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Physicochemical, Mineral and Sensory Properties of Yoghurt Sweetened with Three Different Sweeteners

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Abstract: This study is aimed at comparing the physicochemical, sensory and mineral properties of yoghurt sweetened different sweeteners namely sugar, stevia and goron tula. The physicochemical properties examined include pH, viscosity, titratable acidity (TTA), total solids (TS) and brix while the minerals analyzed included calcium (Ca), magnesium (Mg), potassium (K), iron (Fe), and phosphorus (P). The yoghurt samples were prepared using standardized methods. The result of the physicochemical properties show that the pH values ranged from 2.58 to 4.06, viscosity varied from 40.63 to 97.43 cP. Titratable acidity values ranged from 0.85 to 1.75%, total solid values ranged from 13.71 to 35.90% while the brix content ranged from 10.72 to 33.00°Bx. The mineral composition indicates that calcium content ranged from 40.31 to 121.67 mg/100ml. Magnesium content varied from 18.67 to 26.60 mg/100ml. Potassium content ranged from 108.00 to 193.00 mg/100ml while the iron content varied from 2.00 to 9.30 mg/100ml. Finally, phosphorus content ranged from 50.80 to 128.33 mg/100ml. In the overall acceptability, the yoghurt sample prepared with goron tula compares favorably with the one prepared with sugar. The results demonstrated significant ($p \leq 0.05$) variations in all the parameters analyzed. These findings can be useful in determining the desired characteristics of yogurt.

Keywords: *Yoghurt, Sugar, Stevia, Goron tula, Mineral.*

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I. INTRODUCTION

Yoghurt is a widely consumed fermented dairy product valued for its nutritional quality, digestibility, and probiotic benefits. It has been consumed for centuries owing to its nutritional and health benefits, including improved digestion, enhanced immune function, and increased longevity (Li *et al* 2025). It is produced through the fermentation and acidification of milk by viable bacteria, primarily *Lactobacillus bulgaricus* and *Streptococcus thermophilus*, a process that results in a thickened product with an increased shelf life (Hadjimbei *et al.*, 2022). Research has shown that lactic acid bacteria displaced toxin-producing bacteria ordinarily present in the intestine, resulting in prolonged life (Ivanov *et al*., 2021). Yoghurt is among the most popular fermented foods in the world and enjoys wide consumer acceptability due to its taste and health benefits. It can be used as an accompanier of the main meal or as a snack during the day. The word yoghurt probably originates from the Turkish term "yogurmak," which means to thicken, coagulate, or curdle (McGee *et al.*, 2004). It is believed that yoghurt was accidentally discovered around 5000–10,000 BC with the domestication of milk-producing animals. At that time, shepherds in the Middle East carried milk in sacks constructed of intestinal gut, which caused the milk to curdle and sour when it came into contact with intestinal secretions, thus naturally preserving it and enabling a longer storage period for a vital commodity such as milk (Fisberg and Machado, 2015). The Mediterranean diet pyramid suggests the daily consumption of moderate amounts of dairy products, principally yoghurt and cheese (Willett *et al.*, 1995), while dietary recommendations for dairy products throughout the world are 2–3 servings daily (Ratajczak *et al.*, 2021). Currently, three types of yoghurts are industrially made: (i) set-type yoghurt, (ii) stirred-type yoghurt, and (iii) yoghurt drinks, all with or without the addition of fruits and/or other flavorings (Bylund, 2003).

Nutritionally, yoghurt is a rich source of calcium in a bioavailable form, and also provides phosphorus, potassium, vitamin A, vitamin B2, and vitamin B12, as well as high biological value proteins and essential fatty acids (Hadjimbei *et al.* 2022). The proteins in yoghurt have been found to be more digestible than those in unfermented milk. The heat treatment and acid production involved in the fermentation process breaks down milk proteins into smaller, more easily digested forms, while also releasing free amino acids (Yogurt in Nutrition Initiative , 2015). The regular yogurt consumption provides abundant essential nutrients (proteins, minerals, lipids, and carbohydrates), and this supports gut microbiota, immune function, gastrointestinal health, and reducing the risk of chronic diseases such as cardiovascular disease, cancer, and type 2 diabetes (Hasegawa and Bolling, 2023).

Sweetening is an essential step in yoghurt production as it enhances palatability and consumer acceptance. Consumers are interested in products with reduced sugar, a trend which has been attributed to consumers associating high-sugar foods with obesity, diabetes, heart disease, and high blood pressure (Hadjimbei *et al.*2022). Conventional sucrose remains widely used as the standard sweetener in yoghurt, and yoghurt sweetened with sucrose typically receives the highest liking scores in flavour, taste, consistency and appearance compared to other sweeteners, with a longer dominant duration of sweet taste (Danielyan *et al.* 2024). However, most commercialized yogurts that are sold in grocery stores contain added sugars, artificial ingredients, and only a marginal amount of probiotics. Mercola (2017) suggested that homemade yogurt is an excellent way of getting probiotics into your system without the unnecessary chemicals and flavorings found in commercialized yogurts. The use of traditional sweeteners like sugar has raised concerns regarding their potential health effects leading to the search for alternative sweeteners. Stevia, a natural low-calorie sweetener, extracted from the leaves of the stevia plant. It is 200 to 300 sweeter than sugar. Stevia is used in a wide range of foods and beverages, including teas and juices, and as a tabletop sweetener (Cleveland, 2020). Stevia is considered to be hypoglycemic, diuretic, cardio tonic and tonic. The stevia leaves contain protein, fibre and at least 100 phytonutrients (Ahmada *et al.*, 2020). Goron tula (Azanza garckeana F. Hoffm), locally known as "Tula kola nut" in Gombe State and belonging to the family Malvaceae, is an underutilised indigenous fruit in Nigeria with significant nutritional and functional potential (Michael *et a.,l* 2015). The fruits have been reported to have a variety of minerals including phosphorus, calcium, magnesium, iron, potassium, sodium, cobalt, copper, manganese and zinc as well as a vast amount of various vitamins, vitamin C (Danbature *et al.*, 2015).

This study is aimed at comparing the physicochemical, sensory as well as the mineral properties of yoghurt sweetened with these three different sweeteners (sugar, stevia, and goron tula) in order to provide insights into the impact of different sweeteners on its potential health.

II. MATERIALS AND METHODS

Three kilogram(3kg) of powdered cow milk (Dano full ceam) , six gram (6g) of freeze dried starter culture , and one hundred gram (100g) each of granulated sugar (YCA), powdered stevia (YSB), and powdered gorontula (YGC) were purchased from grocery shop at Onitsha in Anambra state., Nigeria. All the raw materials were packaged in a clean bag and taken to the Food Processing Laboratory of Department of Food Technology, Federal Polytechnic Oko, Anambra State, Nigeria; for further processing and analysis

➢ *Production of Yoghurt*

Stirred yoghurt was produced following the method of Okoye and Obi (2016), with slight modifications. Whole milk powder (1 kg) was reconstituted in three litres (3 L) of potable water to obtain a homogeneous milk solution. The reconstitution process was carried out in triplicate using separate, sterile plastic containers to ensure sample uniformity. The reconstituted milk samples were pasteurized at 65°C for 30 minutes. Following pasteurization, the milk was cooled to 43°C. Each cooled milk sample was inoculated with equal quantities of a yoghurt starter (6g) culture containing *Lactobacillus bulgaricus* and *Streptococcus thermophilus*, and thoroughly mixed to ensure even microbial distribution. The inoculated samples were covered and allowed to ferment undisturbed for 12 hours at ambient conditions. At the end of fermentation, 100 g of each sweetener **(**sugar, stevia, and goron tula**)** was added separately to the respective yoghurt samples. Each sample was stirred thoroughly to achieve uniform dispersion of the sweeteners, resulting in stirred yoghurt. The yoghurt samples were then stored under refrigerated conditions (4°C) prior to further physicochemical and sensory analyses.

➢ *Analysis*

The pH was determined using calibrated Seven Easy Mettler Toledo pH meter , the viscosity was determined using Dynamic Controlled Stress Rheometer, the titratable acidty was determined by titrating the yoghurt samples with a standardized alkaline solution and expressing the results as a percentage of lactic acid, the total solids was determined by evaporating a known weight of yoghurt sample until constant weight and expressing the results as a percentage while the brix value was determined by using a refractometer. The mineral (calcium, magnesium, potassium, iron, phosphorus) content of the yoghurt samples were determined by absorption spectrometer as described by Kirk (1991). All analyses were done in triplicates. The results were subjected to one way analysis of variance (one-way ANOVA) using SPSS 20.0 version software while the means were separated with Duncan multiple range test at a significance level of $p < 0.05$.

➢ *Sensory Evaluation*

The yoghurt samples were subjected to sensory evaluation using 20 semi trained panelists drawn from among the students of Federal Polytechnic Oko, Anambra State, Nigeria. 15 ml of each of the yoghurt sample was put into covered cups, for every panelist. The samples were labeled with 3-digit codes to avoid bias and then served in counterbalanced order whereby if 2 different samples were served; the first half of the panel would receive the first one while the other half received the next sample. The panelists were provided with clean water to rinse their mouths between sample tasting. The parameters assessed were colour, aroma, taste, texture and overall acceptability. A 9-point hedonic rating scale where 9 represents like extremely and 1

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represents dislike extremely was used (Ihekoronye *et al.*, 2018).

III. RESULTS AND DISCUSSION

Table 1 revealed the Physicochemical and Mineral composition of yoghurt sweetened with three different sweeteners (sugar, stevia, goron tula). Physicochemical properties play a vital role in determining the quality and sensory attributes of the yoghurt samples. pH affects the product's acidity and stability. Lower pH values indicate higher acidity. Codex (2003) reported that, the maximum pH value of yoghurt is (4.50) in order to prevent the growth of any pathogenic. The optimum acidic conditions of commercial yoghurt are generally considered to fall within the pH range of 4.0–4.4, beyond which excessive sourness becomes a sensory concern (Hoxha *et al*., 2023). The pH values recorded across the three yoghurt samples differed significantly ($p \leq 0.05$), with YCA recording the highest pH (4.06), followed by YSB (3.10) and YGC (2.50). The pH of YCA falls within this acceptable range, suggesting that sucrose-sweetened yoghurt underwent fermentation within the standard. The lower pH values of YSB and YGC, however, suggest enhanced lactic acid production is influenced by the composition of the respective sweeteners. The pH values of the yoghurt samples were comparable with the pH of five commercial yoghurt samples evaluated by Igbabul *et al.* (2014). Saleem *et al*. (2024) reported that the growth of lactic acid bacteria in yoghurt causes the accumulation of organic acids, primarily lactic acid. These differences in pH may be attributed to the different sweetening agents used.

The titratable acidity (TTA) values indicates an increase in the order YCA (0.85%) < YSB (0.91%) < YGC (1.75%), all significantly different ($p \leq 0.05$). The typical titratable acidity range for finished yoghurt falls between 0.85–1.20% lactic acid equivalent (Li *et al*,2025). The lower titratable acidity value indicate lower acidity. The sugar sweetened yoghurt had the least TTA. The TTA of YSB falls within this acceptable range, The TTA of YGC, at 1.75%, considerably exceeds this standard range, which may be due to the rich polyphenolic and organic acid content of Goron tula (*Azanza garckeana*) contributing to the total measurable acidity of the product.

Viscosity values increased significantly ($p \leq 0.05$) from YCA (40.63 cP) to YSB (56.27 cP) to YGC (97.43 cP). Viscosity is a critical determinant of yoghurt texture and consumer perception. Viscosity and firmness of yoghurt increase with an increase in total solid content, with viscosity being affected by total solids, acidity, milk composition, homogenisation, type of culture, stabiliser, and degree of proteolysis (Hoxha *et al*., 2023). The progressively higher viscosity observed across YCA, YSB, and YGC is consistent with the corresponding increase in total solids content and titratable acidity. The high viscosity of YGC is attributed to the carbohydrate-rich composition of Goron tula.

Total solids content and Brix values followed the same increasing pattern: YCA (13.71%; 10.72 °Bx) < YSB (21.70%; 19.00 °Bx) < YGC (35.90%; 33.00 °Bx), all significantly different. The addition of sucrose increases the total solids of the yoghurt mix and strengthens the gel network, with a range of alternative sweeteners used commercially particularly for low-calorie products (Yogurt in Nutrition Initiative, 2015). However, note that the total solids and Brix of YGC are consistent with the known compositional richness of *Azanza garckeana*, which has a proximate carbohydrate content of approximately 69% on a dry weight basis, contributing substantially to the soluble solid load of the finished product. (Hoxha *et al* 2023). The high Brix of YGC therefore reflects the dense soluble solids contributed by Goron tula powder. Total soluble solids as measured by refractometry are widely reported to increase proportionally with the carbohydrate content of added ingredients in yoghurt formulations. The goron tula sweetened yoghurt has the highest total solids (35.90 %), followed by Stevia (21.7%) and sugar (13.71%). Goron tula significantly increased the concentration of solids in the yoghurt, while Stevia has a moderate effect and sugar has the lowest impact.

Calcium is important for bone health and various physiological processes. Calcium content was highest in YCA (121.67 mg/100 ml), followed by YGC (70.17 mg/100 ml) and lowest in YSB (40.13 mg/100 ml), with significant differences across all samples. Total calcium content in commercial yoghurts shows wide variation (1090–2050 mg/L), largely due to differences in the addition of dairy-derived ingredients during manufacturing. (Crown *et al*., 2024). The highest calcium in YCA reflects the inherent calcium supplied by the milk base Yoghurt's acidic pH, resulting from lactic acid production during fermentation, increases calcium ionisation and its passive diffusion across intestinal membranes (Mora *et al.*, 2022). Some studies indicate that yoghurt consumption leads to higher calcium uptake compared to milk, suggesting that fermentation enhances mineral bioavailability (Mora *et a.,l* 2022). The elevated calcium in YGC as against that of YSB may be partly attributable to the calcium contribution of Goron tula itself, which has been documented as a source of calcium alongside other minerals including magnesium, potassium, and iron.

Magnesium plays a role in various biochemical reactions and is important for overall health. Stevia-sweetened yoghurt had the highest magnesium content (25.73 mg/100ml) and this is significantly ($p \leq 0.05$) different from other yoghurt samples. Magnesium values were significantly higher in both YSB (25.73 mg/100 ml) and YGC (26.60 mg/100 ml) compared to YCA (18.67 mg/100 ml), while YSB and YGC were not significantly different from each other. Magnesium content in commercial yoghurts typically ranges from 101–177 mg/L (Crown *et* al., 2024). The increased magnesium content of YGC aligns with the known mineral richness of *Azanza garckeana*.

Potassium was significantly highest in YGC (193.00 mg/100 ml), followed by YCA (120.67 mg/100 ml), with YSB recording the lowest value (108.00 mg/100 ml). Potassium in yoghurts has been reported at an average of

143.53 mg/100 g in commercial drinking yoghurts, with this mineral playing an important role in cardiovascular health and blood pressure regulation. (Hadjimbei *et al* 2022). The differences could be attributed to the type of milk powder used. The substantially higher potassium in YGC is consistent with Goron tula being an indigenous fruit source recognised for its potassium content.

Iron content increased significantly across samples: YCA (2.00 mg/100 ml) < YSB (4.70 mg/100 ml) < YGC (9.30 mg/100 ml). however, the high iron content in YSB and especially YGC represents a notable enrichment attributable to the iron content of the added sweeteners. Milk and dairy products are considered very poor sources of iron, with low contributions of dairy products to total iron intake (Graczykowska *et al*., 2021). *Azanza garckeana* has been identified as a source of dietary iron, making its inclusion in yoghurt a potentially meaningful strategy for improving the iron density of fermented dairy products, particularly within the Nigerian context where iron deficiency anaemia remains a public health concern (Micheal *et al.*,2015)

Phosphorus was highest in YCA (128.33 mg/100 ml), then followed by YSB (59.00 mg/100 ml) and further to YGC (50.80 mg/100 ml). The high phosphorus in YCA is consistent with the well-documented phosphorus content of dairy-based yoghurts, where casein micelles serve as the primary phosphorus reservoir. (Crown *et al*., 2024). Phosphorus is a mineral that forms hydroxyapatite — the main structural component of bones and enamel — along with calcium, and dairy products are considered a good source of bioavailable phosphorus (Mora *et al*., 2022).

The sensory evaluation revealed significant ($p \leq 0.05$) differences among all yoghurt samples across appearance, aroma, taste, texture, and overall acceptability. The yoghurt sweetened with goron tula (YGC) compare favourably with that sweetened with sugar. This could be as a result of the enhanced texture, which contributed to its highest overall acceptability score. The stevia-sweetened sample (YSB) recorded the lowest scores in most attributes, possibly due to its distinct aftertaste. These results show the influence of sweetener type on sensory properties and provide an insight into consumer preference and product development.

Table 1: Physicochemical and Mineral Composition of Yoghurt Sweetened with Three Different Sweeteners (sugar, stevia, goron tula)

Parameters	YCA	YSB	YGC
pH	$4.06^a \pm 0.01$	$3.10^b \pm 0.01$	$2.50^c \pm 0.01$
Titratable Acidity (%)	$0.85^c \pm 0.04$	$0.91^b \pm 0.00$	$1.75^a \pm 0.02$
Viscosity (cP)	$40.63^c \pm 0.04$	$56.27^b \pm 0.02$	$97.43^a \pm 0.00$
Brix(^{0}Bx)	$10.72^c \pm 0.02$	$19.00^b \pm 0.05$	$33.00^a \pm 0.00$
Calicum(mg/100ml)	$121.67^a \pm 0.09$	40.13c±0.11	$70.17^b \pm 0.14$
Magnesium(mg/100ml)	$18.67^b \pm 0.52$	$25.73^a \pm 0.30$	$26.60^a \pm 0.21$
Potassium(mg/100ml)	$120.67^b \pm 0.08$	$108.00^c \pm 0.00$	$193.00^a \pm 0.04$
Iron(mg/100ml)	$2.00^c \pm 0.50$	$4.70^b \pm 0.08$	$9.30^a \pm 0.06$
Phosphorus (mg/100ml)	$128.33^a \pm 0.21$	$59.00^b \pm 0.01$	$50.80^c \pm 0.60$
Appearance	$8.10^a \pm 0.15$	$7.20^c \pm 0.18$	$7.40^b \pm 0.12$
Aroma	$7.85^a \pm 0.20$	$7.10^c \pm 0.22$	$7.30^b \pm 0.15$
Taste	$7.90^a \pm 0.18$	$7.00^b \pm 0.29$	$8.20^a \pm 0.013$
Texture	$7.70^b \pm 0.16$	$7.15^c \pm 0.19$	$8.10^a \pm 0.10$
Overall Acceptability	$7.88^b \pm 0.14$	$7.07^c \pm 0.17$	$7.92^a \pm 0.11$

➢ *Keywords*

YCA is yoghurt sweetened with sugar ; YSB is yoghurt sweetened with stevia is while Yoghurt sweetened with gorontula is coded YGC. Values are means ± SD. Means in the same row for the same parameter bearing the different subscript letter are significantly ($p \leq 0.05$) different.

IV. CONCLUSION

In summary, the physicochemical and mineral data of Table 1 shows that the choice of sweetener exerts significant effects on the quality attributes of yoghurt. YCA has the most conventional physicochemical profile but it is c limited in mineral diversity. YGC exhibited superior performance across several functional parameters — including viscosity, total solids, titratable acidity, potassium, magnesium, and iron — reflecting the mineral-rich and carbohydrate-dense composition of *Azanza garckeana*. These findings suggest that Goron tula represents a promising functional sweetener for yoghurt enrichment, with potential nutritional advantages over conventional sucrose for health-conscious and nutritionally vulnerable consumers.

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