Original Research Article

PROXIMATE, PHYSICOCHEMICAL AND SENSORY ATTRIBUTES OF STIRRED YOGHURT FLAVOURED WITH AFRICAN STAR APPLE PULP (*Chrysophyllum albidum*)

ABSTRACT

Aims: To Investigate the Proximate, Physicochemical and Sensory attributes of Stirred Yoghurt Flavoured with African Star Apple Pulp (*Chrysophyllum Albidum*)
Study design: Randomized Completely Block Design (RCBD)
Place and Duration of Study: Department of Food Science and Technology, Faculty of Agriculture, University of Nigeria, Nsukka, Enugu State Nigeria between December 2018 and October 2019.
Methodology: The materials as well as the other ingredients used for the preparation of the flavoured stirred yoghurt include: African star apple, skimmed milk (Dano^{TM}), sugar and Yoghurmet (Starter culture) were sourced from Ogige main market in Nsukka Local Government Area of Enugu State, Nigeria. Yoghurt was produced, flavoured with African star apple pulp at different proportions to formulate five samples of stirred yoghurt. The formulation ratios of yoghurt to African star apple pulp were as follows: 100:0, 90:10, 80:20, 70:30, 60:40, 50:50. The African star apples were pulped and the pulp blended using a blender. The blended pulps were pasteurized before being added to the processed yoghurt.

Results: The result of physicochemical analysis revealed that viscosity (2.65 ± 0.06 cP – 3.25 ± 0.06 cP), total solids (22.35 ± 0.06% - 30.20 ± 0.06%), total titratable acidity (0.36 ± 0.00% - 0.39 ± 0.01%) and pH (5.20 ± 0.00 - 5.40 ± 0.00) differed significantly ($P < 0.05$) as the control sample YC (100:0) was compared with the yoghurt samples flavoured with African star apple pulp. The proximate parameters - Carbohydrate (11.20 ± 0.64% - 21.41 ± 0.10%), moisture content (71.53 ± 0.05% - 80.36 ± 1.17%) and ash content (1.30 ± 0.00% - 1.98 ± 0.03%) of the formulated yoghurt samples showed significant ($P < 0.05$) decrease as concentration of ASA pulp increased while crude protein (3.67 ± 0.01% - 4.92 ± 0.02%), fat (1.21 ± 0.02% - 2.72 ± 0.03%) and crude fibre (0.20 ± 0.00% - 1.40 ± 0.00%) showed significant ($P < 0.05$) increase with increasing concentration of ASA pulp. Among the formulated yoghurt samples, sample YP_1 was the most preferred with respect to colour (7.25 ± 0.91), taste (7.25 ± 1.07), aftertaste (7.00 ± 1.17), mouthfeel (6.95 ± 1.40), flavour (7.25 ± 0.64) and overall acceptability (7.30 ± 0.73).

Conclusion: Although the control sample YC (100:0) had most preferred sensorial qualities, yoghurt samples flavoured with African star apple pulp would rival the "used-to plain yoghurt" with improved awareness, and usage lower than 20% of the ASA pulp in yoghurt samples would maintain the product's acceptability among the variety-loving dairy consumers.

***Keywords**: African star apple (Chrysophyllum albidum), stirred Yoghurt, physicochemical, proximate, sensory, flavoured yoghurt.*

1. INTRODUCTION

Yoghurt is a fermented dairy product obtained from the lactic acid fermentation of milk. It is one of the most popular fermented milk products in the world. Yoghurt is a food staple that can be enjoyed in many ways. Fermentation of the milk sugar (lactose) produces lactic acid which acts on milk protein to give yoghurt its texture and characteristic tang [1]. Yoghurt is unique from the structural as well as compositional viewpoints, because it is solid and has the highest water content of all solid milk products [2]. Two microorganisms *Lactobacillus bulgaricus* and *streptococcus thermophilus*, growing together symbiotically, are responsible for the lactic fermentation of the yoghurt [3]. Yoghurts vary in appearance, flavour and ingredients. The quality and composition of applied bacterial cultures affect the quality of the yoghurt obtained as the result of the milk fermentation processes. Yoghurt is an increasingly popular cultured dairy product in most countries. This is partly because of an increased awareness of the consumers regarding possible health benefits of yoghurt. Yoghurt is easily digested, has high nutritional value, and is a rich source of carbohydrates, protein, fat, vitamins, calcium, and phosphorus. Because milk protein, fat, and lactose components undergo partial hydrolysis during fermentation, yoghurt is an easily digested product of milk [4]. In the culturing of milk to form yoghurt, *Streptococcus thermophilus* grows faster and produces both lactic acid and carbon (IV) oxide. The lactic acid and carbon (IV) oxide produced stimulates *Lactobacillus bulgaricus* growth [4]. These cultures can be purchased directly from local stores in tablet or freeze-dried forms. The lactic acid produced is also responsible for the characteristic flavour and texture of yoghurt and helps to maintain the quality of the yoghurt during storage and packaging [5]. The regular consumption of live culture yoghurt produces a higher level of immunity, boosting interferon by stimulating infections-fighting white blood cells in the blood stream with anti-tumor effects [6]. Yoghurt is nutritionally rich in protein, carbohydrate, vitamins and minerals for example, calcium which contributes to a healthy living including decreasing the risk of colon cancer, improve digestion among other benefits [7].

Flavoured yoghurt has gained popularity in recent years. Artificial or natural flavours may be used. Natural flavours are usually in the form of fruits. Flavoured yoghurt has definitely an edge over plain yoghurt in that, the high acidity encountered in the product is less pronounced; the objectionable off-flavour is suppressed and the need to concentrate the milk is also eliminated. Many hundreds of exotic fruits, including fleshy fruits such as apple, peach, kiwi fruits as well as berries such as strawberries, blackberries blackcurrant, blueberries, have been used in manufacturing foods including yoghurt produced and sold in Nigeria [8]. This over-dependence on exotic fruit flavours has led to increase in the cost of yoghurt production thereby making it unaffordable for low income earners. Meanwhile, there are many indigenous and under- utilized fruits that grow amply but have not been used in flavoring yoghurt; such fruit include African star apple.

African star apple (*Chrysophyllum albidum*) is one of the indigenous wild fruit trees with enormous potentials for establishment [9]. It belongs to the family of *Sapotaceae* and naturally occurs in Nigeria, Uganda, Niger Republic, Cameroon and Ivory Coast [30]. In Western Nigeria, the fruit is called “Agbalumo” and popularly referred to as “Udara” in South-Eastern Nigeria. *Chrysophyllum albidium* is a popular tropical fruit tree and widely distributed in the low rain forest zones and frequently found in villages [31]. The roots, barks and leaves of C. albidium have been employed in folk medicine for the treatment of diseases. The fruit is seasonal (December-March) and has immense economic potentials [32]. It is found mainly in the rural and urban centres in the month of December to April as its major fruiting season [10]. The usefulness of its trees lies on its production of sweet fleshy fruits which had been reported to be a rich source of vitamin C and Iron. The fruit also adds flavours to diets. It contains invaluable raw materials for the production of many cherished consumable items such as, desserts, confectionary, syrups and beverages, while the leaves and seeds are used in the pharmaceutical as an anticoagulant in blood bank [11].The fruit when ripe, is highly perishable and has a very short life span; it deteriorates within 5 - 7 days of harvest [12].The short life span, lack of effective preservation techniques for its fruits have necessitated the search for an alternative use for efficient utilization [13]. The fruit when ripe, is ovoid to sub-globe, pointed at the apex up to 6 cm long and 5 cm in diameter with an orange to golden yellow skin or peel. Within the pulp are three to five seeds which are not edible. The fruits are also suitable for the production of fruit jams and jellies because they are rich in pectin.

Plate 1: African star apple fruit [14]

2. MATERIALS AND METHODS

2.1 Raw materials

The materials as well as the other ingredients used for the preparation of the flavoured stirred yoghurt include: African star apple (Plate 1), skimmed milk (Dano^{TM}), sugar and Yoghurmet (Starter culture) were sourced from Ogige main market in Nsukka Local Government Area of Enugu State, Nigeria.

2.2 Sample Preparation

2.2.1 Processing of African star apple pulp

African star apple pulp (Plate 1) was prepared according to [15] method and were sorted to separate the fresh and good fruits from the insect-infected ones, graded, washed thoroughly with water to further eliminate adherent dirt to obtain fruits free of sand and other extraneous materials. The gross weight of the fruits was determined (Digital Balance, Model 302N, England) and peeled to remove the back. They were cut into two to remove the seeds. The fruits were put in an electric blender (Kenwood FP 730, United Kingdom) for easy blending and homogenization (Fig 1). The blended African star apple pulp was pasteurized, stored in an air tight container and kept in a refrigerator prior to further usage.

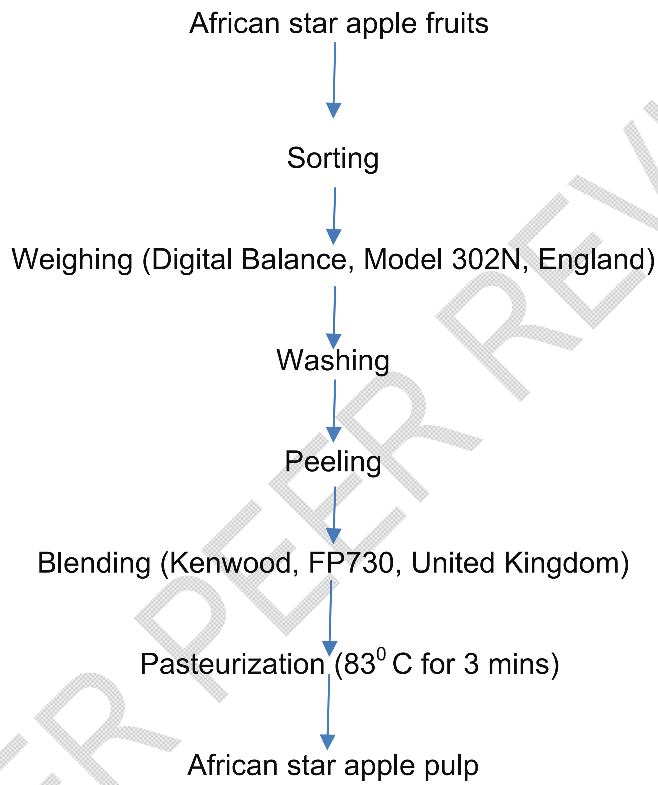

Figure 1: The Flow Chart for the extraction of African Star Apple Pulp [15] [33]

Plate 2: Pasteurized African star apple pulp [15]

2.2.2 Formulation of flavoured yoghurt

Stirred yoghurt was formulated using the method of [16] with some modifications. In order to produce 2 litres of yoghurt, skimmed milk and sugar were mixed with distilled water and pasteurized for 30 minutes at a temperature of 85^0C to destroy the undesired microorganisms in the raw materials. After pasteurization, the mixture was cooled to a temperature of 42 ± 2^0C which is the ideal growth temperature of the starter culture. The starter culture was then inoculated into the mixture and vigorously mixed. The mixture was left to incubate for 12 hours. After 12 hours, the yoghurt became set. Pasteurized African star apple pulp was added after fermentation, mixed, smoothened and divided into six portions according to formulation ratios of yoghurt**:** African star apple pulp as follows: 100:0, 90:10, 80:20, 70:30, 60:40, 50:50. Figure 2 shows the production of flavoured stirred yoghurt.

Milk product

↓

Standardization of milk

↓

Homogenization (55 – 65^{o}C; 15 – 20 MPa)

↓

Pasteurization (85 ^{0}C for 30mins)

↓

Cooling to inoculate temperature (42 ^{0}C ± 2^{0}C)

↓

Inoculation of starter culture (2% v/v)

↓

Fermentation / Incubation (42- 45^{0}C; 12 hours)

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Incorporation of pasteurized African star apple fruit pulp

↓

Mixing and smoothening

↓

Filling

↓

Cold storage

↓

flavoured stirred yoghurt

Figure 2: Production of yoghurt flavoured with African star apple pulp [17]

Plate 3: Yoghurt sample control (YC)

Plate 4: Stirred yoghurt flavoured with pasteurized African star apple pulp
YP_1 –YP_5 (Pasteurized African star apple pulp at 10,20,30,40,50% concentrations)

2.3 Sample Analysis

2.3.1 Proximate Composition Analysis

The method of Association of Official Analytical chemists (AOAC, 2010) was used for the determination of moisture, crude fat, ash, crude fibre and crude protein (N × 6.25) contents.

2.3.1.1 *Determination of Moisture content*

The moisture content of yoghurt samples was determined according to the standard method of Association of Official Analytical chemists [18]. The crucibles were washed thoroughly and afterwards dried in an oven at 100 ^{o}C for 1 hour. The hot dried crucibles were cooled and then noted down (W_1). The sample (2 g) were weighed into the crucibles (W_2) and dried at 70 ^{o}C until a constant weight was obtained (W_3). The moisture content of the samples was calculated as given in Equation (1).

$$\%\,Moisture\ Content = \frac{W_2 - W_3}{W_2 - W_1} \times 100 \qquad (1)$$

Where: W_1 = Initial weight of empty crucibles; W_2 = weight of crucible + weight of sample before drying; W_3 = weight of dish + weight of sample after drying.

2.3.1.2 *Determination of Ash content*

The ash content of the samples was determined according to the standards of [18]. A pre-heated and cooled crucible was weighed (W_1) and 2 grams of each of the samples was weighed into two preheated cooled crucibles (W_2). The samples were charred on a Bunsen flame inside a fume cupboard. The charred sample in the crucible was then transferred into a preheated muffle furnace at 550^{o}C for 2 hours until a white or light grey ash was obtained (W_3). It was then cooled in a dessicator, weighed and recorded. The ash content of the samples was calculated using Equation (2)

$$\%\,Ash\ content\ = \frac{W_3 - W_1}{W_2 - W_1} \times 100 \qquad (2)$$

Where: W_1 = Weight of empty crucible, W_2 = Weight of crucible + sample before ashing, W_3 = Weight of crucible + sample after ashing.

2.3.1.3 *Determination of crude fat content*

The fat content of the sample was determined using the standard method of [18]. A soxhlet extractor with a reflux condenser and a 500ml round bottom flask was fixed. The sample (2 g) was weighed into a labelled thimble and petroleum ether (300 ml) filled into the round bottom flask. The extraction thimble was sealed with cotton wool. The Soxhlet apparatus after assembling was allowed to reflux for about 6 hours. The thimble was removed with care and the petroleum ether collected on the top and drained into the container for re-use. When the flask was free of ether, it was removed and dried at 70^{o}C for 1 hour in an oven. It was cooled in dessicator and then weighed. The fat content of the samples was calculated using Equation (3).

$$\%\,fat\ content = \frac{Weight\ of\ fat}{Weight\ of\ the\ sample} \times 100 \qquad (3)$$

2.3.1.4 *Determination of crude fibre content*

The crude fibre was determined using the method described by [18]. 5 ml of the sample was digested with 200 ml of 0.22 N H_2SO_4, it was filtered and washed severally and transferred into another conical flask. The mixture was then dissolved in a 200 ml of 1.25% NaOH solution, boiled for 30minutes, cold filtered and washed with boiling water. The residue was dried at 105^oC for 2 hours, cooled in a dessicator and weighed. It was incinerated at 550^oC for 2 hours in a muffle furnace, cooled again in a dessicator and weighed. The percentage of crude fibre was calculated as shown in Equation 4.

$$\%\ \text{Crude Fibre} = \frac{W_2 - W_1}{W_3} \times 100 \qquad (4)$$

Where: W_1 = weight of the sample before incineration, W_2 = Weight of the sample after incineration, W_3 = weight of the original sample.

2.3.1.5 *Determination of protein content*

The protein content of the samples was determined according to the standard methods of [18] using Kjeldahl method.

2.3.1.5.1 *Digestion of the sample*

The sample (2 g) was weighed into Kjeldahl digestion flask followed by addition of anhydrous barium sulphate ($BaSO_4$) and hydrated copper (II) tetraoxosulphate (VI) as a catalyst. 25 ml of concentrated tetraoxosulphate (VI) acid (H_2SO_4) was added with few boiling chips. The flask with its content was heated in a fume chamber until a clear solution was obtained. The solution was cooled to room temperature after which it was transferred into a 250 ml volumetric flask and made up to the level with distilled water.

2.3.1.5.2 *Distillation*

The distillation unit was cleaned and the apparatus set up. A 100 ml conical flask (receiving flask) containing 5 ml of 2% Boric acid (H_3BO_4) was placed under the condenser with the addition to 2 drops of methyl red indicator. A digest of 5 ml was pipetted into the apparatus through the small funnel, washed down distilled water followed by the addition of 5 ml of 60% sodium hydroxide (NaOH) solution. The digestion flask was heated until 100 ml of distillate (ammonium sulphate) was collected in the receiving flask.

2.3.1.5.3 *Titration*

The solution in the receiving flask was titrated with about 0.04 M Hydrochloric acid (HCl) to get a pink colour. The same procedure was carried out on the blank.

$$\% \text{ Nitrogen} = \frac{V_s - V_b \times N_{acid}}{W} \times 0.0401 \times 100 \qquad (5)$$

Where: V_s = volume (ml) of acid required to titrate the sample; V_b = volume (ml) of acid required titrate blank; N_{acid} = Normality of acid (0.1 N); W = weight of sample in gram.

2.3.1.6 *Determination of Carbohydrate content*

Carbohydrate was determined using Nitrogen Free method described by [18]. It was calculated by getting the sum of the other proximate parameters and subtracting it from 100 as Nitrogen-Free Extract (NFE) as follows:

$$\% \text{ Carbohydrate (NFE)} = 100 - (M + P + F + A + F_c) \qquad (6)$$

Where: M =Moisture content, P =Protein, F =Fat, A= Ash, F_c = Crude fibre.

2.3.2 Physicochemical Analysis

2.3.2.1 Determination of pH content

The pH of the yoghurt samples (5 ml) was measured electrometrically using a standard pH meter (model 20 pH Conductivity meter, Denver Instrument, United Nations Inventory Database) according to [18] method. This instrument was standardized using buffer solutions of pH 4.0 and 9.0. The pH electrode was dipped into yoghurt and after a few minutes of equilibration, the pH of the samples was measured.

2.3.2.2 *Determination of Titratable acidity*

Titratable acidity was determined using the method of [18]. The sample (5 ml) at 25^0C was measured into a flask and diluted to twice its volume with distilled water. Phenolphthalein indicator (2 ml) was added to each yoghurt sample and titrated with 0.1 M NaOH to the first permanent pink colour. The acidity was reported as the percentage Lactic acid by weight as shown in Equation (7).

$$Titratable\ acidity\ (\%) = \frac{Qty\ of\ yoghurt\ sample}{Qty\ of\ NaOH\ (ml)} \times\ 0.009\ \times\ 100 \quad (7)$$

2.3.2.3 *Determination of Total solids*

Total solids of the samples were determined in accordance with the methods described by [18]. 10ml of the formulated yoghurt sample pipetted into washed, dried and weighed crucible. The dish and its content was put in an oven and dried at 70^0C for 3 hours under pressure. It was cooled in a desiccator and the weight of the solid was determined as shown in Equation (8).

$$\%\ \text{by mass of Total Solid} = \frac{\text{Weight of Dried Solid}}{\text{Sample}} \times 100 \quad (8)$$

2.3.2.4 *Determination of Viscosity*

Sample viscosity was determined by using Ostwald viscometer according to [18]. 20 g of each of the sample was taken and made Newtonian by dissolving in 50 ml of water to obtain the density of each sample, Water was sucked into viscometer and time taken to fall back on its own after sucking to the mark was noted. The procedure was repeated for the remaining yoghurt samples. The apparent viscosity of the formulated samples was calculated using the Equation (9).

$$\text{Apparent viscosity (cP)} = \frac{n_2 \times e_1 \times t_1}{e_2 \times t_2} \quad (9)$$

Where: n_2 = Viscosity of water (0.89), e_2 = Density of sample, t_1 = Time taken for the sample to fall back on its own (seconds), e_2 = Density of water ($1g/cm^3$), t_2 = Time taken for water to fall back on its own (2.5 secs).

2.4 Data analysis and experimental design

The results were laid out in a Randomized Completely Block Design (RCBD). Data generated were subjected to one way analysis of variance (ANOVA) at 0.05 probability level. Duncan's new multiple range test (DNMRT) was used to compare the treatment means using SPSS (version 22.0).

3.0 RESULTS AND DISCUSSION

3.1 Proximate composition of stirred yoghurt flavoured with African star apple pulp

Table 1 shows the proximate composition of yoghurt flavoured with African star apple pulp. The moisture content of the control sample (YC) at 100: 0 (71.53 ± 0.05 %) differed significantly ($P < 0.05$) when compared to the values obtained for the yoghurt samples flavoured with pasteurized African star apple pulp. Sample YP_1 had the highest moisture content (80.36 ± 1.17%) while sample YC had the lowest moisture content (71.53 ± 0.05 %). The moisture content of the yoghurt samples flavoured with pasteurized African star apple pulp decreased from 80.36 ± 1.17 to 77.42 ± 0.37% with increase in concentration of the pulp. The decrease in the moisture content with increase in concentration of African star apple pulp incorporated, could be attributed to increase in total solids in the African star apple pulp which absorb free water in the formulated yoghurt sample. This was in line with the report obtained by [19] on fruit-flavoured yoghurt samples with moisture content ranging from 78.56 to 82.56%.

The ash content ranged from 1.30 ± 0.00 to 1.98 ± 0.03% with the control sample YC (100:0) having the highest ash content. Sample YP_5 had the lowest in ash content (1.30 %). In relation to the control sample, the result revealed a significant ($P < 0.05$) decrease in the ash content between the control sample YC (100:0) and the flavoured yoghurt samples. According to [20, 23], the ash content of the African star apple pulp is usually very low (3.4%). The ash content provides an estimate of the quality of a product [21]. According to Bello and Henry [22], the ash content in relation to the storage time, decreased with increase in storage time.

The fat content of the control sample (YC) at 100:0 had the least fat content at 1.21 % which differed significantly ($P < 0.05$) from the yoghurt samples formulated with pasteurized African star apple pulp. YP_5 had the highest fat content (2.72 ± 0.03 %). The fat content of the yoghurt containing pasteurized African star apple pulp (YP) increased from 2.12± 0.01 to 2.72 ± 0.03% with increase concentration of the pulp. The succulent pulp has been reported to be rich in fat (13.1%) among other nutrients [23]. The higher fat content could be as a result of aggregation of fat due to reduction in the moisture content. This finding was consistent with the report of [24] on fruit-flavoured yoghurt.

Table 1: Proximate composition of yoghurt sample flavoured with African star apple (ASA) pulp

Sample	Moisture	Ash	Fat	Fibre	Protein	Carbohydrate
YC (100 : 0)	$71.53^{d} \pm 0.05$	$1.98^{a} \pm 0.03$	$1.21^{i} \pm 0.02$	$0.20^{f} \pm 0.00$	$3.67^{f} \pm 0.01$	$21.41^{a} \pm 0.10$
YP_1 (90 : 10)	$80.36^{ab} \pm 1.17$	$1.58^{f} \pm 0.00$	$2.12^{g} \pm 0.01$	$0.20^{f} \pm 0.00$	$4.32^{e} \pm 0.00$	$11.40^{cd} \pm 1.15$
YP_2 (80 : 20)	$80.10^{ab} \pm 0.71$	$1.57^{f} \pm 0.00$	$2.25^{f} \pm 0.05$	$0.42^{e} \pm 0.00$	$4.48^{cd} \pm 0.06$	$11.20^{cd} \pm 0.64$
YP_3 (70 : 30)	$78.02^{abc} \pm 2.08$	$1.42^{g} \pm 0.00$	$2.38^{e} \pm 0.02$	$0.80^{d} \pm 0.02$	$4.44^{d} \pm 0.01$	$12.90^{bc} \pm 2.07$
YP_4 (60 : 40)	$77.42^{bc} \pm 0.37$	$1.42^{g} \pm 0.00$	$2.43^{c} \pm 0.02$	$0.96^{b} \pm 0.00$	$4.58^{b} \pm 0.02$	$13.20^{bc} \pm 0.42$
YP_5 (50 :50)	$77.69^{abc} \pm 0.08$	$1.30^{h} \pm 0.00$	$2.72^{a} \pm 0.03$	$1.40^{a} \pm 0.00$	$4.92^{a} \pm 0.02$	$11.97^{cd} \pm 0.12$

Values are mean ± standard deviation of three replicate readings. Means on the same column with different superscripts are significantly different ($P < 0.05$)

Key: Sample YC: Yoghurt control, Samples YP_1 –YP_5 (Pasteurized African star apple pulp at 10, 20, 30, 40, 50% concentrations)

The fibre content of the control sample (YC) at 100: 0 concentration was 0.20 ± 0.00 %. There was significant ($P < 0.05$) difference between the yoghurt samples formulated with pasteurized African star apple pulp (YP) and the control sample (YC). Sample YP_5 had the highest fibre content of 1.40 ± 0.00 %. The fibre content of the yoghurt formulated with pasteurized pulp (YP) increased from 0.20 ± 0.00 to 1.40± 0.00 % with increase in concentration of the pulp which is as a result of fibre content of African star apple pulp [25].

The crude protein content of the formulated yoghurt sample with African star apple pulp increased with increase in the concentration of the pulp incorporated. There was significant (($P < 0.05$) difference between the control sample (YC) at 100: 0 and the other yoghurt samples. Sample YP_1 had the lowest protein content (4.32± 0.00 %) while sample YP_5 (50:50) had the highest protein content. African star apple (ASA) pulp is said to be very rich in protein. Consequently, the increase in the protein content of the samples with the increase in the amount of ASA pulp added could be attributed to the dilution effect. This trend corroborates with the report of [22], a study on the effect of storage period on the proximate composition of African star apple pulp.

The carbohydrate content of the yoghurt sample (YC) at 100: 0 concentration, which differed significantly ($P < 0.05$) from those yoghurt samples flavoured with pasteurized African star apple pulp, was 21.41 ± 0.10%. Sample YC had the highest carbohydrate content (21.41± 0.10%). The carbohydrate content of the yoghurt formulated with pasteurized pulp (YP) ranged from 11.2 ± 0.64% to 21.4± 0.10%. Within the formulated yoghurt samples, there was a slight increase in carbohydrate content. The slight increase could be seen in the light of the pasteurized pulp which is high in carbohydrate, thus influencing the observed increase within the formulated samples. However, it was rather more of a depression than increase, with increase in concentration of the pulp. The said decrease in carbohydrate content of the yoghurt samples containing African star apple pulp, could be as a result of some bacterial enzymatic activities (i.e. fermentation) which caused the conversion of lactose in the yoghurt's milk base to lactic acid consequently, leading to the reduction in the carbohydrate content of the formulated yoghurt samples.

3.2 Physicochemical composition of stirred yoghurt flavoured with African star apple pulp

There was no significant ($P > 0.05$) difference between the pH of the control sample YC (100:0) and the yoghurt samples YP_1 (90:10), and YP_4 (60:40) flavoured with African star apple pulp. However, there was significant ($P < 0.05$) difference in the pH between the control sample YC (100:0) and ASA pulp- flavoured YP_2 (80:20), YP_3 (70:30) and YP_5 (50:50). Noticeably, some yoghurt samples flavoured with African star apple pulp (YP_1 and YP_4) and (YP_2 and YP_3) showed no significant ($P > 0.05$) difference in pH. The pH of the formulated yoghurt samples containing African star apple (ASA) pulp dropped with increase in the concentration of the pulp incorporated. The addition of African star apple pulp which led to a depression in pH could be ascribed to high content (1000 - 3000mg / 100g) of ascorbic acid present in African star apple fruit, the value which is ten-fold higher than that of cashew or guava fruit [26]. Ascorbic acid in ASA pulp influences the pH of the product formulated by increasing the acidity thus leading to drop in its pH (Table 2). This observed trend was in agreement with the finding of [19] on fresh and dried cashew pulp-flavoured yoghurt.

The viscosity content of the control sample YC (100:0) differed ($P < 0.05$) significantly from the yoghurt samples flavoured with pasteurized African star apple pulp. Sample YP_2 had the least viscosity content (2.65 ± 0.06 cP) while the control sample YC (100:0) had the highest viscosity (3.25 ± 0.06 cP). The viscosity of the ASA pulp flavoured yoghurt samples decreased from 3.25 ± 0.06 cP to 2.65 ± 0.06 cP as concentration of the pulp added in the formulated samples increased (Table 2). The reason for this drop in the viscosity, in comparison to the control sample YC, could be attributed to the decrease in water-retaining ability of milk protein when fruit was added to the yoghurt [27]. This observed trend was consistent with the report of [28] on strawberry-added yoghurt. Furthermore, similar trend in viscosity of yoghurt flavoured with fruit, had been reported by [29].

Table 2: Physicochemical properties of yoghurt samples flavoured with African star apple pulp

Yoghurt Samples	pH	Viscosity (cP)	Total solid (%)	TTA (%)
YC (100: 0)	$5.30^{b} \pm 0.00$	$3.25^{ab} \pm 0.06$	$30.20^{a} \pm 0.00$	$0.36^{m} \pm 0.00$
YP_1 (90 : 10)	$5.30^{b} \pm 0.00$	$3.05^{cde} \pm 0.06$	$22.70^{d} \pm 0.12$	$0.37^{lm} \pm 0.06$
YP_2 (80 : 20)	$5.40^{a} \pm 0.00$	$2.65^{i} \pm 0.06$	$22.35^{e} \pm 0.06$	$0.37^{l} \pm 0.00$
YP_3 (70 : 30)	$5.35^{a} \pm 0.06$	$3.10^{bcd} \pm 0.00$	$22.65^{d} \pm 0.17$	$0.39^{k} \pm 0.01$
YP_4 (60 : 40)	$5.30^{b} \pm 0.00$	$3.10^{bcd} \pm 0.00$	$22.65^{d} \pm 0.06$	$0.37^{l} \pm 0.00$
YP_5 (50 :50)	$5.20^{c} \pm 0.00$	$2.90^{efg} \pm 0.12$	$22.45^{e} \pm 0.06$	$0.39^{k} \pm 0.01$

Values are mean ± standard deviation of three replicate readings. Means on the same column with different superscripts are significantly different ($P< 0.05$)
Key: Sample YC: Yoghurt control, Samples YP_1 –YP_5 (pasteurized African star apple pulp at 10, 20, 30, 40, 50% concentrations)

For total solids, the control yoghurt sample YC (100:0) had the highest value 30.20 ± 0.00% which differed significantly ($P < 0.05$) from those yoghurt samples flavoured with African star apple pulp (Table 2). The formulated yoghurt samples containing pasteurized ASA pulp decreased from 22.70 ± 0.12 to 22.35 ± 0.06% with increase in concentration of the pulp. The observed low total solids in the yoghurt samples flavoured with ASA pulp could be attributed to factors such as increased enzymatic activity (fermentation) of the Lactic acid bacteria (LAB), as well as fermentation period, leading to the drop in the total solid contents of the product.

Table 2 showed the total titratable acidity (TTA) of the control yoghurt samples YC (100:0) was 0.36 ± 0.00%. Samples YP_3 and YP_5 which showed no significance ($P >0.05$) in their TTA, had higher value of titratable acidity than other yoghurt samples flavoured with African star apple pulp. There was significant ($P < 0.05$) difference between the TTA of the control sample and the formulated yoghurt samples. There was a steady increase in the titratable acidity which corresponded to an increase in ASA pulp added in the yoghurt samples. This could be ascribed to certain intrinsic factors such as the high content of ascorbic acid in the fruit pulp, the increased microbial activity of LAB, and the pH of the product [28]. The titratable acidity also showed a correlation with pH of the yoghurt samples flavoured with ASA pulp.

3.3 Sensory evaluation of stirred yoghurt flavoured with African star apple pulp

The sensory scores for the yoghurt samples flavoured with African star apple pulp and the control samples for colour, flavour, taste, aftertaste, consistency and overall acceptability are shown in Table 3.

Table 3 showed the sensory scores of the yoghurt samples containing African star apple (ASA) pulp. The control sample YC (100:0) had the highest level of preference for colour (8.40 ± 0.75). There was significant ($P < 0.05$) difference between the control sample YC (100:0) and formulated yoghurt samples containing pasteurized African star apple pulp with respect to colour. Within the formulated yoghurt samples, sample YP_1 (7.25 ± 0.91) was most preferred while sample YP_5 (5.95 ± 1.63) the least. The level of preference for colour (appearance) decreased with increasing level of ASA pulp incorporated in the formulated yoghurt samples. This was found to be consistent with the finding of [30] on yoghurt flavoured with solar-dried bush mango pulp.

Sample YC (100:0) as shown in Table 3, had the highest flavour score 8.45 ± 0.76 and differed significantly ($P < 0.05$) from other yoghurt samples flavoured with pasteurized African star apple pulp. The flavour of the yoghurt samples flavoured with pasteurized African star apple pulp containing 10, 20, 30, 40, 50% concentrations decreased with increase in concentration of African star apple pulp from 7.25 ± 0.64 to 6.10 ± 1.29. This implies that among the formulated yoghurt samples, sample YP_1 was the most preferred as it was rated highest with respect to flavour. This agreed with the report of other researchers [19,30].

There was also a decrease in the mouthfeel from 6.95 ± 1.40 to 5.45 ± 1.79 of the formulated yoghurt samples with pasteurized African star apple pulp. Sample YC (100:0) had the highest value of 8.10 ± 1.21 (Table 3). The mouthfeel of the control sample YC (100:0) differed significantly ($P < 0.05$) with those formulated yoghurt samples in which African star apple pulp was added at 10, 20, 30,40,50% concentrations. Among the formulated yoghurt samples, sample YP_1 (90:10) was most preferred (6.95 ± 1.40).

Similar trend was noticeable in the sensory scores of aftertaste of the yoghurt samples flavoured with ASA pulp and the control sample YC (100:0) i.e. a reduction in the acceptance of aftertaste from 7.00 ± 1.17 to 6.30 ± 1.08. Like other sensory attributes earlier discussed, the plain yoghurt sample (i.e. the control sample YC) had the highest aftertaste score (8.15 ± 1.23). Among the yoghurt samples formulated with African star apple (ASA) pulp, there was no significant ($P > 0.05$) difference in the aftertaste of samples YP_2, YP_3 and YP_4 at 20, 30 and 40% concentrations of ASA pulp respectively (Table 3). In the aftertaste order of preference, Sample YC > Sample YP_1 > Sample YP_2 > Sample YP_3 > Sample YP_4 > Sample YP_5.

The specific trend could not be ascertained with respect to the sensory scores of taste, consistency and overall acceptability. For taste, there was significant ($P < 0.05$) difference between the control sample YC and other yoghurt samples containing African star apple pulp (Table 3). The control sample YC (100:0) maintained the highest taste score while sample YP_1 was more preferred than the other remaining yoghurt samples flavoured with ASA pulp. Thus, Sample YC > Sample YP_1 > Sample YP_3 > Sample YP_2 > Sample YP_4 > Sample YP_5. With respect to consistency, Sample YC > Sample YP_3 > Sample YP_2 > Sample YP_4 >Sample YP_1 > Sample YP_5 while in overall acceptability, Sample YC > Sample YP_1 > Sample YP_3 > Sample YP_2 > Sample YP_5 > Sample YP_4.

Table 3: Sensory evaluation of Yoghurt samples flavoured with African star apple Pulp

Sample	Colour	Taste	Flavour	Mouthfeel	Consistency	Aftertaste	OA
YC (100:0)	8.40^{a} ± 0.75	8.35^{a} ± 0.88	8.45^{a} ± 0.76	8.10^{a} ± 1.21	7.80^{a} ± 1.40	8.15^{a} ± 1.23	8.30^{a} ± 0.923
YP_1 (90 : 10)	7.25^{b} ± 0.91	7.25^{bc} ± 1.07	7.25^{bc} ± 0.64	6.95^{bc} ± 1.40	6.45^{bc} ± 1.36	7.00^{bc} ± 1.17	7.30^{bc} ± 0.73
YP_2 (80 : 20)	6.95^{bc} ± 1.32	6.70^{cde} ± 1.42	7.00^{bc} ± 0.92	6.75^{bc} ± 0.79	6.80^{bc} ± 1.01	6.85^{bcd} ± 0.81	6.95^{cd} ± 0.10
YP_3 (70 : 30)	6.90^{bcd} ± 1.33	6.90^{bcd} ± 0.91	7.00^{bc} ± 0.92	6.75^{bc} ± 1.12	7.05^{ab} ± 0.10	6.85^{bcd} ± 1.23	7.25^{bc} ± 0.91
YP_4 (60 : 40)	6.70^{bcde} ± 1.21	6.20^{de} ± 1.94	6.90^{bc} ± 1.37	6.50^{bc} ± 1.14	6.60^{bc} ± 0.94	6.45^{bcd} ± 1.19	6.65^{cd} ± 1.04

Values are mean ± standard deviation of duplicate readings. Means on the same Colum with different superscripts are significantly different (*P < 0.05*)
Keys: Sample YC: Yoghurt control. Samples YP_1 –YP_5 (Pasteurized African star apple pulp at 10,20,30,40,50% concentrations)

4.0 CONCLUSION

The incorporation of African star apple (ASA) pulp to the stirred yoghurt as a flavourant significantly improved the proximate, physicochemical and sensory attributes. More awareness should be created on the nutritional benefits of African star apple and the numerous health benefits such as improvement in the fibre content, rich protein content, high ascorbic acid content among many others, when added to food products. This would in turn enhance consumers' acceptability of the product in which African Star Apple pulp is incorporated as it was evident that flavoured yoghurt samples with 10% ASA pulp played a second fiddle to the plain yoghurt from the result of sensory studies carried out. It is therefore recommended that African star apple pulp at concentration lower than 20 percent be used to maintain its general acceptability.

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