

Nutritional Composition, Physicochemical Properties, Microbial Quality, Functional Properties and Risk Assessment of Organic and Inorganic Yoghurt

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ABSTRACT

The consumption of yoghurt is steadily increasing due to its recognized health benefits and versatility. However, the quality and nutritional content of yoghurt can vary depending on the source of milk used in its production. This study investigates the physicochemical, sensory, microbial, risk assessment and functional properties of fresh milk-based yoghurt and powdered milk-based yoghurt. 15 Samples of yoghurts coded: LZS, LZU, FFS, FFU, TYS, TYU, TSS, TJU, CYS, CYU, HYS, LZG, CGY, TJG and LZF were bought from supermarket in Nigeria. The ranges for physicochemical properties were pH (4.49 – 5.23), conductivity (3588 – 4988mS/cm), density (2.09 – 2.26g/cm³), viscosity (422 – 493mPa.S), titratable acidity (0.00011 – 0.00013%), moisture (70.40 – 89.30%), ash (1.37 – 5.70%), fat (4.3 – 4.81%), and protein (5.63 – 28.94%). The average concentration (mg/kg) of Na, Mg, K, Ca, Fe, Zn and Cu are 595.53, 280.00, 395.00, 1956.30, 12.14, 1.31 and 0.27 respectively, while Cd was not detected in all samples. Target Hazard Quotient, (THQ) for Fe, Zn and Cu in all samples were < 1 suggesting no potential health risk for consumers. B-glucan, inulin, pectin, gelatin and sodium alginate ranges from (5.48 – 65.6), (10.9 – 46.7), (8.70 – 28.3), (4.29 – 16.7), and (6.45 – 21.7) respectively. General acceptability ratings were between very good and excellent. Total viable bacterial count (TVBC) ranges from (6 – 79cfu/100mL), total viable lactic acid bacterial count (TVLBC) ranged between (12 – 18cfu/100mL) and total viable yeast and mold count (TVYMC) ranged between (2 – 31cfu/100mL). This study revealed that all yoghurt samples analyzed are safe and reliable sources of protein, minerals and nutrients.

Keywords: Yoghurt, Physicochemical, Microbial, Risk Assessment, Health benefits

INTRODUCTION

Yoghurts are milk-based products which have undergone the process of fermentation. They are known to contain distinctive bacterial cultures, *Lactobacillus bulgaricus* and *Streptococcus thermophilus*, which are used to achieve fermentation process in yoghurt production (Sidnei *et al.*, 2018). These bacteria help in the stages of fermentation, transforming lactose (milk sugar) into lactic acid, thereby giving yoghurt its tasty flavour and helps preserve it. The elevated level of lactic acid lowers the pH and makes the clotting of milk possible, or the formation of soft gel which is a distinct characteristic of yoghurt (Dasharath *et al.*, 2018). *Lactobacillus bulgaricus* and *Streptococcus thermophilus* cultures also contributes to the probiotic properties of yoghurt, which can be beneficial for gut health. Yoghurt is a highly sort after because of its prebiotics and probiotics nature (Champagne *et al.*, 2018). It provides benefits, such as improved digestion of lactose, gastrointestinal function, stimulation of the immune system (Mahmoud *et al.*, 2020) and loaded with nutrient and can serve as food. Milk is the base materials for the production of yoghurt. Fresh milk from mammals (cow, ovine, caprine or buffalo) and powdered milk are used in the production of yoghurt, based on the preference of the manufacturer, the desired properties and shelf life (Shahida *et al.*, 2024). Where dairy products are scarce or insufficient, coupled with unavailability of electricity for adequate preservation in most developing countries, powdered milk provides a suitable solution. The powdered milk is derived mainly by the removal of water from milk (Elisama and Elane, 2023) by roller-drying and spray-drying methods. The rationale behind the manufacturing of milk powder is to transform the perishable raw liquid milk into a form which will hinder microbial metabolism and extend its shelf life without significant degradation in the initial quality. The

advantages of powdered milk have made its uses to span across different areas, such as bakeries, infant formulas, nutritional foods, confectionaries, yoghurt and many more. Several factors affect the nutrient composition of yoghurt, some of which include genetic and mammalian variation, types of foods consumed, age of animal, environmental factors, stage of lactation and the time of the year (either wet or dry season).

Conversely, nutritional profile of yoghurt is also dependent on several factors such as, the type of milk, method of milk processing, production temperature, period of heat exposure, exposure to light, and conditions of storage (Gaurav *et al.*, 2021). From the Literature review, there are limited comprehensive data on the therapeutic properties and nutritional variability of different types of yoghurts (fresh milk-based yoghurt and powdered milk based yoghurt) in the market which make it more challenging for consumers to make informed dietary choices. The quality and nutritional content of yoghurt can vary based on the source of milk choice that is considered during production. In addition, paucity of information exists, on the impact of different milk-type, on shelf life and microbial stability of yoghurts. Hence, there is need to elucidate on the health benefit and characteristics of fresh milk-based yoghurt and powdered milk-based yoghurt. This study will specifically concentrate on comparison of physicochemical, sensory evaluation, microbial, functional properties risk assessment of yoghurt produced from two primary milk sources: fresh milk and powdered milk. The yoghurts will be subjected to various analysis to reveal the hygienic status, adulterated level, health benefit and compliance to the world health organization (WHO) and food and drug administration (FDA) requirement for food standard. The aim of this research work is to investigate the physicochemical, sensory evaluation, microbial, risk assessment and functional properties of both fresh milk-based yoghurt and powdered milk-based yoghurt

MATERIALS AND METHODS

Materials

Centrifuge, Atomic Absorption Spectrophotometer (Buck Scientific, Model 235), JENWAY model 3510 pH meter, Conductivity meter Model DDS-307, Haier Thermocool Refrigerator, Shimadzu HPLC system, Digital Viscometer NDJ-5S, sterile McCartney bottles, Eppendorf pipette, Petri-dishes and electro-heating standing temperature air dry oven (JINOTECH, DHG-0A)

Samples Collection and Preparation

The yoghurt (organic and inorganic) samples were bought from different supermarkets in Akure Nigeria. Organic yoghurt connotes yoghurt made from fresh milk and inorganic yoghurt connotes yoghurt made with powdered milk as shown in Table 1. The yoghurt samples were kept in the refrigerator at 4°C in preparation for laboratory analysis.

Table 1: Category of yoghurt samples collected from Akure metropolis Nigeria

S/N	SAMPLE NAME	SAMPLE CODE	CATEGORY
1	L & Z yoghurt sweetened	LZS	Organic
2	L & Z yoghurt unsweetened	LZU	Organic
3	Farm fresh yoghurt sweetened	FFS	Organic
4	Farm fresh yoghurt unsweetened	FFU	Organic
5	Tito yoghurt sweetened	TYS	Inorganic
6	Tito yoghurt unsweetened	TYU	Inorganic
7	TJ yoghurt sweetened	TJS	Inorganic
8	TJ yoghurt sweetened	TJU	Inorganic
9	Cedaa yoghurt sweetened	CYS	Inorganic
10	Cedaa yoghurt unsweetened	CYU	Inorganic
11	Habib yoghurt sweetened	HYS	Organic
12	L & Z Greek yoghurt sweetened	LZG	Organic

13	Cedaa Greek yoghurt sweetened	CGY	Inorganic
14	TJ Greek yoghurt sweetened	TJG	Inorganic
15	L & Z Fura	LZF	Organic

METHODS

Physicochemical Analysis

The physicochemical analysis such as density, titratable acidity and pH were carried out according to AOAC (2010), the pH measurement was carried out using a calibrated meter (JENWAY 3510). The proximate analysis, Conductivity meter Model DDS-307 was used for measurement and Digital Viscometer NDJ-5S was used to determine the viscosity of the yoghurt (AOAC, 2012).

Mineral Analysis

0.50mL of each sample was measured into a clean porcelain crucible. The weight was recorded to the nearest (+0.001 g). The crucible holding the sample was placed in a muffle furnace and ashed at 500°C over a period of 4 hours. It was then allowed to cool down in a desiccator. The ashed samples were poured into a well labeled 50 milliliters centrifuge tubes. The crucibles were rinsed using 5 milliliters of distilled water into the centrifuge tube and rinsed again using 5 milliliters of aqua regia rinsed two times to make a total volume of aqua regia 20 milliliters. The sample was vortexed in order to achieve proper mixing. The sample was centrifuged for 10 minutes at 3000 rpm. The supernatant was decanted into a clean vial sample container for determination (of Ca, Mg, K, Na, Zn, Cu, Fe and Cd) using Atomic Absorption Spectrophotometer (Buck Scientific, Model 235).

Microbial Analysis

Yoghurt samples were collected using sterile McCartney bottles. The media selected for isolation were; Potato Dextrose Agar (PDA) for fungi count and identification and de Man, Rogosa and Sharpe (MRS) Agar for Lactic Acid Bacteria count. The Durham bottles, McCartney bottles were sterilized using the dry heat sterilization method (oven) at 160°C for 1 h. The media were prepared by 23.4 g of PDA (for cultivation of enumeration of yeast and mould from dairy and other food products) was weighed in two places and poured into two Durham bottles and 600 mL was added into each of them. Approximately 40.29 g of MRS (for isolation and cultivation of lactobacillus species) was weighed in two places and poured into two Durham bottles and 600 mL was added into each of them. These were stared respectively, kept in the water bath for 10 mins to homogenize and then transferred into the autoclave to sterilize at 121 °C for 15 mins. After sterilization, it was transferred to the water bath so as to maintain their temperature and prevent them from solidifying.

Serial dilution

9 mL of distilled water was measured into the McCartney bottles, the micro pipette, Eppendorf pipette was placed into the pipette rack and they were sterilized with using the auto clave at 121 °C. Then 1 mL of each yoghurt sample was aseptically withdrawn using the Eppendorf pipette and transferred into the McCartney bottles containing approximately 9 mL of sterile distilled water for the stock solution. Successive dilution of the sample was carried from the stock using a six-fold dilution, from 10⁻¹ to 10⁻⁶ decimal dilution from the solution by serially adding 1 mL into the preceding concentration to 9 mL of the diluent.

Isolation of Microorganisms

The Petri-dishes were labeled with the sample names and the dilution factor from 10⁻¹ to 10⁻⁶ respectively for the 10 samples, a control Petri dish was also labeled. An aliquot of 0.1 mL from each diluent was measured into the Petri-dishes for each sample from 10⁻¹ to 10⁻⁶ respectively using a micropipette, 20 mL of agar was aseptically poured into the sterilized pipette, and the plates were then rock-mixed clock wise and anticlockwise to allow uniform mixing of the inoculums. The plates were then allowed to set and incubated at 37°C for 24 - 48 hours for bacteria and 28°C for 3-5 days for fungi. Microbial growth was observed in all media at the end of the incubation periods as described by Afolabi *et al.* (2017). The total bacterial count was achieved by

counting the colonies on the plates with a colony counter. The fungal isolates were counted and they were identified and characterized on the basis of their colonial morphology and microscopic view in comparison to those of known taxa as described by Afolabi *et al.*, (2017).

Organoleptic analysis

The sensory characteristics were determined using the method of Mantzourani *et al.*, (2018).

Determination of additives

Samples were placed on dry water soaking papers for drying under open, airy and shady place for 2 days. The dried samples were kept at 30°C for 5 h within hot air oven. 5 µL of each sample were taken within cellulose thimble (80 × 20 mm) and placed within the Soxhlet apparatus. 50 mL of petroleum benzene was poured into the Soxhlet apparatus and used to remove non polar substituent such as fatty impurities that can interfere with the analysis of the target compounds in the yoghurt samples. Afterwards, the temperature was set at 60°C to ensure safe, continuous and efficient extraction. The Soxhlet was run for 72 cycles of extraction for each sample, and the fatty extracts collected separately in glass beakers. The thimble with the defatted sample was taken out and dried for 4 hours at 30°C and placed properly within a cleaned Soxhlet setup, and another extraction carried out with ethyl acetate to remove bacteria metabolites and residual lipids from the fermented samples. The final sequence of extraction was followed from the same sample with 90% methanol to extract the polar constituents. The methanolic extracts were kept within glass beakers covered with cotton cloth at 6 – 10°C during which it became crystal dried. The dried extracts were weighed and kept at – 4°C within separate glass micro-centrifuge tubes prior to analysis.

High Performance Liquid Chromatography (HPLC) setup

High Performance Liquid Chromatographic method was employ to determine the concentration of additives in the methanolic extracts of the fifteen yoghurt samples due to its high sensitivity, resolution, and faster analytical time. HPLC was established using Shimadzu chromatography system fitted with C-18 column. The system was equipped with a degasser (DGU-2As), liquid chromatography (LC-20AT), auto sampler (SIL-20A), column oven (CTO-ASvp), fluorescent detector (RF-10AxL), diode array detector (SPD-M20-A), bus module (CMB-20) and fraction collector (FRC-10A). Standards of different polyphenolic compounds were dissolved in methanol to get 1 mg/mL solution. 400µL from each of the solution were taken into a single glass centrifuge tube.

The reverse-phase HPLC was performed using 0.1% solution of acetic acid dissolved in Milli-Q water (solvent A) and acetonitrile (solvent B), and the flow rate was maintained at 0.8 µL/min. The elution began with 10% of solvent B maintained from 0.01 to 2 mins. It was changed from 10 to 30% from 2 to 27 min and followed by the change of concentration of solvent B from 30 to 90% from 27 to 50 min. From 50 to 52 mins, the elution was increased from 90 to 100% and it was maintained to 53 mins and then it was reduced to 10% till 63 min to stop. The chromatographic detection was done at 270 nm wavelength. Ten microliters of each of the sample solution was placed consecutively for the analysis, and each of the report was developed with the specific software (AutoRun) equipped with the chromatographic system.

Human Health Risk Assessment

In order to assess the potential health risks (non-carcinogenic health risks) associated with long term consumption of yoghurt with elevated concentration of a heavy metal, the target hazard quotient (THQ) was employed. The THQ is defined as the ratio of determined doses for one pollutant to its reference dose (RfD), and was calculated using the mathematical equations in (1) and (2).

$$THQ = \frac{EDI}{RfD} \dots \dots \dots \text{eqn. 1}$$

$$EDI = C \times I \dots \dots \dots \text{eqn. 2}$$

Where EDI is the estimated daily intake of heavy metals (mg/kg/days) and RfD is the oral reference dose.

The individual metal toxicity responses (dose response) are 0.001 for Cd, 0.7 for Fe, 0.3 for Zn, and 0.04 for Cu all in mg/kg/day as the Oral Reference Dose (RfD) (USEPA, 2014; Wongsasuluk *et al.*, (2014). C is the mean concentration of heavy metals in yoghurt samples (mg/kg) and I is the intake of yoghurt per kg body weight per day (kg/day·bw(kg)). Exposed population is unlikely to experience any obvious adverse effect at THQ > 1. The severity of health risks caused by toxic elements in yoghurt is enhanced with the increased THQ value. Hazard index (HI) was used to estimate the potential human health risk when more than one heavy metal is consumed. HI was calculated as the sum of THQs:

$$HI = (THQi + THQii + THQiii \dots \dots THQn) \therefore HI = \Sigma THQ$$

RESULTS AND DISCUSSION

Physicochemical composition

The physicochemical parameters of the yoghurt samples were presented in Table 2. The pH of the yoghurt samples was in the decreasing order of HYS > LZU > LZS > CYU = LZG > CYS > FFS > FFU > TYU > TYS > TJG > LZF > TJU = CGY > TJS and ranged from 4.49 to 5.23, for TJS and HYS. The average pH is 4.96. The pH values for all yoghurt samples, except TJS, were above Food and Drugs Association (FDA) limit of 4.6 (FDA, 2013; Kabir, 2022). The pH of yoghurt in this study, which are above 4.6 follows same pattern with the findings of Matter *et al* (2016). The pH of yoghurt samples within the range obtained, in this study, is suitable for consumption, because they fall within the acidic pH region. A lower pH helps to preserve the yoghurt by inhibiting spoilage bacteria from growing. High pH that tends towards neutral (pH 7) could be an indication of contamination or fermentation issues (Mahomud *et al.*, 2021). On the other hand, other study has also shown pH of seven different yoghurt, with an average, minimum and maximum value of 4.34, 4.21 and 4.48 respectively (Demir *et al.*, 2023) which are lower than the values obtained from this study. The conductivity values for the yoghurt samples were in a decreasing order: LZG > CYS > TJG > LZF > CYU > HYS > TYU > LZS > FFU > LZU > TYS > FFS > TJU > TJS > CGY. The standard specification of food and drug Administration (FDA) and World Health Organization (WHO) standard for conductivity of yoghurts was not specified. The density of the yoghurt samples are in the order: TJG > LZF > TYS > FFS > HYS > LZS = LZG > TYU > CYU > FFU = TJS > CYS > LZU > CGY > TJU and ranged from (2.06 - 2.33) g/cm³ accordingly. The texture and nutritional content of yoghurt is a function of its density as higher density often indicates thicker, creamier and nutritious products.

Table 2: Physicochemical Parameter of Yoghurt Samples

Sample	pH	Cond. (mS/cm)	Density (g/cm ³)	Viscosity (mPa.S)	Moisture Content (%)	Titratable Acidity (%)	Ash Content (%)	Fat (%)	Protein (%)
LZS	5.16	4230	2.20	488	82.60	1.17 × 10 ⁻⁴	1.49	4.67	15.27
LZU	5.19	4063	2.14	488	89.20	1.17 × 10 ⁻⁴	3.45	4.55	28.94
FFS	5.00	4020	2.23	490	87.00	1.12 × 10 ⁻⁴	5.70	4.30	8.84
FFU	4.98	4198	2.16	489	89.30	1.09 × 10 ⁻⁴	4.95	4.53	24.12
TYS	4.91	4060	2.24	487	88.10	1.09 × 10 ⁻⁴	2.82	4.81	10.45
TYU	4.94	4318	2.18	488	89.10	1.09 × 10 ⁻⁴	4.48	4.32	22.51
TJS	4.49	3778	2.16	481	79.70	1.10 × 10 ⁻⁴	2.46	4.53	5.63
TJU	4.73	3980	2.06	480	85.30	1.08 × 10 ⁻⁴	4.46	4.63	9.65

CYS	5.07	4978	2.15	487	83.30	1.16×10^{-4}	4.98	4.81	12.06
CYU	5.13	4470	2.17	491	88.40	1.10×10^{-4}	5.45	4.41	23.31
HYS	5.23	4375	2.22	491	80.90	1.21×10^{-4}	3.88	4.68	20.10
LZG	5.13	4988	2.20	493	76.80	1.28×10^{-4}	5.37	4.70	22.51
CGY	4.73	3588	2.09	493	78.40	1.26×10^{-4}	1.37	4.61	15.27
TJG	4.90	4943	2.33	484	70.40	1.16×10^{-4}	1.92	4.52	8.04
LZF	4.82	4475	2.26	493	81.30	1.21×10^{-4}	1.96	4.66	9.65
FDA STANDA RD	4.00- 4.60	NS	NS	NS	85.00	NS	0.90	3.25 - 8.25	NS

NS: NOT SPECIFIED

Key: LZS = (organic; L & Z yoghurt sweetened), LZU (Organic ; L & Z yoghurt unsweetened), FFS (Organic; Farm fresh yoghurt sweetened), FFU (Organic; Farm fresh yoghurt unsweetened), TYS = (Inorganic; Tito yoghurt sweetened), TYU= (Inorganic; Tito yoghurt unsweetened), TJS = (Inorganic; TJ yoghurt sweetened), TJU (Inorganic ;TJ yoghurt sweetened), CYS= (Inorganic; Cedaa yoghurt sweetened), CYU = (Inorganic; Cedaa yoghurt unsweetened), HYS = (Organic; Habib yoghurt sweetened), LZG = (Organic; L & Z Greek yoghurt sweetened) CGY=(Inorganic; Cedaa Greek yoghurt sweetened), TJG = (Inorganic; TJ Greek yoghurt sweetened), LZF = (Organic; L & Z Fura)

The viscosity of the yoghurt samples decreases in the order of LZG = CGS > CYU = HYS = LZF > FFS > FFU > LZS = LZU = TYU > TYS = CYS > TJG > TJS > TJU and ranged from (422 - 493 mPa.S). Viscosity is an important factor which is reliably used to compare the quality of yoghurt samples prepared under different conditions. The viscosity value for all yoghurt samples falls within the range of thick, creamy yoghurts. LZG and CGS has the highest viscosity value of 493, which is consistent with the findings of (Meydani *et al.*, 2019) for Greek yoghurts, however there is no specified available limit, documented by the FDA and WHO. The moisture content (%) of the yoghurt samples show a decreasing trend in the order of FFU > LZU > TYU > CYU > TYS > FFS > TJU > CYS > LZS > LZF > HYS > TJS > CGY > LZG > TJG, and ranged from (70.4 - 89.3)% respectively as shown in Table 2. Eight yoghurt samples were below the FDA standard of 85%, while others were slightly above the standard. The moisture content is a critical factor influencing both quality and properties of yoghurt. Yoghurts with higher moisture content are prone to microbial growth and spoilage, potentially resulting in a shorter shelf-life and vice versa. Yoghurts with lowest moisture content, 70.4% (TJG) in this study is associated with thicker and creamier yoghurt, likewise LZG (76.8%), and CGY (78.4%). While yoghurts with the highest moisture content 89.3% (FFU) was the least viscous. These observations are consistent with the finding of Igbabul *et al.*, (2014), where plain cow milk yoghurts had moisture content ranging from (79.11- 83.02)%. The titration acidity in the yoghurt was from its lactic acid content and other organic acids synthesized by lactic acid bacteria (LAB) during the fermentation of milk (Tamime and Robinson, 2005). The titratable acidity value in terms of lactic acid in this study follow the order of: LZG > CGY > HYS = LZF > LZS = LZU > CYS = TJG > FFS > TJS = CYU > FFU = TYS = TYU > TJU respectively with TJU having a minimum of 1.08×10^{-4} % and highest value of 1.28×10^{-4} % observed in (LZG). Titratable acidity which expresses the percentage of lactic acid present in the yoghurts in this study were below the FDA standard and also lower in comparison with the findings of Matela *et al.*, 2019 (which ranged from 0.69% to 1.81%). This could be due to lower availability of fermenting microbes. The percentage ash content of the yoghurt samples was found to be in decreasing order: CYU > LZG > FFS > CYS > FFU > TYU > TJU > HYS > LZU > TYS > TJS > LZF > TJG > LZS > CGY.

The percentage ash content of yoghurt was not specified by FDA for comparison however, the percentage ash content ranged from 1.37% to 5.70% for CGY and CYU respectively. A study carried out by Ihuoma and Shulamite (2023) reported percentage ash content to range between 5.16% and 6.28%. A separate study conducted by Mbaeyi-Nwaoha (2014) reported the ash content of plain yoghurts to be between 1.21% and 1.38%. Both results are considerably at variance with the result obtained from this study. This could be attributed to differences in production protocol and importantly, the breed of cattle which serves as milk sources for powdered milk production and organic yoghurt production. The content of ash in the yoghurt samples suggests the presence of minerals, which enhances bone formation and mineralization (Matela *et al.*, 2019). The fat content (%) of the 15 yoghurt samples analyzed was in the order: TYS = CYS > LZG > HYS > LZS > LZF > TJU > CGY > LZU > FFU = TJS > TJG > CYU > TYU > FFS, and have a range between 4.3% to 4.81% with an average of 4.58%. The percentage of fat obtained in this study is within the FDA standard and higher in comparison with Olugbuyiro (2011) study on Physicochemical and Sensory Evaluation of nine (9) Market Yoghurt in Nigeria with minimum and maximum percentage fat content reported to be 1.88% and 4.00% respectively. The fat content of yoghurt contributes significantly to its caloric value. Additionally, fat provides essential fatty acids and fat soluble vitamins (such as A, D, E, and K), which are beneficial for health. Therefore, consuming any of the yoghurts in this study will provide adequate supply of fat and soluble vitamins needed by man.

In Nigeria, yoghurt with a fat content of 4.3% to 4.81% is suitable and provides health benefits. Obatolu (2017) in a separate study examined the fat content of yoghurt produced from cow milk to be 4.8%, which is similar to the maximum fat content in this study. The protein content of the yoghurt samples investigated in this study is reported to be in this order: LZU > FFU > CYU > TYU = LZG > HYS > LZS = CGY > CYS > TYS > TYU > LZF > FFS > TJG > TJS. The FDA recommended standard for protein in yoghurt was not specified in the label of all the sample purchased for comparison with the results of the analysed samples, however, a minimum of 5.6% protein content in whole milk yoghurt was recommended by the Turkish Food Codex Communiqué of fermented dairy product (Bilgin and Kaptan, 2016). The protein content of the yoghurt samples in this study were greater than the minimum of 5.6% recommended by Turkish Food Codex Communiqué of fermented dairy product. The minimum, maximum and average protein content of yoghurt samples in this study are 5.63% (TJS), 28.94% (LZU) and 15.76% respectively.

Generally from this study, the unsweetened versions of yoghurts have a higher protein content compared to the sweetened samples. This could be attributed to the absence of added sugars or sweeteners, which might otherwise dilute the protein concentration. Greek yoghurts, known for their straining process that removes whey, tend to have higher protein content compared to regular yoghurts which is evident in the LZG and CGY. Unsweetened and Greek yoghurts generally offer higher protein content, making them more suitable for individuals seeking to increase their protein intake. This variability allows consumers to select products that best fit their nutritional needs and preferences (Ademosun *et al.*, 2019).

Mineral compositions of yoghurt

The Table 3 shows the means concentration of sodium in seven organic and eight inorganic yoghurts. The concentration of sodium was in this order: TJG > CYS > CGY > LZU > TYU > HYS > FFU > TYS > TJU > FFS > LZS > LZG > TJS > CYU > LZF, and ranged from 325 mg/L (LZF) to 1617 mg/L (TJG). All the yoghurt samples analyzed in this study were below the WHO oral reference dose (RfD) for sodium (2300 mg/day) in human diets. Therefore, the consumption of the analyzed samples of yoghurt within Akure metropolis are safe for consumption and does not pose any health risks associated with excessive intake of sodium when consumed frequently. However, the range in sodium content for inorganic yoghurts is much wider compared to organic yoghurts. The highest value in the inorganic category (1617 mg/L) suggests greater variability and possibly less standardization in sodium content among inorganic yoghurt brands.

It could also be due to different manufacturing processes, added ingredients, or preservation methods. For consumers looking to increase their sodium intake, inorganic yoghurts might be a better option to maintain a balanced diet without the risk of excessive sodium consumption. Independent sample t-test shows that there is no significant difference ($P > 0.05$) in the mean concentration of sodium in the organic and inorganic yoghurt samples. The observed differences could be attributed to random variation.

Table 3: Mineral composition of Yoghurt

Sample	Na (mg/L)	Mg (mg/L)	K (mg/L)	Ca (mg/L)	Fe (mg/L)	Zn (mg/L)	Cu (mg/L)	Cd (mg/L)
LZS	415 ± 0.01	241 ± 0.03	264 ± 0.02	1676 ± 0.08	4.68 ± 0.02	1.16 ± 0.01	0.04 ± 0.02	ND
LZU	715 ± 0.01	354 ± 0.01	276 ± 0.06	2633 ± 0.06	6.18 ± 0.01	1.99 ± 0.03	0.13 ± 0.01	ND
FFS	438 ± 0.04	215 ± 0.05	161 ± 0.01	1749 ± 0.06	5.48 ± 0.03	1.50 ± 0.01	0.24 ± 0.01	ND
FFU	542 ± 0.01	292 ± 0.01	573 ± 0.05	2409 ± 0.03	6.56 ± 0.02	1.75 ± 0.02	0.19 ± 0.02	ND
TYS	520 ± 0.02	299 ± 0.08	491 ± 0.05	2164 ± 0.03	13.7 ± 0.01	1.43 ± 0.04	0.39 ± 0.03	ND
TYU	670 ± 0.01	358 ± 0.02	326 ± 0.01	2908 ± 0.02	17.1 ± 0.02	1.76 ± 0.01	0.37 ± 0.01	ND
TJS	365 ± 0.01	289 ± 0.01	443 ± 0.03	1495 ± 0.05	17.1 ± 0.05	1.21 ± 0.01	0.37 ± 0.02	ND
TJU	499 ± 0.01	435 ± 0.05	342 ± 0.04	1826 ± 0.05	9.66 ± 0.02	0.09 ± 0.01	0.12 ± 0.02	ND
CYS	737 ± 0.01	305 ± 0.01	467 ± 0.01	2388 ± 0.19	9.56 ± 0.05	1.17 ± 0.01	0.20 ± 0.01	ND
CYU	362 ± 0.02	191 ± 0.01	114 ± 0.03	1296 ± 0.07	10.9 ± 0.01	0.55 ± 0.01	0.19 ± 0.02	ND
HYS	667 ± 0.03	251 ± 0.06	363 ± 0.01	1708 ± 0.01	13.4 ± 0.02	0.58 ± 0.01	0.22 ± 0.02	ND
LZG	366 ± 0.03	182 ± 0.05	223 ± 0.01	1065 ± 0.01	12.8 ± 0.02	0.48 ± 0.01	0.34 ± 0.01	ND
CGY	725 ± 0.01	236 ± 0.08	480 ± 0.06	1824 ± 0.01	15.0 ± 0.02	0.97 ± 0.02	0.42 ± 0.01	ND
TJG	1617 ± 0.02	355 ± 0.03	946 ± 0.01	2895 ± 0.04	22.6 ± 0.02	3.15 ± 0.01	0.41 ± 0.01	ND
LZF	235 ± 0.01	197 ± 0.03	456 ± 0.06	1309 ± 0.03	17.6 ± 0.01	1.81 ± 0.02	0.45 ± 0.01	ND
	2300 mg/day	200-400 mg/day	3510 mg/day	2500 mg/day	18 mg/day	11 mg/day	2.1 mg/day	-

Note: The values in Mean ± Standard Deviation (SD) (n = 3).

Key: LZS = (organic; L & Z yoghurt sweetened), LZU (Organic ; L & Z yoghurt unsweetened), FFS (Organic; Farm fresh yoghurt sweetened), FFU (Organic; Farm fresh yoghurt unsweetened), TYS = (Inorganic; Tito yoghurt sweetened), TYU= (Inorganic; Tito yoghurt unsweetened), TJS = (Inorganic; TJ yoghurt sweetened), TJU (Inorganic ;TJ yoghurt sweetened), CYS= (Inorganic; Cedaa yoghurt sweetened), CYU = (Inorganic; Cedaa yoghurt unsweetened), HYS = (Organic; Habib yoghurt sweetened), LZG = (Organic; L & Z Greek yoghurt sweetened) CGY= (Inorganic; Cedaa Greek yoghurt sweetened), TJG = (Inorganic; TJ Greek yoghurt sweetened), LZF = (Organic; L & Z Fura)

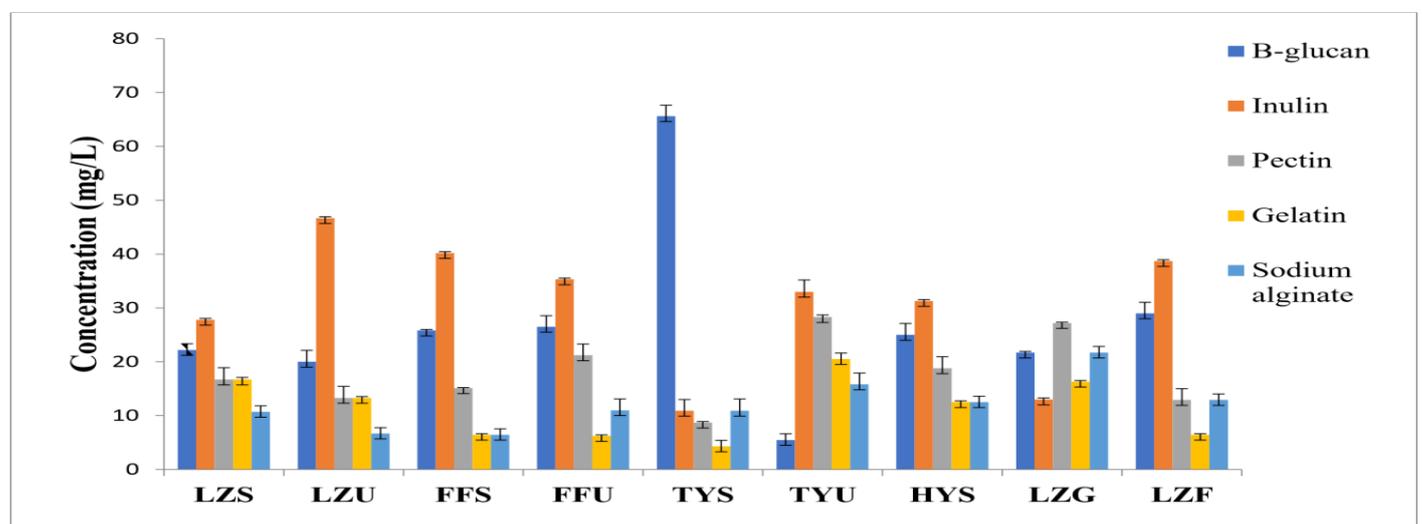
The sodium content of yoghurt in this study is slightly higher than those observe in the study of Ibhaze *et al*, 2020. The magnesium concentration for the yoghurt samples in this study are as follows; TJU > TYU > TJG > LZU > CYS > TYS > FFU > TJS > HYS > LZS > CGY > FFS > LZF > CYU > LZG and ranged from 182 mg/L (LZG) to 435 mg/L (TJU) in the yoghurt samples analyzed. The concentration of magnesium in the yoghurt samples falls within the WHO oral reference dose (RfD) of 200-400 mg/day, except for LZG (182 mg/L), LZF (197 mg/L) and TJU (435 mg/L). The magnesium content in both organic and inorganic yoghurts are significantly different, indicating that yoghurt type (organic vs inorganic) does not necessarily predict its magnesium content. Independent sample t-test revealed that there is no significant difference (P>0.05) in the

mean concentration of magnesium in the organic and inorganic yoghurt samples. The concentration of potassium in the yoghurt samples are in the order: TJG > FFU > TYS > CGY > CYS > LZF > TJS > HYS > TJU > TYU > LZU > LZS > LZG > FFS > CYU. The minimum and maximum concentration of potassium is 114 mg/L (CYU) and 946 mg/L (TJG) respectively. The concentration of magnesium in all yoghurt samples are within the oral reference dose (RfD) of 3510 mg/day. This result goes further to show that yoghurt is a good source of magnesium. And regular intake of yoghurt will enhance the supply of magnesium to maintain human healthy state. The mean concentration of calcium in the yoghurt samples are as follows: TYU > TJG > LZU > FFU > CYS > TYS > TJU > CGY > FFS > HYS > LZS > TJS > LZF > CYU > LZG. The concentration of calcium in the yoghurt samples ranged from 1065 mg/L (LZG) to 2908 mg/L (TYU). The concentration of calcium in the yoghurt samples were all below the oral reference dose (RfD) of 2500 mg/day, except TYU (2908 mg/L) and TJG (2895 mg/L) which were slightly higher than the daily requirement to maintain a healthy living. The result further infers that frequent consumption of yoghurt is pathway to healthy living, as it provides essential minerals required for body growth and development.

Iron was also investigated in all the yoghurt samples and their concentration were as follows, TJG > LZF > TYU = TJS > CGY > TYS > HYS > LZG > CYU > TJU > CYS > FFU > LZU > FFS > LZS. The lowest and highest concentration of iron in the yoghurt samples analyzed is 4.68 mg/L (LZS) and 22.6 mg/L (TJG) respectively. The examined values were below the oral reference dose (RfD) of 18 mg/day, except TJG (22.6 mg/L) which is slightly above the RfD value. The mean concentration of zinc in the yoghurt samples in this study are in this order: TJG > LZU > LZF > TYU > FFU > FFS > TYS > TJS > CYS > LZS > CGY > HYS > CYU > LZG > TJU. The lowest and highest concentrations of zinc in the yoghurt samples analyzed are 0.09 mg/L (TJU) and 3.15 mg/L (TJG) respectively. The examined values were below the oral reference dose (RfD) of 11 mg/day which may not pose any health risk to consumers. The mean concentration of copper in the yoghurt analyzed samples follow the order: LZF > CGY > TJG > TYS > TYU = TJS > LZG > FFS > HYS > CYS > FFU = CYU > LZU > TJU > LZS. The lowest and highest concentrations of copper in the yoghurt samples analyzed are 0.04 mg/L (LZS) and 0.45 mg/L (LZF) respectively. The examined values were all below the oral reference dose (RfD) of 2.1 mg/day. Cadmium was also investigated in all the yoghurt samples but was not detected (ND). This is significant in inferring that the yoghurts examined in this study are completely free from cadmium which has been known to very toxic and capable of causing several health disorders in human, therefore, indicating that the consumption of all the samples may not warrant any toxic concern to consumers.

Additives in Yoghurt Samples

The mean concentration of additives found in the samples as shown in Figure 1 ranged from; B-glucan (5.48 ± 1.15 - 65.6 ± 2.05), Inulin (10.9 ± 2.10 - 46.7 ± 0.25), Pectin (8.70 ± 0.20 - 28.3 ± 0.40), Gelatin 4.29 ± 1.12 - 16.7 ± 0.40) and Sodium alginate (6.45 ± 1.10 - 21.7 ± 1.15). Pectin derived from fruits, helps to thicken and stabilize the yoghurt while Gelatin is used to give the yoghurt a firmer texture.



The Figure 1 presents the mean concentration of essential additives that are being incorporated in the production of yoghurts.

Identification, colonial morphology and characteristics isolates from yoghurts

Table 4 shows the prediction of fungi/yeast present in the following yoghurts samples: LZS, LZU, FFS, FFU, TYS, TYU, TJS, TJU, CYS, CYU, HYS, LZG, CGY, TJG and LZF. The yoghurt samples were tested for growth at 37 °C, true hyphae, chlamyospores, urea, ascospores, maltose, galactose, raffinose, xylose, arabinose, glucose, mannitol, sucrose and lactose. *S. cerevisiae* and *C. albican*

were isolated in LZU, FFU, TYU, TJU, CYU and LZF. While all other yoghurt samples had only *S. cerevisiae* isolate.

Table 4: Identification, colonial morphology and characteristics of isolates from Yoghurts

SAMPLE	GROWTH AT 37 °C	PSALMOTPH	CHLAMYDOSPORES	UREA	ASCOSPORES	MALTOSE	GALACTOSE	RAFFINOSE	XYLOSE	ARABINOSE	GLUCOSE	MANNITOL	SUCROSE	LACTOSE	PROBABILE ISOLATE
LZS	+				+	+	+	+		+	+	+	+		<i>S. cerevisiae</i>
LZU	+	+	+	-	+	+	+	+	+	+	+	+	+	-	<i>C. albican</i> <i>S. cerevisiae</i>
FFS	+				+	+	+	+		+	+	+	+		<i>S. cerevisiae</i>
FFU	+	+	+	-	+	+	+	+	+	+	+	+	+	-	<i>C. albican</i> <i>S. cerevisiae</i>
TYS	+				+	+	+	+		+	+	+	+		<i>S. cerevisiae</i>
TYU	+	+	+	-	+	+	+	+	+	+	+	+	+	-	<i>C. albican</i> <i>S. cerevisiae</i>
TJS	+				+	+	+	+		+	+	+	+		<i>S. cerevisiae</i>
TJU	+	+	+	-	+	+	+	+	+	+	+	+	+	-	<i>C. albican</i> <i>S. cerevisiae</i>
CYS	+				+	+	+	+		+	+	+	+		<i>S. cerevisiae</i>
CYU	+	+	+	-	+	+	+	+	+	+	+	+	+	-	<i>C. albican</i> <i>S. cerevisiae</i>
HYS	+				+	+	+	+		+	+	+	+		<i>S. cerevisiae</i>
LZG	+				+	+	+	+		+	+	+	+		<i>S. cerevisiae</i>
CGY	+				+	+	+	+		+	+	+	+		<i>S. cerevisiae</i>
TJG	+				+	+	+	+		+	+	+	+		<i>S. cerevisiae</i>
LZF	+	+	+	-	+	+	+	+	+	+	+	+	+	-	<i>C. albican</i> <i>S. cerevisiae</i>

Key: LZS = (organic; L & Z yoghurt sweetened), LZU (Organic ; L & Z yoghurt unsweetened), FFS (Organic; Farm fresh yoghurt sweetened), FFU (Organic; Farm fresh yoghurt unsweetened), TYS = (Inorganic; Tito yoghurt sweetened), TYU= (Inorganic; Tito yoghurt unsweetened), TJS = (Inorganic; TJ yoghurt sweetened), TJU (Inorganic ;TJ yoghurt sweetened), CYS= (Inorganic; Cedaa yoghurt sweetened), CYU = (Inorganic; Cedaa yoghurt unsweetened), HYS = (Organic; Habib yoghurt sweetened), LZG = (Organic; L & Z Greek yoghurt sweetened) CGY=(Inorganic; Cedaa Greek yoghurt sweetened), TJG = (Inorganic; TJ Greek yoghurt sweetened), LZF = (Organic; L & Z Fura)

Microbial components of yoghurts

The total viable bacterial counts (TVBC) in the yoghurt samples are shown in Table 5. It exhibits a wide variation from 6 cfu/100 mL to 79 cfu/100 mL. The total viable lactic acid bacterial count (TVLBC) in this study ranged from 12 cfu/100 mL to 18 cfu/100 mL, while the total viable yeast and mold count (TVYMC) in this study ranged from 2 cfu/100 mL to 31 cfu/100 mL.

Table 5: Total Viable Bacterial Counts (TVBC) in the Yoghurt Samples

Sample Name	TVBC (cfu/100 mL)	TVLBC (cfu/100 mL)	TVYMC (cfu/100 mL)
LZS	1.2×10^3	1.7×10^3	0.2×10^3
LZU	7.4×10^3	1.8×10^3	2.4×10^3
FFS	1.0×10^3	1.4×10^3	0.6×10^3
FFU	7.8×10^3	1.7×10^3	2.5×10^3
TYS	1.4×10^3	1.0×10^3	0.4×10^3
TYU	6.2×10^3	1.4×10^3	3.1×10^3
TJS	2.2×10^3	1.4×10^3	0.8×10^3
TJU	6.9×10^3	1.5×10^3	3.0×10^3
CYS	0.8×10^3	1.0×10^3	0.6×10^3
CYU	7.9×10^3	1.6×10^3	2.6×10^3
HYS	0.6×10^3	1.2×10^3	0.4×10^3
LZG	1.0×10^3	1.6×10^3	1.2×10^3
CGY	0.8×10^3	1.4×10^3	0.8×10^3
TJG	0.9×10^3	1.6×10^3	1.2×10^3
LZF	7.1×10^3	1.7×10^3	2.8×10^3

Key: LZS = (organic; L & Z yoghurt sweetened), LZU (Organic ; L & Z yoghurt unsweetened), FFS (Organic; Farm fresh yoghurt sweetened), FFU (Organic; Farm fresh yoghurt unsweetened), TYS = (Inorganic; Tito yoghurt sweetened), TYU= (Inorganic; Tito yoghurt unsweetened), TJS = (Inorganic; TJ yoghurt sweetened), TJU (Inorganic ;TJ yoghurt sweetened), CYS= (Inorganic; Cedaa yoghurt sweetened), CYU = (Inorganic; Cedaa yoghurt unsweetened), HYS = (Organic; Habib yoghurt sweetened), LZG = (Organic; L & Z Greek yoghurt sweetened) CGY= (Inorganic; Cedaa Greek yoghurt sweetened), TJG = (Inorganic; TJ Greek yoghurt sweetened), LZF = (Organic; L & Z Fura).

Cultural, biochemical characteristics and identification of bacterial isolated from Yoghurt

The bacteria isolated from the yoghurt samples are presented Table 6. *Lactobacillus delbrueckii subsp. bulgaricus* were identified in thirteen yoghurt samples (LZS, LZU, FFS, FFU, TYS, TYU, TJS, TJU, CYS, HYS, LZG, CGY, and TJG), *Staphylococcus epidermidis* also had thirteen occurrences in the yoghurt samples (LZU, FFS, FFU, TYS, TYU, TJS, TJU, CYS, HYS, LZG, CGY, TJG, and LZF). *Lactobacillus casei* was identified in seven yoghurt samples (LZS, LZU, FFU, TJU, CYU, LZG, and LZF), *Lactococcus lactis* was identified in six yoghurt samples (LZU, FFU, TYU, TJS, TJU, and TJG), *bacillus subtilis* was identified in five yoghurt samples (LZU, FFU, TYU, TJS, and CYU), *Citrobacter freundii* was isolated in LZF and *Lactobacillus fermentum* in TJU.

Table 6: bacterial isolated from Yoghurt samples

S/N	Sample Code	Gram Reaction	Shape	Identified Organism
1	LZS	+	L	Lactobacillus casei
2	LZS	+	L	Lactobacillus delbrueckii subsp. bulgaricus
3	LZU	+	C	Staphylococcus epidermidis
4	LZU	+	L	Lactobacillus delbrueckii subsp. bulgaricus

5	LZU	+	L	Bacillus subtilis
6	LZU	+	L	Lactococcus lactis
7	LZU	+	L	Lactobacillus casei
8	FFS	+	L	Lactobacillus delbrueckii subsp. bulgaricus
9	FFS	+	C	Staphylococcus epidermidis
10	FFU	+	C	Staphylococcus epidermidis
11	FFU	+	L	Lactobacillus delbrueckii subsp. bulgaricus
12	FFU	+	L	Lactococcus lactis
13	FFU	+	L	Bacillus subtilis
14	FFU	+	L	Lactobacillus casei
15	TYS	+	L	Lactobacillus delbrueckii subsp. bulgaricus
16	TYS	+	C	Staphylococcus epidermidis
17	TYU	+	C	Staphylococcus epidermidis
18	TYU	+	L	Bacillus subtilis
19	TYU	+	L	Lactobacillus delbrueckii subsp. bulgaricus
20	TYU	+	L	Lactococcus lactis
21	TJS	+	L	Lactobacillus delbrueckii subsp. bulgaricus
22	TJS	+	L	Lactococcus lactis
23	TJS	+	C	Staphylococcus epidermidis
24	TJS	+	L	Bacillus subtilis
25	TJU	+	C	Staphylococcus epidermidis
26	TJU	+	L	Lactococcus lactis
27	TJU	+	L	Lactobacillus delbrueckii subsp. bulgaricus
28	TJU	+	L	Lactobacillus fermentum
29	TJU	+	L	Lactobacillus casei
30	CYS	+	L	Lactobacillus delbrueckii subsp. bulgaricus
31	CYS	+	C	Staphylococcus epidermidis
32	CYU	+	L	Lactobacillus casei
33	CYU	+	L	Bacillus subtilis
34	HYS	+	L	Lactobacillus delbrueckii subsp. bulgaricus
35	HYS	+	C	Staphylococcus epidermidis
36	LZG	+	L	Lactobacillus casei
37	LZG	+	L	Lactobacillus delbrueckii subsp. bulgaricus
38	LZG	+	C	Staphylococcus epidermidis
39	CGY	+	L	Lactobacillus delbrueckii subsp. bulgaricus
40	CGY	+	C	Staphylococcus epidermidis
41	TJG	+	L	Lactobacillus delbrueckii subsp. bulgaricus
42	TJG	+	L	Lactococcus lactis
43	TJG	+	C	Staphylococcus epidermidis
44	LZF	+	L	Lactobacillus casei
45	LZF	+	C	Staphylococcus epidermidis
46	LZF	+	R	Citrobacter freundii

Key: LZS = (organic; L & Z yoghurt sweetened), LZU (Organic ; L & Z yoghurt unsweetened), FFS (Organic; Farm fresh yoghurt sweetened), FFU (Organic; Farm fresh yoghurt unsweetened), TYS = (Inorganic; Tito yoghurt sweetened), TYU= (Inorganic; Tito yoghurt unsweetened), TJS = (Inorganic; TJ yoghurt sweetened), TJU (Inorganic ;TJ yoghurt sweetened), CYS= (Inorganic; Cedaa yoghurt sweetened), CYU = (Inorganic; Cedaa yoghurt unsweetened), HYS = (Organic; Habib yoghurt sweetened), LZG = (Organic; L & Z Greek yoghurt sweetened) CGY=(Inorganic; Cedaa Greek yoghurt sweetened), TJG = (Inorganic; TJ Greek yoghurt sweetened), LZF = (Organic; L & Z Fura) ; **Shape** : (L = Long Rod, C = Cocci, R = Rod)

Organoleptic and Sensory Properties

The report of the organoleptic evaluation is presented Table 7 below. A total number of twenty (20) respondents participated. Rating of parameters such as appearance (colour), aroma, taste and general acceptance were evaluated on a scale of 0-4. 0 stands for poor, 1 stand for fair, 2 stands for good, 3 stands for very good and 4 stands for excellent. In the appearance rating, HYS and CGY had excellent as the highest frequency of 18 out of the 20 respondents. This implies that 90% of the respondents considered both products as excellent. Similarly, the same trend of ratings is also observed for aroma, taste and general acceptance. The results of table 7 show that the appearance rating was between very good and excellent. This is suggestive that the textural and viscosity of the fifteen examined yoghurts are suitable and of good standard. The same pattern of rating was observed for aroma, where respondents only agreed with ‘very good and excellent’. Furthermore, it is evidence that a good number of respondents rated very good and excellent for taste and general acceptance, and only about 2 percent agreed with ‘good’. This observation clearly reveals that the mouth feel and sensory properties of the yoghurt samples examined are in compliance with the established WHO/FDA standards. And will continue to have increased sales among the general public. In general, the overall acceptance follows the order: HYS > CGY = FFU > LZS = TJS = TJU = LZF > TYU = CYS = LZG = TJG > LZU = FFS = TYS = CYU.

Table 7: Organoleptic Evaluation of yoghurt samples

SAMPLE	APPEARANCE ACCEPTABILITY					AROMA					TASTE					GEN.				
	0	1	2	3	4	0	1	2	3	4	0	1	2	3	4	0	1	2	3	4
LZS	-	-	-	5	15	-	-	-	6	14	-	-	1	3	16	-	-	-	3	17
LZU	-	-	-	4	16	-	-	-	5	15	-	-	2	2	16	-	-	-	5	15
FFS	-	-	-	8	12	-	-	-	4	16	-	-	1	5	14	-	-	2	3	15
FFU	-	-	-	6	14	-	-	-	5	15	-	-	-	5	15	-	-	-	2	18
TYS	-	-	-	7	13	-	-	-	7	13	-	-	-	6	14	-	-	-	5	15
TYU	-	-	-	6	14	-	-	-	6	14	-	-	-	5	15	-	-	-	4	16
TJS	-	-	-	5	15	-	-	-	4	16	-	-	-	6	14	-	-	-	3	17
TJU	-	-	-	6	14	-	-	-	6	14	-	-	-	3	16	-	-	-	3	17
CYS	-	-	-	11	9	-	-	-	5	15	-	-	-	7	13	-	-	-	4	16
CYU	-	-	-	7	13	-	-	-	4	16	-	-	-	6	14	-	-	-	5	15
HYS	-	-	-	2	18	-	-	-	3	17	-	-	-	2	18	-	-	-	1	19
LZG	-	-	-	3	17	-	-	-	5	15	-	-	-	4	16	-	-	-	4	16
CGY	-	-	-	2	18	-	-	-	8	12	-	-	-	3	17	-	-	-	2	18
TJG	-	-	-	4	16	-	-	-	4	16	-	-	-	3	17	-	-	-	4	16
LZF	-	-	-	3	17	-	-	-	5	15	-	-	-	2	18	-	-	-	3	17

Key: 0 = Poor, 1 = Fair, 2 = Good, 3 = Very good and 4 = Excellence. Respondents: 20

LZS = (organic; L & Z yoghurt sweetened), LZU (Organic ; L & Z yoghurt unsweetened), FFS (Organic; Farm fresh yoghurt sweetened), FFU (Organic; Farm fresh yoghurt unsweetened), TYS = (Inorganic; Tito yoghurt sweetened), TYU= (Inorganic; Tito yoghurt unsweetened), TJS = (Inorganic; TJ yoghurt sweetened), TJU (Inorganic ;TJ yoghurt sweetened), CYS= (Inorganic; Cedaa yoghurt sweetened), CYU = (Inorganic; Cedaa yoghurt unsweetened), HYS = (Organic; Habib yoghurt sweetened), LZG = (Organic; L & Z Greek yoghurt sweetened) CGY= (Inorganic; Cedaa Greek yoghurt sweetened), TJG = (Inorganic; TJ Greek yoghurt sweetened), LZF = (Organic; L & Z Fura)

Human Health Risk Assessment

Considering the existing variation in weight of adult body, and daily intake of yoghurt among different people, the health risk index was calculated for adult, with an average age of 70 and an estimated ingestion rate of 0.21 kg/day. The average consumption amounts of yoghurts have been widely studied in the past (Fu, 2015). Furthermore, the estimated daily intake (EDI) was calculated for Fe, Zn and Cu in fifteen (15) different types of yoghurt purchased within Akure metropolis. The result is presented in Table 8. The minimum and maximum EDI for Fe is 0.983 mgkg⁻¹bw/day(LZS) and 4.746 mgkg⁻¹bw/day(CYU). The minimum and maximum EDI for Zn is 0.116 mgkg⁻¹bw/day(TJG) and 0.662 mgkg⁻¹bw/day(CYU). The minimum and maximum EDI for Cu is 0.008(LZS) and 0.025 (TYS). It was observed that the EDI for Fe, Zn and Cu in the yoghurts samples were lower than the oral reference dose (RfD). This observation agrees with the observations of Christophoridis *et al.*, 2019, who reported heavy metal intake for average consumption of yoghurts in Greece, to be extremely low and contributes only a small fraction to the tolerable daily intake for Fe, Zn and Cu.

Table 8: EDI of metals (mg kg⁻¹ bw per day) via consumption of yoghurt by an average adult person.

Samples	Fe	Zn	Cu
LZS	0.983	0.244	0.008
LZU	1.300	0.418	0.027
FFS	1.151	0.315	0.050
FFU	1.378	0.368	0.040
TYS	2.029	0.019	0.025
TYU	2.008	0.246	0.042
TJS	2.289	0.116	0.040
TJU	2.814	0.122	0.046
CYS	3.150	0.204	0.088
CYU	4.746	0.662	0.086
HYS	2.873	0.300	0.082
LZG	3.591	0.370	0.078
CGY	3.696	0.380	0.095
TJG	2.688	0.101	0.071
LZF	3.591	0.254	0.078
Oral Reference Dose	18.000	11.000	2.100

Key: LZS = (organic; L & Z yoghurt sweetened), LZU (Organic ; L & Z yoghurt unsweetened), FFS (Organic; Farm fresh yoghurt sweetened), FFU (Organic; Farm fresh yoghurt unsweetened), TYS = (Inorganic; Tito yoghurt sweetened), TYU= (Inorganic; Tito yoghurt unsweetened), TJS = (Inorganic; TJ yoghurt sweetened), TJU (Inorganic ;TJ yoghurt sweetened), CYS= (Inorganic; Cedaa yoghurt sweetened), CYU = (Inorganic; Cedaa yoghurt unsweetened), HYS = (Organic; Habib yoghurt sweetened), LZG = (Organic; L & Z Greek yoghurt sweetened) CGY= (Inorganic; Cedaa Greek yoghurt sweetened), TJG = (Inorganic; TJ Greek yoghurt sweetened), LZF = (Organic; L & Z Fura)

The estimation of non-carcinogenic risk of Fe, Zn and Cu consumed were determined using target hazard quotient (THQ) values. THQ is a useful parameter for the evaluation of risks associated with the intake of contaminated yoghurts. Hence, the THQ values are presented in Table 9. The THQ for Fe, Zn and Cu in all yoghurts samples were less than one (THQ < 1), suggesting that the consumers of yoghurt in Akure are unlikely to be exposed to a potential health risk (associated with Fe, Zn and Cu) through their consumption of yoghurts.

The severity of health risks caused by toxic elements in yoghurt is enhanced with the increasing THQ value. HI has been reported to assess the overall non-carcinogenic effects of multiple heavy metals in individual yoghurts (Saha and Zaman, 2013).

Table 9: THQ for daily exposure to metals through consumption of yoghurts

Samples	Fe	Zn	Cu
LZS	0.055	0.022	0.004
LZU	0.072	0.038	0.013
FFS	0.064	0.029	0.024
FFU	0.077	0.033	0.019
TYS	0.113	0.002	0.012
TYU	0.112	0.022	0.020
TJS	0.127	0.011	0.019
TJU	0.156	0.011	0.022
CYS	0.175	0.019	0.042
CYU	0.264	0.060	0.041
HYS	0.160	0.027	0.039
LZG	0.200	0.034	0.037
CGY	0.205	0.035	0.045
TJG	0.149	0.009	0.034
LZF	0.200	0.023	0.037

Key: LZS = (organic; L & Z yoghurt sweetened), LZU (Organic ; L & Z yoghurt unsweetened), FFS (Organic; Farm fresh yoghurt sweetened), FFU (Organic; Farm fresh yoghurt unsweetened), TYS = (Inorganic; Tito yoghurt sweetened), TYU= (Inorganic; Tito yoghurt unsweetened), TJS = (Inorganic; TJ yoghurt sweetened), TJU (Inorganic ;TJ yoghurt sweetened), CYS= (Inorganic; Cedaa yoghurt sweetened), CYU = (Inorganic; Cedaa yoghurt unsweetened), HYS = (Organic; Habib yoghurt sweetened), LZG = (Organic; L & Z Greek yoghurt sweetened) CGY= (Inorganic; Cedaa Greek yoghurt sweetened), TJG = (Inorganic; TJ Greek yoghurt sweetened), LZF = (Organic; L & Z Fura)

CONCLUSION

There exist slight variations in physicochemical parameters, including pH, conductivity, density, viscosity, moisture, titratable acidity, ash, fat, and protein content of the yoghurt samples. Most samples had pH values above the FDA limit of 4.6, potentially indicating low availability of fermenting microbes. Greek yoghurts demonstrated higher viscosity and protein content, while higher moisture content in some samples suggested a shorter shelf-life. The viscosity value for all yoghurt samples falls within the range of thick and creamy yoghurts. The fat content was relatively high, contributing to caloric value and essential nutrients. Unsweetened and Greek yoghurts generally offer higher protein content, making them more suitable for individuals seeking to increase their protein intake. This could be due to the absence of added sugars or sweeteners, which might otherwise dilute the protein concentration. *S. cerevisiae* and *C. albican* were isolated in LZU, FFU, TYU, TJU, CYU and LZF. While all other yoghurt samples have only *S. cerevisiae* isolate. The THQ for Fe, Zn and Cu in all yoghurts samples were less than one (THQ < 1), suggesting that the consumers of yoghurt in Akure are unlikely to be exposed to a potential health risk (associated with Fe, Zn and Cu) through their consumption of yoghurts, as at the time of this investigation. Nevertheless, there still need to establish the therapeutic mechanism of yoghurt on a particular aspect of human health and how variations in formulation affect its efficacy.

Author Contributions

Amoo Isiaka Adekunle: Conceptualization, methodology, Resources, visualization, supervision, project administration, interpretation of data, review and editing; **Muraina Mutairu Omoniyi:** methodology, Formal analysis, investigation, Resources, data analysis and interpretation, writing original draft ; **Ilade Odunayo Josephine:** Visualization, Resources, investigation, interpretation of data, review and editing

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