PHYSICOCHEMICAL AND ANTIOXIDANT PROPERTIES OF GREEK YOGHURT FORTIFIED WITH CARROTS

ADEKUNLE, Ibironke, IBHAZE, Gladys Abiemwense, OLANIYI, Taofikat, ADETOKUN, John and ALOKAN, Julius Adebayo

Department of Animal Production and Health, School of Agriculture and Agricultural Technology, Federal University of Technology, PMB 704, Akure, Ondo State, Nigeria.

Corresponding Author: Adekunle, I. Department of Animal Production and Health, School of Agriculture and Agricultural Technology, Federal University of Technology, PMB 704, Akure, Ondo State, Nigeria. **Email:** adeibini17@gmail.com **Phone:** +234 703 736 9843

***Received** June 03, 2024; **Revised** June 22, 2024; **Accepted** July 16, 2024*

ABSTRACT

This study investigates the impact of carrots on the physicochemical and antioxidant properties of Greek yoghurt in 24-hour, 7-, 14- and 21-day storage periods. Greek yoghurt was produced by reconstituting 1500 g of powdered milk with 5 litres of water, homogenised, pasteurised at 45° C for 3 minutes, and cooled. 15000 g of sugar and blanched carrots were added at varying levels: 0 g (T1) control, 100 g (T2), 200 g (T3), 300 g (T4), and 400 g (T5). The mixture was incubated at 43°C for 14 hours, strained, packaged, and refrigerated at 4°C for 21 days. A completely randomised 5×4 factorial design was adopted. Results showed significant effects (p<0.05) of storage and carrot inclusion on all parameters. Water holding capacity ranged from 61.38 ± 0.03 to 68.06 ± 0.06% and viscosity from 521.03 ± 0.01 to 544.67 ± 0.02 Pa.s. The pH values increased with storage from 4.40 ± 0.00 to 5.11 ± 0.00 and decreased with carrot inclusion, from 5.23 ± 0.01 to 4.67 ± 0.00. Moisture content increased with storage from 53.84 ± 0.02 to 62.60 ± 0.03%, while fat (7.69 ± 0.01 to 6.50 ± 0.00%), protein (12.75 ± 0.01 to 9.72 ± 0.01%) and carbohydrate (23.74 ± 0.03 to 19.72 ± 0.03%) contents decreased over time. Antioxidant activity (DPPH) decreased over time, with T3 having the highest (43.41 ± 0.03%) and T5 having the lowest (34.43 ± 0.01%) values. In conclusion, adding 200 g/L of Greek yoghurt provides the best functional Greek yoghurt product.

Keywords: Carrot, Greek yoghurt, Fortification, Storage, Nutrition

INTRODUCTION

Yoghurt has been reported to be one of the most ancient and popular fermented food products, made from either raw, powdered, creamed, or skimmed milk with its unique lactic acid-producing bacteria as a starter culture (Chandan and Kilara, 2013). Yoghurt differs in form, flavour, aroma and texture, due to methods of production and chemical composition (Farag *et al*., 2022). However, Greek-style yoghurt, also called strained yoghurt, is distinctively produced as a concentrated, thick, semisolid fermented milk product produced after draining the whey, resulting in a thicker and creamier product (Lange, 2013). Nelios *et al*. (2023) reported that the removal of the whey makes Greek yoghurt contain twice the protein contained in regular yoghurt, making it an important protein source for vegans and vegetarians.

Studies have reported the nutritional and health benefits associated with yoghurt consumption, which include protection against gastrointestinal upsets, enhanced digestion of lactose, decreased risk of cancer, lower blood cholesterol, improved immune response, and helping the body assimilate protein, calcium and iron (Van de Water and Naiyanetr, 2003; Ibhaze *et al*., 2022a). Beyond these benefits, the colouration and flavour of yoghurt have been considered as other factors influencing consumers' consumption and acceptability of Greek yoghurt (Ścibisz *et al*., 2019). The use of synthetic colourants, flavours or fragrances in yoghurt production is not well accepted by consumers (McAvoy, 2014), even though it has been banned in Europe due to its carcinogenic effects and other health-related complications that may arise. Hence, the food industry has resulted in the use of natural food colourings through the application of pigmented substances to improve the colour, aroma and acceptability of yoghurts. These functional foods could supply bioactive compounds, and antioxidants, enhancing health-protective factors, and reducing free radicals, and cell damage (Senadeera *et al*., 2018).

Fruits like carrot (*Daucus carota* L. Apiales: Apiaceae) are some of the fruits consumed in most parts of the world and have been reported to be a valuable source of natural antioxidants, improve health, reduce cancer development, prevent vitamin A deficiency (Chandan *et al*., 2017; Surbhi *et al.,* 2018). Thus, this study aimed to evaluate the physicochemical, proximate and antioxidant properties of 21-day stored Greek yoghurt fortified with varying levels of carrot.

MATERIALS AND METHODS

Preparation of Carrot and Carrot Fortified Yoghurt: The fresh carrots were cleaned, washed, grated and blanched for 3 minutes to deactivate the enzymes. Powdered milk (1500 g) was reconstituted with 5 litres of clean water, homogenized and pasteurized at 45° C for 3 minutes, then cooled to 43°C. 15000 g of granulated sugar was added and stirred then blanched carrots were added at varying levels of 100 g (T2), 200 g (T3), 300 g (T4), 400 g (T5), and the control (T1) with no carrot. The mixture was thereafter incubated at 43° C for 14 hours and then strained using a cheesecloth to remove the whey. The formed Greek yoghurt was then packaged in plastic containers refrigerated at 4°C and stored for 21 days.

Experimental Design: The experimental design was a completely randomised design (CRD) in a 5×4 factorial arrangement (5 treatments × 4 storage days) with three (3) replicates per treatment.

Determination of Physical Properties

Viscosity: The viscosity of the Greek Yoghurt was measured with a digital rotary Viscometer (NDJ-5S). Samples were subjected to the spindle speed of 60 rpm with a spindle size of 7 mm at a constant temperature of 28°C for 5 minutes for 24 hours, 7, 14 and 21 days respectively. The measurement was expressed in Pa.s. The samples were analyzed by a texture profile analyzer using a TA4/1000 probe (Fox *et al.,* 2017).

Water holding capacity: 10 g of Greek yoghurt was centrifuged at 3000 rpm for 60 minutes at 10°C. The supernatant was removed at 10 minutes and the wet weight of the pellet was recorded. The water holding capacity was expressed as a percentage of pellet weight relative to the original weight of Greek yoghurt (Parnell-Clunies *et al.,* 1986).

Determination of Proximate Composition: The moisture, protein, ash and fat contents were determined according to the method of AOAC (2012). Carbohydrates were determined using a mathematical function as described by Igbabul *et al*. (2014). Carbohydrate = 100% - (% of ash + protein + fat + moisture).

Determination of pH Value: The pH of flavourants and yoghurt samples was determined using the pHep pocket-sized pH metre by dipping the electrode into the samples and then the pH was read.

Determination of Antioxidant Properties (DPPH): The free radical scavenging ability of the Greek Yoghurt against DPPH (1,1-diphenyl-2-picryhydrazyl) was done as described by Mensor *et al.* (2001). 1 ml of Greek yoghurt was mixed with 1ml of 0.4 M methanolic solution of the DPPH.

The mixture was left for 30 minutes in the dark before measuring the absorbance at 516 nm. The scavenging activity percentage was determined thus: DPPH Scavenged (%) = A Control - A test /A Control x 100.

Data Analysis: Data were subjected to analysis of variance (ANOVA) and treatment means were separated using New Duncan's Multiple Range Test (NDMRT). The data analysis was performed with SPSS 25.0 software (SPSS, 2017).

RESULTS

Physical Properties and pH of Carrot-Fortified Greek Yoghurt at Different Storage Periods: The physical properties of carrot-fortified Greek yoghurt at different storage periods are shown in Table 1. It was observed that the water holding capacity and viscosity decreased as the storage period progressed from day 1 to 21, with values ranging between 61.38 ± 0.03 – 68.06 ± 0.06% and 521.03 ± 0.01 – 544.67 ± 0.02 Pa.s respectively. The treatment effect showed an inverse relationship between the water-holding capacity and viscosity. With the treatment inclusion of carrot, the water holding capacity ranged from 65.17 ± 0.05 – 66.52 ± 0.04% with treatment T5 (400 g carrot) having the lowest value and highest viscosity value (553.27 ± 0.01 Pa.s). The interaction effect revealed superior values (68.46 ± 0.09%) in T1 at 24 hours for water holding capacity (574.87 ± 0.01 Pa.s) in T5 at day 14 for viscosity. The storage period, treatment and their interaction effect had a significant effect ($p<0.05$) on the pH values obtained, which were found to increase as the storage periods increased from 4.40 ± 0.00 to 5.11 ± 0.00. However, the pH decreased from 5.23 ± 0.01 in yoghurt with no carrot (T1) to 4.67 ± 0.00 in those with 400 g (T5). There was no observed pattern in the pH values obtained as a result of the interaction between storage and carrot inclusion.

Proximate Composition of Carrot-Fortified Greek Yoghurt at Different Storage Periods: The proximate composition of carrot-fortified Greek yoghurt at different storage periods is presented in Table 2. Storage effect significantly influenced ($p<0.05$) the parameters investigated. The moisture content increased with increased storage period from 53.84 ± 0.02 – 62.60 ± 0.03%, while ash (1.98 – 1.16%), fat (7.69 ± 0.01 – 6.50 ± 0.00%), protein (12.75 ± 0.01 – 9.72 ± 0.01%) and carbohydrate (23.74 ± 0.03 – 19.72 ± 0.03%) decreased with increased storage period. The treatment effect revealed that yoghurt containing 200 g carrot (T3) had the lowest moisture (52.95 ± 0.01%), fat (4.49 ± 0.00%) and protein (9.25 ± 0.00%) but the highest ash (2.19 ± 0.00%) and carbohydrate (31.12 ± 0.03%) contents. The interaction effect had no fixed pattern, however, T3 at 21-day storage had the highest moisture content (66.11 ± 0.01%) ash (2.85 ± 0.01%), and carbohydrate (35.54 ± 0.04%) was at its peak in T1 at 24-hour storage.

Antioxidant Properties of Greek Yoghurt Fortified with Carrots at Different Storage Periods: The antioxidant properties of Greek yoghurt fortified with carrots at varying levels at different storage periods are presented in Figures 1 – 3. The storage period, treatment and interaction had a significant effect ($p<0.05$) on DPPH (1,1-diphenyl1-2-picrylhydrazyl). DPPH decreased from 43.28 ± 0.04 – 34.57 ± 0.03% as the storage period increased. Treatment 3 (200 g carrot) had the maximum DPPH value (43.41 ± 0.03%), while treatment 5 had the minimum value (34.43 ± 0.01%). Interaction effect showed that on day 1 (24 hours), T1 had the utmost value of 66.01 ± 0.02%, at days 7 and 14, DPPH was highest in T2 (54.35 ± 0.04% and 43.05 ± 0.01% respectively) while on day 21, the highest DPPH concentration was at its peak (45.70 ± 0.02%).

DISCUSSION

Water holding capacity and viscosity are factors that influence the shelf life of yoghurt products. Water holding capacity (WHC) decreased as the days of storage increased, this was in agreement with the report of Dimitrellou *et al*. (2020) on yoghurt fortified with grape juices. This may arise as a result of syneresis, a phenomenon that occurs due to the contraction of the protein network in yoghurt, which forces out water molecules (Arab *et al.,* 2023).

Table 1: Physical properties and pH of carrot-fortified Greek yoghurt at different storage periods

Parameters	Water Holding Capacity (%)	Viscosity (Pa.s)	pH
Storage effect			
D1	68.06 ± 0.06[d]	544.67 ± 0.02[c]	4.40 ± 0.00[a]
D2	67.84 ± 0.06[c]	531.03 ± 0.01[b]	4.81 ± 0.00[b]
D3	65.94 ± 0.05[b]	521.03 ± 0.01[a]	5.00 ± 0.00[c]
D4	61.38 ± 0.03[a]	521.91 ± 0.01[a]	5.11 ± 0.00[d]
Treatment effect			
T1 (0 g carrot)	66.41± 0.05[c]	509.80 ± 0.00[a]	5.23 ± 0.01[e]
T2 (100 g carrot)	65.44 ± 0.05[b]	512.95 ± 0.00[b]	5.07 ± 0.00[d]
T3 (200 g carrot)	66.52 ± 0.04[c]	522.89 ± 0.00[c]	4.58 ± 0.00[a]
T4 (300 g carrot)	65.48 ± 0.06[b]	549.82 ± 0.01[d]	4.60 ± 0.00[b]
T5 (400 g carrot)	65.17 ± 0.05[a]	553.27 ± 0.01[e]	4.67 ± 0.00[c]
Storage * Treatment			
D1 * T1	68.46 ± 0.09[f]	493.18 ± 0.01[a]	4.49 ± 0.01[b]
D1 * T2	67.96 ± 0.10[e]	504.98 ± 0.01[b]	4.75 ± 0.00[c]
D1 * T3	68.42 ± 0.09[f]	502.98 ± 0.01[b]	4.25 ± 0.00[a]
D1 * T4	67.74 ± 0.10[e]	543.47 ± 0.00[de]	4.30 ± 0.00[b]
D1 * T5	67.72 ± 0.10[e]	562.17 ± 0.01[f]	4.21 ± 0.00[a]
D7 * T1	68.28 ± 0.11[f]	512.07 ± 0.01[c]	5.35 ± 0.00[e]
D7 * T2	67.75 ± 0.10[e]	536.17 ± 0.01[d]	5.06 ± 0.00[d]
D7 * T3	68.27 ± 0.10[f]	505.48 ± 0.00[c]	4.43 ± 0.00[b]
D7 * T4	67.55 ± 0.10[e]	551.57 ± 0.01[ef]	4.50 ± 0.00[b]
D7 * T5	67.37 ± 0.09[e]	549.87 ± 0.00[ef]	4.75 ± 0.00[c]
D14 * T1	66.55 ± 0.10[d]	535.47 ± 0.01[d]	5.50 ± 0.01[f]
D14 * T2	65.78 ± 0.10[c]	537.67 ± 0.00[d]	5.20 ± 0.00[e]
D14 * T3	66.54 ± 0.10[d]	522.97 ± 0.00[c]	4.72 ± 0.00[c]
D14 * T4	65.67 ± 0.09[c]	552.37 ± 0.01[ef]	4.74 ± 0.00[c]
D14 * T5	65.13 ± 0.09[c]	574.87 ± 0.01[f]	4.80 ± 0.00[c]
D21 * T1	62.37 ± 0.10[b]	511.07 ± 0.00[c]	5.57 ± 0.01[f]
D21 * T2	60.26 ± 0.09[a]	512.67 ± 0.00[c]	5.27 ± 0.00[e]
D21 * T3	62.85 ± 0.09[b]	507.78 ± 0.00[c]	4.90 ± 0.00[d]
D21 * T4	60.97 ± 0.10[a]	551.87 ± 0.01[ef]	4.89 ± 0.00[d]
D21 * T5	60.47 ± 0.10[a]	526.17 ± 0.01[d]	4.92 ± 0.00[d]

[abcdef] means along the same column with different superscripts are significantly different ($p<0.05$); D1 = 24 hours, D7 = 7 days, D14 = 14 days, D21 = 21 days, T1 = No carrot, T2 = 100 g carrot, T3 = 200 g carrot, T4 = 300 g carrot, T5 = 400 g carrot

Table 2: Proximate composition (%) of carrot-fortified Greek yoghurt at different storage periods

Parameters	Moisture	Ash	Fat	Protein	Carbohydrate
Storage effect					
D1	53.84 ± 0.02[a]	1.98 ± 0.03[d]	7.69 ± 0.01[d]	12.75 ± 0.01[d]	23.74 ± 0.03[d]
D2	56.92 ± 0.02[b]	1.59 ± 0.02[c]	7.31 ± 0.02[c]	11.10 ± 0.01[c]	23.08 ± 0.03[c]
D3	59.60 ± 0.01[c]	1.40 ± 0.02[b]	6.94 ± 0.02[b]	10.55 ± 0.01[b]	21.51 ± 0.02[b]
D4	62.60 ± 0.03[d]	1.16 ± 0.00[a]	6.50 ± 0.00[a]	9.72 ± 0.01[a]	19.72 ± 0.03[a]
Treatment effect					
T1 (0 g carrot)	61.37± 0.01[a]	1.44 ± 0.00[c]	6.05 ± 0.01[b]	12.44 ± 0.01[c]	18.79 ± 0.03[c]
T2 (100 g carrot)	56.52 ± 0.02[b]	1.33 ± 0.00[b]	8.37 ± 0.01[d]	10.26 ± 0.01[b]	23.52 ± 0.04[d]
T3 (200 g carrot)	52.95 ± 0.01[a]	2.19 ± 0.00[a]	4.49 ± 0.00[a]	9.25 ± 0.00[a]	31.12 ± 0.03[a]
T4 (300 g carrot)	60.59 ± 0.02[d]	1.17 ± 0.00[a]	8.05 ± 0.01[c]	14.39 ± 0.01[d]	15.80 ± 0.02[b]
T5 (400 g carrot)	59.77 ± 0.01[c]	1.52 ± 0.00[d]	8.57 ± 0.01[a]	18.83 ± 0.02[a]	11.31 ± 0.02[a]
Storage * Treatment					
D1 * T1	46.55 ± 0.01[a]	2.85 ± 0.01[f]	4.95 ± 0.02[c]	10.10 ± 0.01[d]	35.54 ± 0.04[f]
D1 * T2	50.92 ± 0.02[b]	1.74 ±0.00[ef]	9.06 ± 0.02[f]	11.18 ± 0.01[d]	27.43± 0.04[de]
D1 * T3	52.44 ± 0.02[c]	1.84 ±0.00[ef]	6.53 ± 0.02[e]	14.76 ±0.02[ef]	24.43± 0.04[d]
D1 * T4	58.83 ± 0.01[ef]	1.51 ± 0.00[e]	8.80 ± 0.02[f]	17.07 ± 0.03[f]	13.97± 0.03[a]
D1 * T5	60.44 ± 0.01[f]	1.93 ± 0.01[f]	9.10 ± 0.02[f]	10.66 ± 0.02[d]	17.89± 0.03[b]
D7 * T1	48.77 ± 0.00[a]	2.12 ± 0.00[f]	4.73 ± 0.02[c]	9.48 ± 0.02[c]	35.18± 0.04[e]

D7 * T2	55.13 ± 0.01^{d}	1.42 ± 0.00^{e}	8.71 ± 0.02^{f}	10.37 ± 0.02^{d}	24.37 ± 0.04^{d}
D7 * T3	62.92 ± 0.03^{f}	1.60 ± 0.00^{e}	6.13 ± 0.02^{e}	12.12 ± 0.02^{ef}	17.42 ± 0.03^{b}
D7 * T4	59.77 ± 0.01^{ef}	1.20 ± 0.00^{d}	8.23 ± 0.02^{f}	14.73 ± 0.03^{ef}	16.07 ± 0.03^{b}
D7 * T5	57.99 ± 0.02^{e}	1.61 ± 0.00^{e}	8.77 ± 0.02^{f}	8.80 ± 0.01^{d}	23.07 ± 0.04^{d}
D14 * T1	57.54 ± 0.01^{e}	2.03 ± 0.01^{d}	4.21 ± 0.02^{c}	9.16 ± 0.01^{c}	27.28 ± 0.04^{de}
D14 * T2	59.45 ± 0.01^{ef}	1.18 ± 0.00^{d}	8.26 ± 0.02^{f}	10.14 ± 0.02^{d}	21.19 ± 0.04^{c}
D14 * T3	64.03 ± 0.01^{f}	1.27 ± 0.00^{d}	6.09 ± 0.02^{e}	11.62 ± 0.02^{de}	16.99 ± 0.02^{b}
D14 * T4	60.98 ± 0.00^{f}	1.10 ± 0.01^{d}	7.80 ± 0.02^{ef}	13.60 ± 0.02^{e}	16.73 ± 0.02^{b}
D14 * T5	56.00 ± 0.02^{de}	1.39 ± 0.01^{d}	8.34 ± 0.02^{f}	8.26 ± 0.01^{b}	26.24 ± 0.04^{de}
D21 * T1	58.93 ± 0.01^{ef}	1.74 ± 0.00^{ef}	4.09 ± 0.02^{c}	8.25 ± 0.01^{b}	27.22 ± 0.04^{de}
D21 * T2	60.57 ± 0.01^{f}	0.99 ± 0.00^{c}	7.47 ± 0.02^{ef}	9.35 ± 0.01^{c}	21.83 ± 0.04^{c}
D21 * T3	66.11 ± 0.01^{f}	1.06 ± 0.00^{d}	5.46 ± 0.02^{d}	11.23 ± 0.02^{de}	16.32 ± 0.03^{b}
D21 * T4	62.71 ± 0.01^{f}	0.88 ± 0.00^{b}	7.39 ± 0.02^{ef}	12.18 ± 0.02^{de}	16.84 ± 0.03^{b}
D21 * T5	64.65 ± 0.00^{f}	1.15 ± 0.01^{d}	8.08 ± 0.02^{f}	7.62 ± 0.01^{a}	18.50 ± 0.03^{bc}

^{abcdef} means along the same column with different superscripts are significantly different ($p<0.05$); D1 = 24 hours, D7 = 7 days, D14 = 14 days, D21 = 21 days, T1 = No carrot, T2 = 100 g carrot, T3 = 200 g carrot, T4 = 300 g carrot, T5 = 400 g carrot

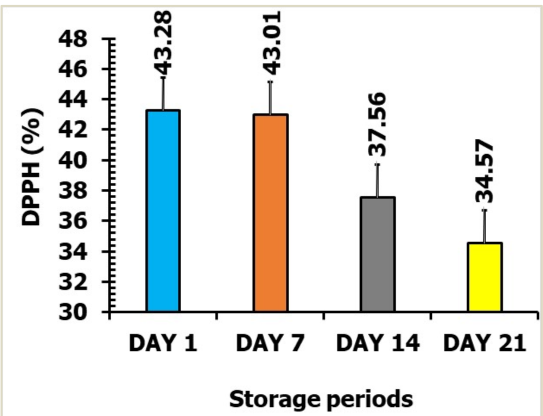

Figure 1: Storage effect on antioxidant (DPPH) concentration of fortified Greek yoghurt at different storage periods

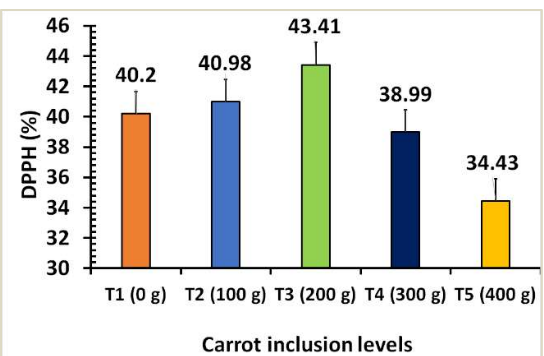

Figure 2: Treatment effect on antioxidant (DPPH) concentration of fortified Greek yoghurt with varying inclusion levels of carrot

As syneresis progresses, the ability of the yoghurt to retain water diminishes, reducing WHC (Gyawali and Ibrahim, 2016; Arab *et al.,* 2023). This decrease may also arise from the degradation or reorganization of the protein network, leading to a weakened structure.

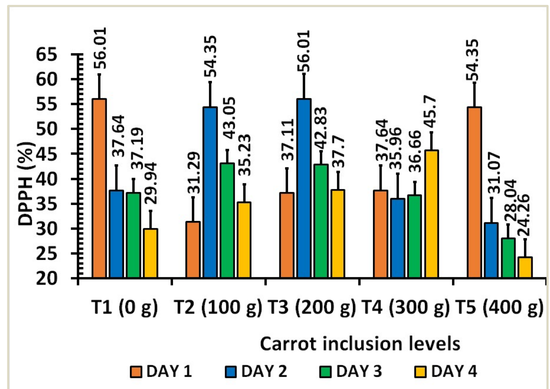

Figure 3: Antioxidant composition of Greek yoghurt with varying inclusion levels of carrot stored for different periods

The decreased viscosity observed with an increasing storage period was in line with the findings of Supavititpatana *et al*. (2010) which reported a decrease in the apparent viscosity of yoghurt with storage time.

Moisture content influences the shelf life of yoghurt products. The observed increase in moisture content as the storage period increased may be due to the absorption of inbuilt moisture in the refrigerator by the product. However, the least moisture content obtained in T3 (200 g) may suggest that it had a better shelf life as high moisture in food will predispose the product to rapid deterioration (Moore, 2020). The decreased values of fat, ash, protein and carbohydrates as the days of storage increased observed in this present study agree with that of Ibhaze *et al.* (2022b), who reported a decrease in ash content as storage days increased in flavoured yoghurt. The high-fat content observed may be attributed to the high-fat content of the full cream milk used in the preparation of the yoghurt in this study (Tavakoli *et al.,* 2019). Fat content in yoghurt contributes to sensory attributes including aroma, texture and flavour. A decrease in ash may affect yoghurt texture by filling the interstitial spaces in the protein and mineral matrix (Lashkari *et al.*, 2014). The reduction in ash content as the storage period increases may be due to a combination of factors like microbial, chemical and leaching during storage (Hossain *et al.* 2024). The decreased protein content agrees with the study of Ihemeje *et al.* (2015) in plain yoghurt. This decrease may be due to further proteolytic enzymes that break down protein molecules into smaller peptides and amino acids, or the microorganisms in the yoghurt, particularly lactic acid bacteria, can continue to grow and metabolize even at refrigeration temperatures (Wang *et al.*, 2021). These bacteria can utilize proteins as a nutrient source, leading to a decrease in protein content over time. Carbohydrate is the major constituent of milk, which the lactic acid bacteria act upon during fermentation (Ihemeje *et al.* 2015). The decrease in carbohydrates may be due to the conversion of the lactose in carbohydrates to lactic acid. Low pH in food and fermented products is desirable; the lower the pH, the fewer types of microorganisms can thrive in such products (Arioui *et al.*, 2017). The increase in pH as the storage period increased is in line with the findings of Ihemeje *et al.* (2015) on the production and quality evaluation of plain, spiced, and flavoured yoghurt (carrot, pineapple, spiced ginger, and pepper fruits). Generally, low pH values are suitable for yoghurt marketed in tropical areas due to poor handling, poor storage conditions (epileptic electricity supply), and high temperatures, which could predispose the product to quicker deterioration as stated by Ibhaze *et al.* (2022b). The antioxidant (DPPH) is a stable free radical compound that reacts with radicals to deactivate or inhibit the damaging effect of radicals on cells and tissue (Senadeera *et al.*, 2018). The DPPH values decreased with the storage period, similar to the report of Ibhaze *et al.* (2023). The high value of yoghurt at 24 hours implies that the yoghurt has a better potency at this stage to inhibit free radicals that usually cause oxidative damage. The decrease in DPPH as the storage period progressed may be attributed to the breakdown of these compounds, the increase in pH content caused by the activities of lactic acid-producing bacteria as the storage period progressed and the interaction of milk polyphenol interactions (Arts *et al.*, 2002). There was an increase in the content of DPPH in the yoghurts up to treatment T3 (200 g carrot) before a further decrease suggesting that the antioxidant activity of the phytochemical compounds was at its peak at this level.

Conclusion: Carrots may be used as a functional food in Greek yoghurt production, however, the decrease in proximate values as the storage period progressed may require quick consumption to avoid deterioration in nutrient composition. Including carrots at 200 g/ L of the Greek yoghurt showed better potential for fortifying Greek yoghurt.

ACKNOWLEDGMENTS

The authors are grateful to the technical staff of the Department of Animal Production and Health, Federal University of Technology, Akure, for their assistance during the study.

REFERENCES

ARAB, M., YOUSEFI, M., KHANNIRI, E., AZARI, M., GHASEMZADEH-MOHAMMADI, V. and MOLLAKHALILI-MEYBODI, N. (2023). A comprehensive review on yoghurt syneresis: Effect of processing conditions and added additives. *Journal of Food Science and Technology*, 60(6): 1656 – 1665.

ARIOUI, F., AIT SAADA, D. and CHERIGUENE, A. (2017). Physicochemical and sensory quality of yoghurt incorporated with pectin from peel of *Citrus sinensis. Food Science and Nutrition*. 5(2): 358 – 364.

ARTS, M., HAENEN, G. R., WILMS, L. C., BEETSTRA, S. A., HEIJNEN, C. G., VOSS, H. and BAST, A. (2002). Interactions between flavonoids and proteins effect on the total antioxidant capacity. *Journal of Agricultural and Food Chemistry*, 50(5) 1184 – 1187.

CHANDAN, R. C. and KILARA, A. (2013). *Manufacturing Yoghurt and Fermented Milks*. Wiley-Blackwell, Hoboken, New Jersey, USA.

CHANDAN, R. C., GANDHI, A. and SHAH, N. P. (2017). Yoghurt: Historical background, health benefits, and global trade. Pages 3 – 29. *In:* SHAH, N. P. (Ed.). *Yoghurt in Health and Disease Prevention.* Academic Press, 125 London Wall, London EC2Y 5AS, United Kingdom.

DIMITRELLOU, D., SOLOMAKOU, N., KOKKINOMAGOULOS, E. and KANDYLIS, P. (2020). Yoghurts supplemented with juices from grapes and berries. *Foods*, 9(9): 1158. https://doi.org/10.3390/foods9091158

FARAG, M. A., SALEH, H. A., EL AHMADY, S. and ELMASSRY, M. M. (2022). Dissecting yoghurt: The impact of milk types, probiotics, and selected additives on yoghurt quality. *Food Reviews International*, 38(Suppl. 1): 634 – 650.

FOX, P. F., GUINEE, T. P., COGAN, T. M. and MCSWEENEY, P. L. (2017). *Fundamentals of Cheese Science*. Second Edition, Springer Nature, Springer Science + Business Media LLC, New York, United States.

GYAWALI, R. and IBRAHIM, S. A. (2016). Effects of hydrocolloids and processing conditions on acid whey production with reference to Greek yoghurt. *Trends in Food Science and Technology*, 56: 61 – 76.

HOSSAIN, M. A., HOQUE, M. M., AHMED, M. M. and AHMED, T. (2024). Probiotic yoghurt-like fermented milk product enriched with *Lactobacillus desidiosus* and *Lactobacillus fermentum*: proximate composition, physicochemical, microbiological, and sensory evaluation during refrigerated storage. *Discover Food*, 4: 24. https://doi.org/10.1007/s44187-024-00093-9

IBHAZE, G. A., AKINBANJO, D. T. and ARO, S. O. (2022a). Antioxidant, mineral and hydrophobicity properties of value-added yoghurt made from tropical fruits. *Animal Research International*, 19(1): 4297 – 4307.

IBHAZE, G. A., AKINBANJO, D. T. and JACOB, G. T. (2022b). Evaluation of set yoghurt quality enhanced with selected indigenous fruits. *International Journal of Trend in Scientific Research and Development (IJTSRD)*, 5(6): 690 – 699.

IBHAZE, G. A., OLATUNJI, D. I., ONIBI, G. E. and ADEBAYO, O. A. (2023). Comparative study on different local hydrocolloids on quality of set-type yoghurt made from bovine milk. *Journal of Environmental Science, Toxicology and Food Technology*, 17(2): 41 – 48.

IGBABUL, B., SHEMBER, J. and AMOVE, J. (2014). Physicochemical, microbiological and sensory evaluation of yoghurt sold in Makurdi metropolis. *African Journal of Food Science and Technology*, 5(6): 129 – 135.

IHEMEJE, A., NWACHUKWU, C. N. and EKWE, C. C. (2015). Production and quality evaluation of flavoured yoghurts using carrot, pineapple, and spiced yoghurts using ginger and pepper fruit. *African Journal of Food Science*, 9(3): 163 – 169.

LANGE, I. G. (2013). *Development of a Yoghurt Powder Formulation that can Produce a Recombined Product with Physicochemical and Rheological Properties Similar to Those Found in Commercial Greek-style yoghurts*. M.Sc. Thesis, Department of Agricultural, Food and Nutritional Science University of Alberta, Edmonton, Alberta, Canada.

LASHKARI, H., KHOSROWSHAHI ASL, A., MADADLOU, A. and ALIZADEH, M. (2014). Chemical composition and rheology of low-fat Iranian white cheese incorporated with guar gum and gum Arabic as fat replacers. *Journal of Food Science and Technology*, 51(10): 2584 – 2591.

MCAVOY, S. A. (2014). Global regulations of food colors: Each region has its own definitions of what constitutes a color additive, with related use requirements and restrictions. *The Manufacturing Confectioner*, 94(9): 77 – 86.

MENSOR, L. L., MENEZES, F. S., LEITÃO, G. G., REIS, A. S., SANTOS, T. C. D., COUBE, C. S. and LEITÃO, S. G. (2001). Screening of Brazilian plant extracts for antioxidant activity by the use of DPPH free radical method. *Phytotherapy Research,* 15(2): 127 – 130.

MOORE, S. (2020). *Why is Moisture Content Analysis of Food Important?* https://www.news-medical.net/life-sciences/Why-is-Moisture-Content-Analysis-of-Food-Important.aspx

NELIOS, G., NIKOLAOU, A., PAPAZILAKIS, P. and KOURKOUTAS, Y. (2023). Developing new high-protein-content traditional-type Greek yoghurts based on Jersey cow milk. *Dairy*, 4(1): 235 – 248.

PARNELL-CLUNIES, E. M., KAKUDA, Y., MULLEN, K., ARNOTT, D. R. and DEMAN, J. M. (1986). Physical properties of yoghurt: a comparison of vat versus continuous heating systems of milk. *Journal of Dairy Science*, 69(10): 2593 – 2603.

ŚCIBISZ, I., ZIARNO, M. and MITEK, M. (2019). Color stability of fruit yoghurt during storage. *Journal of Food Science and Technology*, 56: 1997 – 2009.

SENADEERA, S. S., PRASANNA, P. H. P., JAYAWARDANA, N. W. I. A., GUNASEKARA, D. C. S., SENADEERA, P. and CHANDRASEKARA, A. (2018). Antioxidant, physicochemical, microbiological, and sensory properties of probiotic yoghurt incorporated with various Annona species pulp. *Heliyon*, 4(11): e00955. https://doi.org/10.1016/j.heliyon.2018.e 00955

SPSS (2017). *Statistical Package for Social Sciences Version 25*. SPSS Incorporated, Chicago, Illinois, USA.

SUPAVITITPATANA, P., WIRJANTORO, T. I. and RAVIYAN, P. (2010). Characteristics and shelf-life of corn milk yoghurt. *Chiang Mai University Journal of Natural Science*, 9(1): 133 – 147.

SURBHI, S., VERMA, R. C., DEEPAK, R., JAIN, H. K. and YADAV, K. K. (2018). A review: Food, chemical composition and utilization of carrot (*Daucus carota* L.) pomace. *International Journal of Chemical Studies*, 6(3): 2921 – 2926.

TAVAKOLI, M., NAJAFI, M. B. H. and MOHEBBI, M. (2019). Effect of the milk fat content and starter culture selection on proteolysis and antioxidant activity of probiotic yoghurt. *Heliyon*, 5(2): e01204. https://doi.org/10.1016/j.heliyon.2019.e01204

VAN DE WATER, J. and NAIYANETR, P. (2003). Yoghurt and immunity: the health benefits of fermented milk products that contain lactic acid bacteria. Pages 113 – 144. *In:* FARNWORTH, E. R. T. (Ed.). *Handbook of Fermented Functional Foods*. CRC Press, Boca Raton, Florida, United States.

WANG, Y., WU, J., LV, M., SHAO, Z., HUNGWE, M., WANG, J., BAI, X., XIE, J., WANG, Y. AND GENG, W. (2021). Metabolism characteristics of lactic acid bacteria and the expanding applications in food industry. *Frontiers in Bioengineering and Biotechnology*, 9: 612285. https://doi.org/10.3389/fbioe.2021.612285