NATIONAL AGRICULTURAL AND FOOD CENTRE
RESEARCH INSTITUTE FOR ANIMAL PRODUCTION NITRA

Slovak J. Anim. Sci., 58, 2025 (2): 45–55
ISSN 1337-9984, E-ISSN 1338-0095
SCICELL

PHYSICOCHEMICAL AND ORGANOLEPTIC CHARACTERISTICS OF GREEK-TYPE YOGHURT DIFFERENTLY FORMULATED

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ABSTRACT

The demand for high protein and low carbohydrate (sugar) diet has resulted into development of Greek-type yoghurt, which is reported to have an improved nutrient profile, texture and an extended shelf-life. Therefore, this study evaluated the physicochemical and organoleptic properties of Greek-type yoghurt differently formulated. Greek-type yoghurt was prepared from 45 litters of fresh milk, divided into three batches to differently formulate: TN (fortified with gelatine), ST (traditionally strained) and TS (increased total solid). The organoleptic, physicochemical and microbial populations of Greek yoghurt produced commercially (A, B and C) and in the laboratory (TN, ST and TS) were evaluated using the standard procedure on day 0, 14 and 28 in a completely randomized design. Data were subjected to ANOVA at $\alpha = 0.05$. The results show that there was no significant ($P > 0.05$) difference in the TBC of the three commercially available Greek-type yoghurts (A, B, C); product A contained high fungi (0.4×10^5) with no coliform recorded in the three products (A, B, C). Formulated samples revealed TN as a sample with highest number of microbes, while ST had the lowest. As the storage days progressed, microbial count increased; the highest microbial load was recorded on day 28. ST was significantly higher in CP, pH, WHC, fat, total solid and has the lowest value in lactose, syneresis and TTA, while TN was significantly ($P < 0.05$) higher in syneresis and TTA. No significant difference ($P > 0.05$) was observed in the CP of Greek-type yoghurt as the storage days increased; fat, total solid, pH and WHC declined with storage days, while TTA and syneresis increased with storage days. Significant changes in storage were observed during the early days (0 – 13) with no significant changes on latter days (14 – 28). The yoghurt was accepted and rated by the consumer in this sequence: TS>ST>TN.

Key words: milk; Greek-type yoghurt; microbial load; shelf-life

INTRODUCTION

Protein is an inevitable nutrient, which necessitates its inclusion in human's diet. The demand for protein is increasing with increasing population, which results in human sourcing for protein from animal sources such as egg, meat and milk to meet up the demand and combat the problem of malnutrition (Rizzoli, 2014). Milk is defined as white liquid food, produced by the mammary glands of mammals, and it is regarded as nature's most complete food (Gorska-Warsewicz *et al.*, 2019). Milk and milk products are nutrient-dense foods, supplying energy and high-quality protein with a range of essential micronutrients in an easily absorbed form (Rizzoli, 2014). Ismail (2015) reported that milk is a valuable nutritious food for proper development and maintenance, however, it is highly perishable and characterized by short shelf-life. This is because milk is an excellent medium for the growth of micro-organisms capable of causing spoilage and diseases (Orla & Paul, 2017).

The shelf-life of milk can be extended by fermenting and converting milk into certain milk products such as butter, cheese and yoghurt (Behare *et al.*, 2016).

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Received: January 6, 2025
Accepted: May 22, 2025

https://doi.org/10.36547/sjas.1015

Adding value to milk and milk products do not only extend its shelf-life but it also improves its nutritive value, which promotes food safety (FAO & WHO, 2020). Yoghurt is regarded as the most nutritional product among all fermented dairy foods and over the years has been brought into the category of food that contributes to human's health (Behare *et al.*, 2016).

The desire for high protein- low carbohydrate yoghurt drink results in the elimination of whey (a high carbohydrate supernatant) from yoghurt to obtain Greek-type yoghurt, a product with a thicker consistency (de Oliveira, 2014; Camilla *et al.*, 2018). The process of eliminating whey could be achieved through traditional straining, addition of milk powder and fortification with thickener such as pectin, agar, gelatine and starch (Boynton and Novakovic, 2014). The eliminated whey enhanced the production of richer and creamier yoghurt which is low in fat, higher in protein, lower in sugar or carbohydrate (de Oliveira, 2014) and this has increased the demand for this yoghurt variety (Jaoude *et al.*, 2010; Pappa *et al.*, 2024).

The expulsion of whey from Greek-type yoghurt helps in extending its shelf-life by impeding microbial spoilage through reduction of water activity (Rahman, 2007). However, there is paucity of information on the production, nutrition and consumption of Greek--type yoghurt especially in Southwest, Nigeria. Hence, this work evaluated the physicochemical and organoleptic characteristics of Greek-type yoghurt differently formulated.

MATERIAL AND METHODS

The research was carried out at Animal Products and Processing Laboratory, Department of Animal Science, University of Ibadan, Ibadan, Oyo State, Nigeria.

Collection and evaluation of commercial Greek-type yoghurt

Three samples of Greek-type yoghurt produced commercially (A, B, C) were obtained from reliable retail outlet in Ibadan. At purchase, the manufacturing details, such as NAFDAC number, batch number, manufacturing date, expiry date and ingredients, were monitored. The Greek-type yoghurts were transported to the laboratory for evaluation of its microbial population (bacteria, coliform and fungi) according to the procedure of Abdul *et al.* (2018).

Preparation of Greek-type yoghurt

A total of forty-five (45) litres of fresh milk were collected from White Fulani cow. The pH of the milk was determined using a portable pH meter to ascertain the quality of milk. A total of 15 litres were used in preparation of each method adopted. The yoghurt starter culture was a mixed strain of *Lactobacillus delbruekii subsp. bulgaricus*, *Streptococcus thermophilus* at the ratio of 1:1. A total of 700 g of whole milk powder and 200 g of gelatine thickener were purchased from reliable supermarket.

Traditional straining of conventional yoghurt (ST)

A total of fifteen (15) litres of milk were homogenized and pasteurized at a temperature of 66 °C for 30 min. The pasteurized milk was cooled down to 45 °C and inoculated with starter cultures (3 %, v/v). It was then incubated at 45 °C for 12 hours. The yoghurt obtained was poured inside cheesecloth for straining and placed inside a refrigerator at 4 °C; this process was carried out for 4 hours, when the desired mass was obtained (Boynton and Novakovic, 2014).

Increasing the total solid (TS)

The total solid content was increased by adding 700 g of whole powdered milk into 15 litres of homogenized fresh milk; the fortified milk was thoroughly mixed. The mixture was then pasteurized at 66 °C for 30 min, cooled down to 45 °C and inoculated with 3 % of starter culture (v/v). The inoculated mixture was incubated at 45 °C for 12 hours. The fermentation process was stopped by rapid cooling the fermented milk to 20 °C. This was achieved by placing the bottles in an ice bath for 20 min. The Greek-type yoghurt was then poured into clean containers and stored in the refrigerator at 4 °C (de Oliveira, 2014).

Fortification of yoghurt with thickener (TN)

Totally 90 g of gelatine thickener were added to 15 itres of homogenized milk to thicken the yoghurt product. The mixture was heated at 95 °C for 15 min to activate the thickener (gelatine). The mixture was inoculated at 45 °C with a yoghurt starter culture at 3 %, v/v. The inoculated milk was incubated at 45 °C for 12 hours. The fermentation process was stopped by cooling the fermented milk down to 20 °C (Amaral *et al.*, 2020).

Determination of physicochemical properties of Greek-type yoghurt

Titratable acidity, pH, WHC, syneresis, lactose, fat, total solid and protein were determined on day 0, 14 and 28. The measurements of the parameters evaluated were carried out in triplicate.

Titratable acidity

Ten (10) ml of each sample were diluted to 100 ml. The diluent at 20 ml was pipetted into a 100 ml volumetric flask and 1 % of phenolphthalein was added as an indicator. The mixture was titrated against 0.1 N NaOH to an end point of faint pink colour (Tsegay, 2020). Titratable acidity was determined using the equation:

TA (g/L) = (V x 0.9) / m, where:

V – volume (mL); m = mass (g); 0.9 – correction factor for lactic acid.

pH

A glass electrode was used for the pH measurement (pH-meter) according to Gassem *et al.* (1991).

Water holding capacity (WHC)

The yoghurt sample was mixed to ensure homogeneity of the product. Two ml of distilled water were added to 5 g of yoghurt (Y) in 10 ml graduated centrifuge tubes. The mixture was stirred with glass rod to disperse the sample in distilled water. After holding the mixture for 30 min, the mixture was centrifuged for 30 min at 1250 g at 20 °C. The whey expelled (WE) was removed and weighed. The excess water absorbed was expressed as the percentage of water bound by 100 g sample (Goncalevez *et al.*, 2009). The density of the water was determined using the specific gravity bottle. The WHC (g/kg^{-1}) was calculated as follows:

$$\text{WHC} = \frac{100 \times (Y - WE)}{Y}$$

where:

Y – Yoghurt samples (g); WE – Whey expelled

Determination of syneresis

A measuring cylinder was placed under room temperature. A total of 20 g of yoghurt were poured on a funnel with filter paper to separate the whey. This was done for 3 hours under room temperature for each treatment. The syneresis was expressed as the percentage weight of whey (supernatant) over initial weight of each sample.

$$\%\ \text{Syneresis} = \frac{\text{Volume of supernatant}}{\text{Weight of sample}} \times 100$$

Determination of total solid

Ten grams (10 g) of Greek yoghurt of each sample were weighed into crucible of a known weight. The samples in each crucible were then transferred into the oven set at 65 °C to dry to a constant weight for 24 hours. The crucibles were removed from the oven and transferred to a desiccator, cooled for 10 min and weighed (A.O.A.C. 2012). It was calculated as follows:

$$\%\ \text{Total solid} = \frac{W_3 - W_O}{W_1 - W_O} \times \frac{100}{1}$$

where:

W_O – weight of empty crucible; W_1 – weight of crucible plus sample; W_3 – weight of crucible plus oven-dried sample

Determination of lactose, fat and protein

Lactose, fat and protein were analysed chemically according to the official methods of analysis described by the Association of Official Analytical Chemist (A.O.A.C. 2012). Analysis was carried out in triplicate.

Determination of organoleptic properties of Greek-type yoghurt

A total number of 12 trained panellists, at the age ranging from 25 to 45 years, were selected and randomly allocated to differently formulated Greek-type yoghurt. Equal quantities of the differently formulated blind coded samples (ST, TS and TN) were allotted to each of the panellist in a colourless disposable cup to assess the colour, flavour, taste, texture and overall acceptability on a 9-point hedonic scale. An unsalted cracker biscuits and water were provided to the panellists to neutralize afore-taste (Choi *et al.*, 2016).

Microbial status of differently formulated Greek-type yoghurt

The same procedure used to assess the commercially available Greek yoghurt was repeated for the assessment of microbial population of differently formulated Greek-type yoghurt.

Statistical analysis

A completely randomized design (CRD) was used in the study. All the data were subjected to a two-way analysis of variance (ANOVA). Means were compared using Duncan Multiple Range. The SPSS computer software was used for all statistical analyses.

RESULTS AND DISCUSSION

Table 1 evaluated the microbial population of commercial Greek-type yoghurts. Micro-organisms such as bacteria, fungi and coliform invade and cause spoilage to milk and its products, because it is a highly nutritious food. According to Table 1, the commercial products were devoid of total coliform count (TCC) and this could be attributed to good management practices (GMP) of the manufacturers (Rizzoli, 2014). There is no observed significant ($P > 0.05$) difference in the total bacteria count (TBC) of commercial Greek-type yoghurts evaluated, total fungi count (TFC) however varied with each brand, brand A appeared to have the highest count of total fungi.

In Table 2, a range of $1.4 - 1.9 \times 10^5$ cfu/ml was obtained for bacteria count, with the least detected in ST, while highest value was recorded in TN. The least population of fungi was observed in ST and this could be due to high total solid, because the higher the total solid, the lower the water activity (Vareltzis *et al.*, 2016). There was no significant difference in the total coliform count (TCC) of ST, TS and TN, the low value (0.01×10^5) obtained indicated that the yoghurt was produced hygienically. High level of total coliform count (TCC) is usually caused by pre- and post- contamination owing to unhygienic processing, handling, storage and environment, which poses adverse effect on consumer's health. Therefore, it must not be present at high levels (Lamye, 2017) and the result of this study aligned with this. TN was observed to be more susceptible to microbial invasion having the highest microbial counts. Thereby, ST can be predicted to have longer shelf-life than other formulated methods, when the microbial load is considered. Bacteria and fungi cause objectionable changes that lower the product quality, and their growth is favoured by low pH (Lange *et al.*, 2020).

Table 3 shows the effect of storage days on microbial population of differently formulated Greek-type yoghurt. TBC was increasing with increase in storage days, and this corroborated the study of Sarkar *et al.* (2012), that post-pasteurization container and prolonged storage can cause increase in bacteria count. During storage, TCC was not detected on day 0, however, few

Table 1. Evaluation of microbial population of commercial Greek-type yoghurts

Parameters	TN	ST	TS	± SEM
TBC	0.3×10^5	0.4×10^5	0.5×10^5	0.01
TFC	0.4×10^{5a}	0.05×10^{5c}	0.15×10^{5b}	0.01
TCC	ND	ND	ND	ND

[abc]Means on the same row with different superscript are significantly different ($P < 0.05$); TBC: Total bacteria count; TFC: Total fungi count; TCC: Total coliform count; ND: Not detectable; SEM – Standard error of means

Table 2. Evaluation of microbial population of differently formulated Greek-type yoghurts

Parameters	TN	ST	TS	± SEM
TBC	1.9×10^{5a}	1.4×10^{5c}	1.7×10^{5b}	0.08
TFC	0.6×10^{5a}	0.3×10^{5c}	0.5×10^{5b}	0.01
TCC	0.01×10^5	0.01×10^5	0.01×10^5	0.00

[ab]Means on the same row with different superscript are significantly different ($P < 0.05$); TBC: Total bacteria count; TFC: Total fungi count; TCC: Total coliform count; TN: fortified with gelatine; ST: traditionally strained; TS: Increased total solid; SEM – Standard error of means

Table 3. Effect of storage days on microbial population of differently formulated Greek-type yoghurts

Parameters	Day 0	Day 14	Day 28	± SEM
TBC	0.8×10^{5c}	1.5×10^{5b}	1.9×10^{5a}	0.70
TFC	0.10×10^{5b}	0.9×10^{5c}	1.4×10^{5a}	0.01
TCC	ND	0.01×10^{5}	0.02×10^{5}	0.01

^{abc}Means on the same row with different superscript are significantly different (P < 0.05); TBC: Total bacteria count; TFC: Total fungi count; TCC: Total coliform count; ND: Not detectable; SEM – Standard error of means

Table 4. Effect of different methods of formulation on physicochemical properties of Greek-type yoghurts

Parameters	TN	ST	TS	± SEM
CP (%)	3.35^{c}	14.68^{a}	11.05^{b}	0.21
Crude fat (%)	3.30^{c}	6.64^{a}	3.65^{b}	0.18
Lactose (g)	3.84^{b}	0.05^{c}	3.94^{a}	0.02
Total Solid (%)	17.91^{c}	45.18^{a}	29.74^{b}	0.14
WHC (%)	17.91^{c}	56.42^{a}	38.96^{b}	0.28
pH (%)	4.01^{b}	4.20^{a}	4.02^{b}	0.01
TTA (%)	2.22^{a}	1.78^{c}	1.89^{b}	0.05
Syneresis (%)	43.17^{a}	24.17^{c}	31.83^{b}	0.33

^{abc}Means on the same row with different superscript are significantly different (P < 0.05); CP: Crude protein; TBC: Total bacteria count; TFC: Total fungi count; TCC: Total coliform count; TN: fortified with gelatine; ST: traditionally strained; TS: Increased total solid; WHC: Water holding capacity; TTA: Titratable acidity; SEM – Standard error of means

numbers of TCC were counted on day 14 and 28 (0.01 and 0.02×10^{5}). This presence could be because of unsteady power supply and inadequate refrigeration in the storage environment (Baylis *et al.*, 2011; Lamye, 2017). Al-Kadamany *et al.* (2003) reported, that the quality of Greek-type yoghurt can be affected by microbial invasion, which may cause certain changes in the nutritive value and in some physicochemical properties. Table 4, 5, 6, show that, physicochemical characteristics varied with methods of formulation and length of storage (shelf-life) (Lange *et al.*, 2020).

Table 4 shows the effect of different methods of formulation on physicochemical properties of Greek-type yoghurts. The highest crude protein was observed in ST (14.68) probably because protein content remained intact throughout the process of straining (El-Abbaddi *et al.*, 2014). The author also reported, that the higher the density or degree of concentration of yoghurt, the higher the protein content, which could be the reason for the high value obtained in ST. TS appeared as the second best in crude protein with a value of 11.05 %, which was similar to those obtained by Conolly (2018) as the maximum protein content (11.00 %), when he fortified yoghurt with varying levels of milk powder. Nutritionally, fortification of Greek-type yoghurt with milk powder (TS) increases the density, which, in turn, may influence the crude protein (CP). ST had least amount of lactose (0.05) indicating that the whey, eliminated from the yoghurt mass, released larger percentage of the lactose. Low level of lactose in Greek-type yoghurt, especially in the strained process, suggests that Greek-type yoghurt is a healthy food for diabetic patient. This corroborated the classification of Greek-type yoghurt as a high protein/low lactose food by American Dairy Association (2015). CP was observed to increase with total solid, fat content and WHC in ST. This is because total solids and protein content play a significant role in yoghurt, and their effect can be sometimes confounded, because they are dependent variables (Sodini *et al.*, 2014) as it maintains the texture, stability and water holding capacity of the yoghurt. Furthermore, high total solid also influenced the fat content (Shaker *et al.*, 2000).

The highest WHC (56.42) was recorded in ST. TS performed second best in WHC (38.96) because the total solid was increased with milk powder, so that milk powder is probably an agent of improving water holding capacity (Lange *et al.*, 2020). As WHC is decreasing, TTA is increasing, as observed in TN having titratable acidity (TTA) of 2.22, syneresis of 43.17 and WHC of 17.91. This implies that TN does not have the ability to hold or retain water, thereby, resulting in yoghurt separation. WHC indicates the ability of the protein to retain water within the Greek-type yoghurt structure (Wu *et al.*, 2001), which indicates that the higher the protein, the higher the WHC and the lower the syneresis. ST has a better resistance against syneresis because of the high total solid and WHC. Syneresis is a common defect in fermented milk products. It is a contraction of the gel without the application of any external forces and is related to instability of the gel network resulting in the loss of the ability to entrap all the serum phase (Lucey *et al.*, 1998).

The effect of storage days on physicochemical properties of differently formulated Greek-type yoghurts is presented in Table 5. It was observed that crude protein and fat remain unaffected through the all days of storage (28 days) of Greek-type yoghurt. Lactose, total solid, WHC and pH reduced with increase in storage days, while titratable acidity (TTA) and syneresis were increasing as the product aged. Syneresis increased with length of storage from 16.50 to 18.70, TTA increased with increase in storage (1.74 to 2.09), while pH decreased with increase in storage days (4.33 – 3.85). Increase in TTA is influenced by low protein, rate of lactose fermen-

Table 5. Effect of storage days on physicochemical properties of differently formulated Greek-type yoghurts

Parameters	Day 0	Day 14	Day 28	± SEM
Crude protein(%)	11.63	11.55	11.38	0.21
Crude fat (%)	4.06[b]	4.90[a]	4.62[a]	0.18
Lactose(g)	2.84[a]	2.53[b]	2.45[c]	0.16
Total solid (%)	34.73[a]	32.72[b]	32.00[b]	0.14
WHC (%)	56.83[a]	54.42[b]	53.94[b]	0.28
pH (%)	4.33[a]	4.05[b]	3.85[c]	0.01
TTA (%)	1.74[b]	2.06[a]	2.09[a]	0.05
Syneresis (%)	16.50[b]	18.17[a]	18.70[a]	0.33

[abc]Means on the same row with different superscript are significantly different ($P < 0.05$); WHC: Water holding capacity, TTA: Titratable acidity; SEM – Standard error of means

Table 6. Effect of storage days and method of formulation on physicochemical properties of differently formulated Greek-type yoghurts

Parameters	TN			ST			TS			± SEM
	0	14	28	0	14	28	0	14	28	
Crude protein	3.59[d]	3.33[d]	3.71[d]	15.55[a]	15.54[a]	14.00[b]	13.75[b]	13.63[b]	12.37[c]	0.37
Crude fat	4.17[b]	3.75[c]	3.60[d]	4.96[b]	7.83[a]	7.13[ab]	3.74[c]	3.66[d]	3.55[e]	0.03
Lactose	6.89[a]	6.02[b]	5.86[c]	0.06[e]	0.04[e]	0.04[e]	3.69[d]	3.81[d]	3.70[d]	0.03
Total solid	24.00[d]	16.61[e]	15.11[f]	53.68[a]	49.93[b]	48.98[b]	36.83[c]	35.90[c]	35.00[c]	0.23
WHC	24.00[e]	18.61[f]	14.11[g]	85.50[a]	80.70[b]	78.95[b]	61.00[c]	59.95[c]	55.95[d]	0.48
pH	4.23[b]	4.00[c]	3.83[d]	4.55[a]	4.03[c]	4.00[c]	4.21[ab]	4.11[b]	3.71[d]	0.02
TTA	1.60[d]	1.84[c]	1.97[b]	1.60[d]	2.04[b]	2.05[b]	2.04[b]	2.30[a]	2.32[a]	0.08
Syneresis	21.50[c]	44.00[b]	46.00[a]	11.20[f]	11.59[f]	12.01[f]	17.70[d]	18.50[d]	20.00[c]	0.57

[abcdefg]Means on the same row with different superscript are significantly different ($P < 0.05$); TN: fortified with gelatine; ST: traditionally strained; TS: Increased total solid; WHC: Water holding capacity; TTA: Titratable acidity; SEM – Standard error of means

tation and increase in storage days (Schmidt *et al.*, 1996). The least TTA was recorded on day 0 and it increased as the product ages on day 14 and 28, however, with no significant difference. This result corresponded with the research of Campos *et al.* (2018), who stored Greek yoghurt for 21 days under ideal conditions and observed no significant changes on the latter days. The increase in titratable acidity (TTA) and decrease in pH during the storage are attributed to fluctuations in syneresis as the length of storage increases. The degree of syneresis and microbial activity will be increasing when pH falls below 4.8, thereby, causing increase in TTA, which indicates high bacteria activity (Lucey *et al.*, 1998). This could be the reason for high microbial activity in TN 1.9×10^5 (Table 2), because it has the least pH (4.01; Table 4). Although, Kirdar and Gun (2002) stated, that pH can reach 3.7 without affecting the product acceptance negatively, this guarantee consumption safety and acceptance of TN with a pH of 3.85 (Table 5).

In Table 6, the crude protein of Greek-type yoghurt ranged from 3.33 to 15.55 %. This agreed with the conclusion of Camilla *et al.* (2018) that Greek-type yoghurt is a high-protein yoghurt because of the amount of protein participating in the gel network (Sodini *et al.*, 2014). Storage days does not influence the crude protein of TN, what could be because thickener can withstand extended storage, vigorous handling and pH extremes (Mousavi *et al.*, 2019). The amount of crude fat varied with the different method of formulation with a range of 3.55 − 7.83. The amount of lactose also varied with the production process, with the least observed in the Greek-type yoghurt produced by straining. This is because of the whey expelled from the yoghurt mass (Yang, 2016). The highest pH was recorded in ST ranging from 4.00 to 4.55 followed by TS (4.00 − 4.11). pH value is one of the valid measures of probiotic activity in Greek-type yoghurt (Fergusson, 2017). High pH indicates the abundance of beneficial microorganisms, what implies that ST contained more beneficial microorganisms. Moreover, this agrees with the result of Fergusson (2017) that Greek-type yoghurt, produced by traditional straining (ST), is the most effective because of its high probiotic activity. ST is less susceptible to microbial activity and deterioration because of its high pH, low TTA and low syneresis. The syneresis of TN increased from 21.50 to 46.00 on storage, probably influenced by low total solid (protein/fat), low WHC, inappropriate fermentation period or lengthened storage days. The syneresis of TS and TN noticeably increased on days 1 − 13 with no significant difference on the latter days of storage (14 − 28). In addition to storage period, syneresis increases, when yoghurt recipe is devoid of preservative (Vareltzis *et al.*, 2016), which could be an underlying factor responsible for high degree of syneresis, obtained in this study, as all the methods were formulated without preservatives. Also, low total solid and WHC result in low density mass, which increases the pore size in the protein matrix of yoghurt gel, thereby, causing increase in syneresis (Vareltiz *et al.*, 2016). When Greek-type yoghurt was fortified with powdered milk (TS), it reduced the pore size, increased the total solid and boosted the protein content without significant effect on the amount of lactose.

Table 7 shows the organoleptic properties of Greek-type yoghurt evaluating the colour, texture, taste, flavour and overall acceptability. According to Mousavi *et al.* (2019), sensory assessment helps to define the product properties, which are prominent concerning the product acceptability to the consumer. The colour of ST is significantly higher ($P < 0.05$) than TS and TN. The

Table 7. Organoleptic properties of differently formulated Greek-type yoghurts

Parameters	TN	ST	TS	± SEM
Colour	2.65^b	3.00^a	2.73^b	0.55
Texture	1.89^c	2.67^b	3.17^a	0.51
Taste	1.92^c	2.58^b	3.50^a	0.33
Flavour	2.17^c	3.92^b	4.83^a	0.47
Overall acceptability	1.92^c	3.37^b	3.75^a	0.56

^{abc}Means on the same row with different superscript are significantly different ($P < 0.05$); TN: fortified with gelatine; ST: traditionally strained; TS: Increased total solid; SEM − Standard error of means colour of ST appeared to be slightly off white and this agrees with the colour reported by some researchers. Mousavi *et al.*, (2019) reported a creamy white colour, while Walstra *et al* (2005) observed a slight white colour, which could be a result of little dispersion of fat globules and casein micelles. It was reported that when Greek--type yoghurt is traditionally strained, the colour will be brighter compared to when another ingredient for thickening or solidification is added (Walstra *et al.* 2005), because addition of powdered milk and gelatine result in colour modification. The colours of TS and TN were scored as moderately off-white. TS is significantly ($P < 0.05$) higher in texture (3.17), what can be attributed to addition of powdered milk, which increases the total solid, WHC and protein content of the yoghurt.

Protein content plays a major role in texture of Greek-type yoghurt due to high amount that participates in gelling of yoghurt product (Schkoda *et al.*, 2001). Tamine *et al.*, (2014) found that variation in protein content leads to great variation in physical and sensory properties among Greek-type yoghurts. The protein of TS ranged from 12.37 to 13.75, which influenced the texture (El-Abbadi *et al.*, 2014) giving a thicker (3.17) and creamy yoghurt compared to TN that has the least protein content (3.33 – 3.71) was observed to have the least, porous and weak texture of 1.89. Fat content also contributes to creamy texture (Tomaschunas *et al.*, 2012). The firm texture of Greek-type yoghurt is capable of influencing consumer's acceptance because a creamier and thicker product tends to be more palatable (Mohameed *et al.*, 2004). High protein, total solid, WHC and fat are factors that reacted together to give a firm, creamy texture that is more acceptable. The fat content in the powdered milk used to fortify TS could also be a contributory factor to creaminess.

However, Greek-type yoghurt fortified with thickener (TN) is characterized with porous texture and syneresis. Syneresis affects the rheological properties of Greek-type yoghurt by affecting the perception (Li and Guo, 2006), as consumer thinks there is something microbiologically wrong with the yoghurt (Lee and Luccy, 2010). According to Walstra *et al.* (2005), Greek-type yoghurt is regarded as a less sweet product. The taste of TS was slightly sour while that of ST is moderately sour, and TN was scored to be extremely sour. Consumers highly rated and preferred a slightly sour product. The taste of TS (3.50) is significantly ($P < 0.05$) preferred to ST (2.58) and TN (1.92); the addition of powdered milk enhanced the taste of TS. The less-sweetness and moderate sourness of ST is as a result of whey that is strained out of the yoghurt mass. Lactose is responsible for sweetness and it is contained in the whey (ADA, 2015).

Flavour is one of the factors that influence quality and acceptability of yoghurt (Marissa, 2010). The least flavour was obtained in TN (2.17) and TS was significantly ($P < 0.05$) higher in flavour. This is in line with the research of Desai *et al.* (2013) that Greek-type yoghurt, fortified with milk powder, has an improved flavour compared to Greek-type yoghurt fortified with thickener. Greek-type yoghurt fortified with thickener displayed a burnt or beefy flavour (too acidic or sourness) Some researchers reported that when total solid is increased with milk powder, it gives strong flavour, which does not mute the natural yoghurt flavour (Mousavi *et al.*, 2019). This could be attributed to the strong flavour obtained in TS (4.83). The acceptability and preference given to TS is because of the interaction between texture, taste and flavour. It can, therefore, be deduced from this research that consumers prefer a creamy, firm, sweet aromatic flavour with slight sourness, which corresponds with the report of Desai *et al.* (2013).

CONCLUSION

The microbial evaluation of the commercial and formulated Greek-type depicted that Greek-type yoghurt is a high protein/low carbohydrate food, safe for human consumption. Among all the products evaluated, ST properly fit into high protein and low carbohydrate yoghurt. TS appeared as the second best in physicochemical traits, while TN had the least values. TS was preferred by the consumers. The nutritive value of each method of formulation decreased with increase in shelf-life, while variables that can render the products unwholesome increased with increase in storage days. Deterioration was rapid on the early days of storage (0 – 13) with slight deteriorative changes observed on the latter days of the storage (14 – 28).

ACKNOWLEDGEMENT

The authors acknowledged the contribution of laboratory technologists of the University of Ibadan, who assisted in the chemical analysis of the experiment.

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All authors have read and agreed to the published version of the manuscript.

CONFLICT OF INTEREST

The authors declare that there are no conflicts of interest.

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