debris. The cleaned samples were then used for the production of SSTM, OCTM, pure starter cultures and yoghurt-like products in the laboratories of the Department of Food Science and Technology, University of Agriculture, Makurdi, Nigeria.

Methods

Production of SSTM

Tigernut milk was produced using the method described by earlier researchers [15]. One kilogram of sorted and cleaned tigernut was washed with distilled water and soaked for 6-8 hours in 3 liters distilled water set at 60°C to soften the fiber and to inactivate the enzymes. The soaked tigernuts were then washed with several aliquots of distilled water and drained using plastic baskets. The cleaned tigernuts were blended several times into a smooth slurry with a blender (Kenwood Major, Model KM230, Kenwood Ltd., Havant Hants, UK). The final mixture was macerated for 10 minutes. The slurry was filtered through two layers of cheesecloth and made up to 4 liters with distilled water (28°C). The resultant milk was dispensed into 1liter sterile bottles and pasteurized in a boiling water bath at 60°C for 30 minutes. The SSTM cooled under the fan was used for the purification and production of pure starter cultures, OCTM and for the formulation of SSTM+5% NFDM yoghurt premixes.

Isolation of lactic acid bacteria

Strains of yoghurt bacteria composed of *Streptococcus thermophilus* and *Lactobacillus Bulgaricus* were isolated from a commercial yoghurt (Nassara Yoghurt, Shehu Nassara Enterprise, Nigeria). Spread plate technique was used on M17 for *Streptococcus thermophilus* [20] and MRS medium for *Lactobacillus bulgaricus* [21]. The suspension was spread over the surface of the medium with a sterilized spreading glass rod. The plates were incubated anaerobically for 48 hours at 42°C in a carbon dioxide incubator. The yellow and white colonies were confirmed to be *Streptococcus thermophilus* and *Lactobacillus bulgaricus* respectively by series of biochemical and cultural tests [22]. Typical colonies were sub-cultured in the differential medium to obtain pure cultures of each organism.

Production of OCTM

The method used was described by previous worker [23]. One liter of SSTM was measured into each of four layered and sterilized (121.1^{o}C, 15 min.) cheese cloth bags. The bags were tied up and placed in a stainless-steel vat containing 80% sugar solution for 2 hours. This permitted rapid movement of water out of the SSTM, and the resultant was the OCTM used for the formulation of tigernut milk yoghurt premixes.

Production of Pure Starter Cultures

Isolates from the pure cultures obtained were grown in sterilized SSTM plus yeast extract and glucose (SSTMYG) [24]. The SSTMYG was prepared with 3g yeast and 10g glucose added to 1 liter of SSTM and enumeration was by standard plate count on nutrient agar plates [25]. A 10 ml of SSTMYG was transferred into petri dishes and M17 and MRS agar media were added on pour plates respectively for *Streptococcus thermophilus* and *Lactobacillus bulgaricus* cultures. Each culture was subsequently diluted to give approximately 10^6 cells/ g and the two cultures were combined to give a 1:1 ratio of *Streptococcus thermophilus* and *Lactobacillus bulgaricus* bacteria. The mixed starter culture was kept under refrigeration (2±1^{o}C) until required for inoculation and fermentation of pasteurized tigernut milk products.

Production of Tigernut milk Yoghurt Premixes

Five (5) tigernut milk-based yoghurt premixes consisting of OCTM plus 0% fructose, OCTM plus 0.2% fructose, OCTM plus 0.4% fructose, OCTM plus 0.6% fructose and SSTM plus 5% NFDM (control) were formulated. The premixes also contained 0.1% yeast extract and 0.5% gelatin stabilizer. They were blended for 3 min. in a Kenwood blender, heated for 30 min. at 90^{o}C in separate plastic containers, cooled in an ice bath to 30^{o}C, inoculated with 1% of the starters (*Streptococcus thermophilus* and *Lactobacillus bulgaricus*) and incubated for fermentation for 16 hours at 37^{o}C.

Storage Studies

Each of the five formulated tigernut milk yoghurt-like products was transferred into 500ml plastic containers (sterilized 121.1^{o}C, 15 min.) with airtight lids and stored at 5^{o}C for 3 weeks. Storage stability was assessed using aliquots samples of tigernut milk yoghurt-like products at 0-, 7-, 14- and 21-days storage. The variables for storage stability of the yoghurts were total solids, moisture, viscosity, titratable acidity and appearance, mouthfeel, flavor and acceptability.

Analyses
All analyses were carried out in triplicates on the stored tigernut milk yoghurt samples.

Physicochemical Properties
TS, moisture of the resultant tigernut milk yoghurts were determined according to the method described by previous researchers [26]. Viscosity was determined by the method of Beuchat [27]. Total titratable acidity (TTA) was determined according to the method used by earlier workers [28]. The pH of samples was determined by the method of Akpapunam and Sefa-Dedeh [29].

Microbiological Properties

Lactic Acid Bacteria Counts
Lactobacillus bulgaricus were enumerated using MRS medium, and plates were incubated at 37°C for 48 h under anaerobic conditions [21].

Streptococcus thermophilus were enumerated using M17 agar, and plates were incubated at 37°C for 48 h under aerobic conditions [20].

Yeasts and Molds Counts
Yeast and mold counts were made using the method of [30]. Mold counts were made on Oxytetracycline + chloramphenicol potato dextrose agar (OCPDA). Yeast counts were made on OCPDA containing 0.25% sodium propionate. Plates were incubated at 37°C for 48 h. Yeasts and molds are among undesirable microorganisms' Gram-negative psychrotrophs, coliforms and LAB can cause spoilage of dairy products [6, 30].

Sensory Evaluation
The sensory evaluation was carried out using the method of Iwe [31]. A trained twenty-member panel, comprising of staff and students at Adamawa State University Mubi, Nigeria, who were also regular users of commercial yoghurts, was chosen to evaluate the products' sensory parameters (appearance, mouthfeel, flavor and acceptability). Each sensory attribute was rated on a 9-point Hedonic rating scale (1 = disliked extremely while 9 = liked extremely) [9]. Panelists evaluated all yoghurt samples at the storage period of 0, 7, 14 and 21 days.

Shelf-life predictions
The shelf-life of the yoghurt-like products was determined using a modification of the method of Gernah [12]. Predictive equations generated by simple linear regression analysis (Minitab 15, LLC, State College, Pennsylvania, USA) of results obtained for changes in pH and sensory evaluation (appearance, mouthfeel, flavor and acceptability) of the yoghurt-like products during storage for 0, 7, 14 and 21 days aided in determining the shelf-life of the products.

$$y = B_o + B_1x + e \quad (1)$$

Where:
y = the variable of primary interest (dependent variable)
B_o = the y intercept of the line
B_1 = the slope of the line
x = the predictor variable (independent variable)
e = observable error

Time (in days) was used as independent variable (x) while the other measured parameters were used as the dependent variables (y).

Statistical Analyses
Results were analyzed with SPSS 24 commands for descriptive analyses, One-Way ANOVA and Post Hoc Tests [9]. Least Significant Difference, Tamhane and Duncan Multiple Range Tests were used to compare and separate the means and the homogenous subsets. A probability of ($p<0.05$) was used to establish statistical significance.

RESULTS AND DISCUSSION

Effect of Storage Time, Osmotic Concentration and Fructose Levels of Supplementation on Physico-Chemical Properties of Tigernut Milk Yoghurts

Total Solids (TS)
TS values significantly ($p<0.05$) decreased with increase in storage time (Figure 1 (a)). TS values decreased from 15.96 to 14.17% in OCTM + fructose yoghurts; 14.58 to 13.88% in OCTM + 0% fructose; and 12.66 to 11.18% in SSTM + NFDM respectively on 0 and 21days storage. TS of OCTM yoghurts on 0 and 21days storage were significantly ($p<0.05$) higher than TS of SSTM + NFDM yoghurt was due to osmotic concentration, removal of water and increasing levels of fructose supplementation. Similar result was also reported by earlier researchers [15]. This is due to removal of water through osmotic concentration, the water holding capacity by fructose and increase in dry matter content. This is important as TS played significant roles in the storage stability and shelf-life of yoghurts. The firmness of yoghurt was highly dependent on the TS content and the increase of the solids content improves the nutritional value of the yoghurt, makes it easier to produce firmer yoghurt and improves the stability of yoghurt by reducing the tendency for it to separate in storage [17].

Viscosity
The effect of storage time on viscosity of yoghurt-like products is shown in Figure 1 (b). Viscosity significantly ($p<0.05$) increased from 0 to 7 days, then values decreased by 14 and 21days of storage. The viscosity values varied between

174.34cP to 185.23cP on 0 day storage; the same values increased to 185.41cP to 203.41cP on 7 days storage and significantly ($p<0.05$) decreased to 96.81cP and 119.22cP on 21 days storage in SSTM + 5% NFDM and in OCTM + 0.6% fructose respectively. The initial significant increase in the viscosity of yoghurts from 0 to 7 days could be due to the maturation of yoghurts which is a process of fermentation during which *Streptococcus thermophilus* and *Lactobacillus bulgaricus* convert milk's lactose into lactic acid, increase thickness and acidification, flavor development, absorption of water and dry matter content of yoghurt. During fermentation, the two yoghurt bacteria, *Streptococcus thermophilus* and *Lactobacillus bulgaricus*, can produce polysaccharides (that is slime), which can increase viscosity of fermented products [10, 32]. Viscosity is also an important parameter that correlates with the consistency, texture and flow of the yoghurt. Subsequently, the decreased viscosity on 14 and 21 days storage could be due to the reduction in protein content and post-fermentation acidification with further breakdown of macromolecules such as polysaccharides and polypeptides to smaller units, such as dextrins and peptides by the enzymes, as well as microbial activity on carbohydrates and proteins. Similar findings were reported by researchers during yoghurts storage [33, 34].

Moisture

Results of changes in moisture are presented in Figure 1 (c). Moisture values ranged from 85.42% in OCTM + 0% fructose to 87.34% in SSTM + NFDM yoghurts on 0 day storage and the same values significantly ($p<0.05$) increased to 86.12 and 88.82% on 21 days storage respectively. The increase in moisture content of yoghurt in SSTM + NFDM and OCTM + 0.6% fructose yoghurts could be due to the increased solubility of NFDM and fructose supplements, compared to OCTM + 0% fructose. The increase in moisture content with increase in storage time could affect the quality, storage stability and shelf-life of these yoghurts. In spite of yoghurt’s acidic property, it is still prone to spoilage during storage and preservation because of high water content (85%) [35].

Titratable Acidity

Results of changes in TTA are presented in Figure 1 (d). The values ranged from 0.62 to 1.12% in OCTM + 0% fructose; 0.68 to 1.15% in OCTM + 0.2% fructose; 0.72 to 1.22% in OCTM + 0.4% fructose; 0.74 to 1.28% in OCTM + 0.6% and 0.75 to 1.37 in SSTM + NFDM on 0 and 21 days storage respectively. Lactic acid significantly ($p<0.05$) increased with increase in storage time and increasing levels of fructose supplementation. The TTA of yoghurt-like products increased could be as a result of the increase in carboxylic and sulphydryl acids generated from the various milk components and lactic acid from fermentation of lactose, sucrose, fructose and glucose by *Streptococcus thermophilus* and *Lactobacillus bulgaricus*

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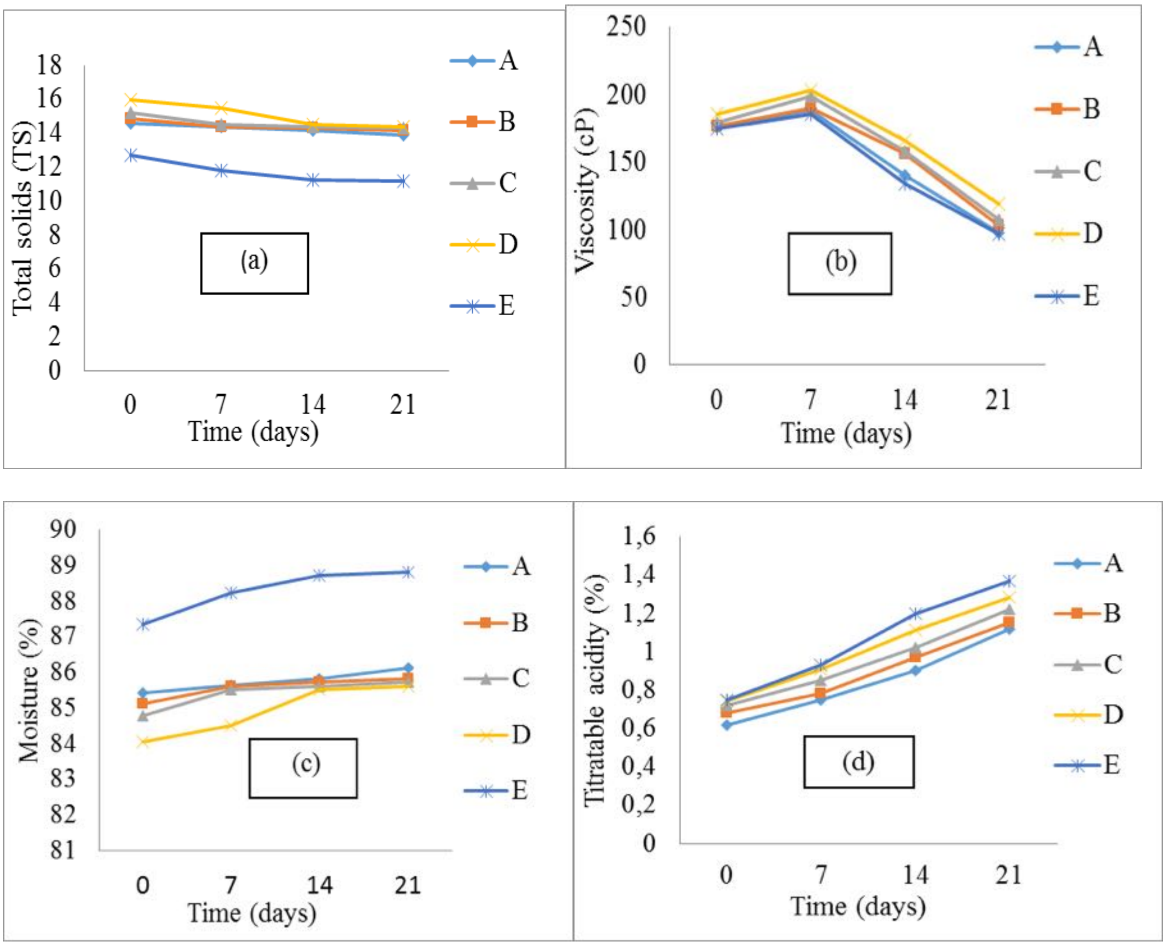
[32, 35]. Also, higher lactic acid values were observed in SSTM + NFDM and OCTM + 0.6% fructose. This could be due to high moisture content in SSTM, the acidifying microflora activity and fermentation of lactose, sucrose, fructose, caseinates and phosphates from NFDM by *Streptococcus thermophilus* and *Lactobacillus bulgaricus* [33, 34, 36]. The TTA for all the tigernut milk yoghurt-like products on 21 days storage were similar to recommended lactic acid 1.0 % [37, 38].



A=OCT + 0% fructose; B=OCTM + 0.2% fructose; C=OCTM + 0.4% fructose; D=OCTM + 0.6% fructose and E=SSTM + 5% NFDM

Figure 1: Effects of Storage Time on: (a) Total Solids; (b) Viscosity; (c) Moisture and (d) Titratable Acidity of Yughurt-like Products from Osmo-concentrated Tigemut Milk (OCTM) and Single Strength Tigemut Milk (SSTM)

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pH

The pH significantly ($p<0.05$) decreased with increase in storage time, with increasing levels of fructose supplementation and with fortification of SSTM with NFDM. Lowest values were observed in SSTM + NFDM and OCTM + 0.6% fructose. The pH values on 21 days storage were 3.91 in OCTM + 0% fructose; 3.87 in OCTM + 0.2% fructose; 3.80 in OCTM + 0.4% fructose; 3.61 in OCTM + 0.6% fructose and 3.58 in SSTM + NFDM yoghurts. The pH values of yoghurt samples were in conformity with recommended standards for yoghurts pH between 3.7-4.5 and acidity 1.5% (max.) [38]. The lowest pH in SSTM + NFDM and OCTM + 0.6% fructose yoghurts could be due to the fermentation of lactose from NFDM and supplemented fructose by LAB to lactic acid and other organic acids during storage. These observations are in agreement with previous researchers who reported that fructose as well as lactose are readily fermentable sugars and appropriate substrates for lactic acid production by LAB [15, 35]. There was significant ($p<0.05$) decrease in pH after 6 and 12 h of fermentation from 6.44-3.57 and 3.52 for tigernut yoghurts with sugar and from 6.46-3.67 and 3.62 for tigernut yoghurts with date [10].

Effect of Storage Time, Osmotic Concentration and Fructose Levels of Supplementation on Microbiological Properties of Tigernut Milk Yoghurts

Lactic Acid Bacteria

Streptococcus thermophilus counts significantly ($p<0.05$) increased on 7 and 14 days and then declined on 21 days storage in all yoghurts. SSTM + NFDM had the highest growth 8.9 log (CFU/g) while OCTM + 0% fructose had the lowest growth 7.1 Log (CFU/g) on 14 days storage. *Lactobacillus bulgaricus* counts followed the same trend of changes as *Streptococcus thermophilus* with respect to increase in storage time in all yoghurts. But, highest growth was observed in SSTM + NFDM and lowest in OCTM + 0% fructose, respectively, 8.6 Log (CFU/g) and 6.8 Log (CFU/g) on 14 days storage. The significant ($p<0.05$) high counts in *Streptococcus thermophilus* and *Lactobacillus bulgaricus* are within acceptable limits (10^6-10^8 CFU/g) as compared to standards reported by researchers [39]. This could be due to little competition as spoilage microorganisms and enzymes were destroyed or inactivated by pasteurization and good manufacturing practice, and handling, packaging and storage conditions. Similar findings were reported by previous researchers [36]. The result is also an indication of good nutritional, health benefits, safety and longer shelf-life of tigernut milk yoghurt-like products. The low temperature storage, good packaging and manufacturing conditions of experimental yoghurt-like products slow down the activities of LAB, yeasts and molds [7, 39, 40]. The significant ($p<0.05$) increase in *Streptococcus thermophilus* and *Lactobacillus bulgaricus* counts with increase in storage time, fructose levels of supplementation and fortification of SSTM with NFDM could be due to hydrolysis, physicochemical and microbiological activities. The SSTM + NFDM had higher counts of *Streptococcus thermophilus* and *Lactobacillus bulgaricus* than OCTM yoghurts and could be due to high moisture content in SSTM, the presence of some growth promoters, such as salts, free amino acids, or vitamins present in tigernut extract and lactose from NFDM. The spoilage rate can be influenced by factors such as moisture content, pH, processing parameters, and temperature of storage [6]. Subsequently, the reduction in LAB counts (CFU/g) on 21 days storage could be attributed to the high acidity that resulted from the presence of lactic and acetic acids, which decrease the viable microorganisms as *Streptococcus thermophilus* and *Lactobacillus bulgaricus* which are sensitive to pH, lactic acid, hydrogen peroxide and dissolved oxygen in fermented milk [6, 35]. The finding appeared favorable for sanitary quality and safety and for human consumption of the yoghurt-like products produced.

Yeasts and Molds Counts

Yeasts and molds were absent at the beginning and end of storage of tigernut milk yoghurt-like products. This could be due to the good hygienic practices, quality of raw materials and ingredients used and good manufacturing, packaging, storage conditions and absence of contamination. Similar findings were also reported by previous researchers [39, 40]. Therefore, the absence of yeasts and molds in yoghurt-like products appeared favorable for shelf-stability, human consumption and sustainability for storage, as there might not be spoilage, alteration to the stability and organoleptic qualities.

Effect of Storage Time, Osmotic Concentration and Fructose Levels of Supplementation on Sensory Properties of Tigernut Milk Yoghurts

Results of changes in appearance, mouthfeel, flavor and acceptability scores for the yoghurt-like products during storage are shown in Figure 2 (e-h). The sensory parameter scores significantly ($p<0.05$) decreased with increase in storage time. As such, appearance values ranged from 7.93 in OCTM + 0.6% fructose on 0 day storage to 6.62 in SSTM + NFDM on 21 days storage; mouthfeel values ranged from 7.93 in OCTM + 0.2% fructose on 0 day storage to 5.53 in SSTM + NFDM yoghurts on 21 days storage. Flavor scores ranged from 7.42 in OCTM + 0.6% fructose on 0 day storage to 4.31 in SSTM + NFDM on 21 days storage and acceptability scores ranged from 8.23 in OCTM + 0.2% fructose on 0 day storage to 4.31 in SSTM + NFDM yoghurts on 21 days storage. The sensory evaluation results showed that SSTM + NDFM and OCTM + 0.6% fructose yoghurts had the lowest scores in appearance, mouthfeel, flavor and acceptability on 21 days storage on a 9-point Hedonic rating scale. This could be due to the high rate of reduction in TS, high acidity, high moisture and uptake of water during storage and increase in microbial and enzymatic activities on 7 and 14 days storage. OCTM + 0.2% fructose, OCTM

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+ 0.4% fructose and OCTM + 0% fructose yoghurts had higher mean scores in appearance, mouthfeel, flavor and acceptability than SSTM + NDFM and OCTM + 0.6% fructose yoghurts during the whole period of storage. This could be due to their high TS, and viscosity, low water uptake, fermentation of sugars (sucrose, fructose, glucose) to lactic acid and chemical reactions with lipids and proteins. This result is in accordance with earlier reports on 0 day storage of soyoghurts from osmo-concentrated soymilk [15]. The typical yoghurt flavor is due to the lactic acid in combination with various carbonyls and other compounds produced by thermal degradation of lipids, lactose and proteins during heat treatment of milk [36]. The osmotic concentration and increasing levels of fructose supplementation significantly ($p<0.05$) increased appearance scores of OCTM yoghurts and values ranged from 7.84 to 7.93 respectively in OCTM + 0.2% fructose and OCTM + 0.6% fructose on 0 day storage. Otherwise, mouthfeel scores 7.73 and 7.72 respectively for OCTM + 0% fructose and SSTM + NFDM yoghurts were not significantly ($p<0.05$) different between each other on 0 day storage. Meanwhile, osmotic concentration had significantly ($p<0.05$) increased the flavor scores of OCTM + 0% fructose and as a result was significantly ($p<0.05$) different and higher than that of SSTM + NFDM yoghurts on 0 day storage. The finding appeared favorable for an increased acceptability, human consumption and competitiveness of these tigernut milk yoghurts.

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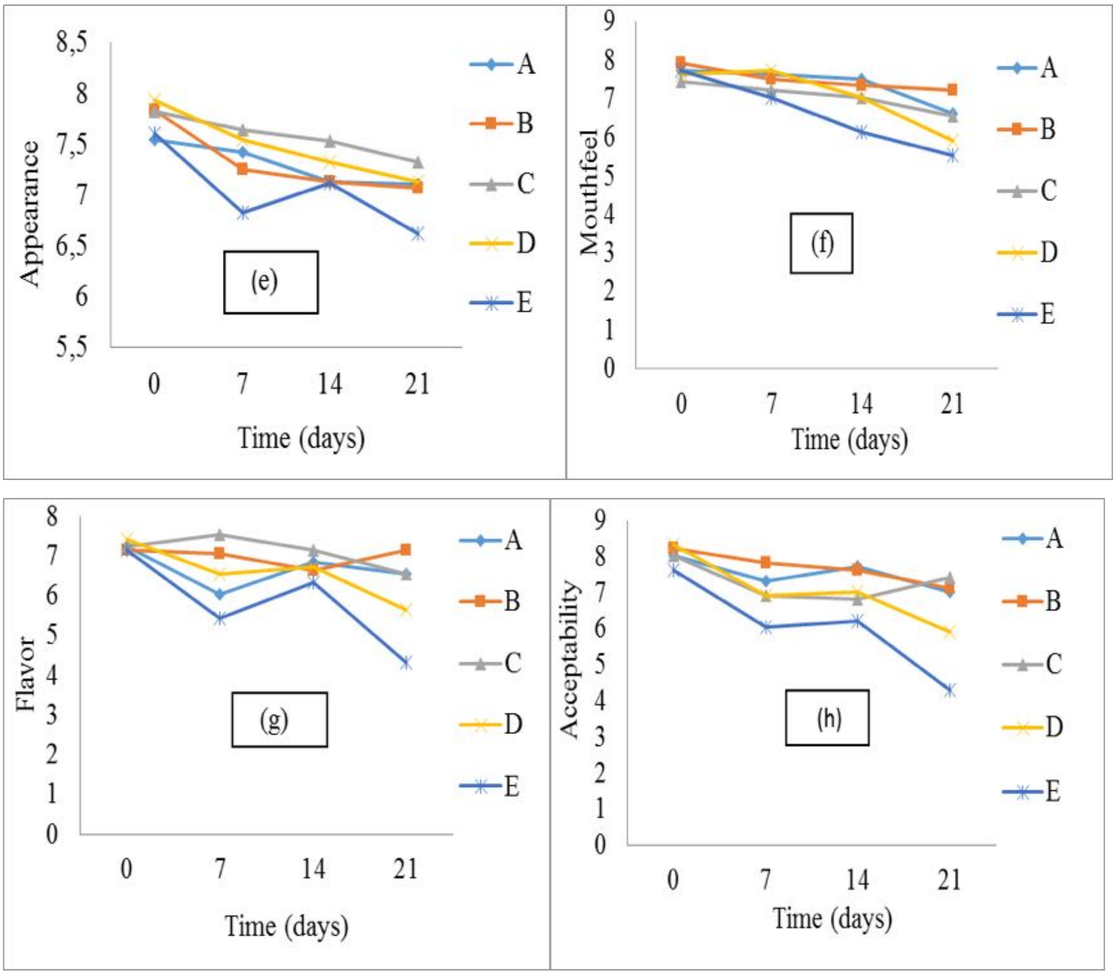

A = OCTM + 0% fructose; B = OCTM + 0.2% fructose; C = OCTM + 0.4% fructose; D = OCTM + 0.6% fructose and E = SSTM + 5% NFDM

Figure 2: Effects of Storage Time on: (e) Appearance; (f) Monthfeel, (g) Flavor and (h) Acceptability of Yoghurt-like Products from Osmo-concentrated Tigernut Milk (OCTM) and Single Strength Tigernut Milk (SSTM)

Effect of Storage Time, Osmotic Concentration and Fructose Levels of Supplementation on Shelf-Life of Tigernut Milk Yoghurts

Results of shelf-life of tigernut milk yoghurt-like products are presented in Table 1. The shelf-life values in OCTM yoghurts were significantly ($p<0.05$) different and higher than that for SSTM + NFDM yoghurt. The OCTM + 0.2% fructose yoghurt had the highest average shelf-life value (36.85 days) followed by OCTM + 0.4% fructose (35.03 days) and OCTM + 0% fructose (32.70 days). The lowest average shelf-life value of 21.84 days was recorded in SSTM + NFDM yoghurt. The slow changes during storage in pH and sensory scores in appearance, mouthfeel, flavor and acceptability result in longer shelf-life of OCTM + 0% fructose, OCTM + 0.2%

fructose and OCTM + 0.4% fructose yoghurts than for SSTM + NFDM and OCTM+0,6% fructose yoghurts. It could also be due to the effects of osmotic concentration, quality of raw material and ingredients used, and good manufacturing practice, packaging and storage conditions. The organic acids produced during fermentation improve on keeping qualities of the product due to decrease in pH and also confer unique sensory characteristics [10]. A shelf-life of 21 days and beyond can be attained with fluid milk products that have been heated sufficiently to kill virtually all of the vegetative bacterial cells and protected from recontamination [6]. The lower shelf-life in SSTM + NFDM and OCTM + 0.6% fructose could be due to microbial spoilage, high moisture content, high reduction rate in TS, drastic changes in pH and sensory scores in flavor, mouthfeel and acceptability during storage.

CONCLUSION AND RECOMMENDATIONS FOR DEVELOPMENT

Storage at 5°C for 21 days did not alter significantly ($p<0.05$) the physicochemical properties, sensory qualities as well as acceptability and shelf-life of OCTM + 0% fructose, OCTM + 0.2% fructose and OCTM + 0.4% fructose yoghurts. However, high levels of fructose supplementation to OCTM and fortification of SSTM with NFDM resulted in significant ($p<0.05$) high moisture content, drastic reduction of sensory qualities as well as acceptability, pH and shelf-life of SSTM + NFDM and OCTM + 0.6% fructose yoghurts during storage. The osmotic concentration had increased the TS, enabled the storage of tigernut milk yoghurts for a longer period, but also preserved flavor, nutritional characteristics and prevented microbial spoilage. Also, tigernut milk yoghurt-like products supported the growth of the fermenting microorganisms *Streptococcus thermophilus* and *Lactobacillus bulgaricus*, as evidenced in the viable counts.

Therefore, osmotic concentration and 0.2% fructose supplementation could be employed as a simple and effective technology for the production of high quality tigernut milk yoghurts with a shelf-life of 5 weeks with storage at 5°C. The scaling-up of results could contribute to utilization of osmotic concentration technologies and fructose supplementation, improve nutrition and human consumption of quality and shelf-stable tigernut milk and yoghurt-like products in Niger. Hence, it is also essential to investigate the nutritional quality and health benefits of the tigernut milk yoghurts for fighting food insecurity, malnutrition and micronutrients deficiencies.

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Author contributions

Dr Magagi Saidou performed the field and laboratory investigations and analyses. He analyzed the data, conceptualized and wrote the methodology and original draft article. He coordinated the reviews and contributions by co-authors. He is also the corresponding author for the article publication in AJFAND. Professors Ariahu C. C. and Gernah, D. I. supervised the work and validated the research project results and the original article drafted for their directions. Prof. Adam T. and Dr Amani A. contributed in the administration, review and visualization of the article draft.

Conflicts of interest

The authors declared that there is no conflict of interest.

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Table 1: Shelf-Life of Tigernut Milk Yoghurt-Like Products

Shelf-life					
Sensory parameter	**Tigernut yoghurt-like products**				
	OCTM				**SSTM**
	Fructose (%)				**NFDM (%)**
	0	**0.2**	**0.4**	**0.6**	**5**
Appearance	52.02[d]	36.84[b]	53.71[e]	37.20[c]	31.15[a]
Mouthfeel	25.96[c]	40.60[e]	34.17[d]	21.45[b]	19.82[a]
Flavor	28.88[c]	50.25[e]	32.57[d]	22.28[b]	17.94[a]
Acceptability	31.16[e]	30.84[d]	29.72[c]	19.75[b]	17.20[a]
pH	25.45[d]	25.67[e]	24.95[c]	23.71[b]	23.05[a]
Average	32.70[c]	36.85[e]	35.03[d]	24.88[b]	21.84[a]

Values are means of shelf-life determinations

Means with the same subscripts letters within the same row are not significantly different ($p<0.05$)

OCTM-Osmo-cocentrated Tigernut Milk, SSTM-Single Strength Tigernut Milk, NFDM-Non-Fat Dry Milk

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