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Effects of Fermentation Time on the Proximate Composition and Sensory Attributes in the Production of Baobab Pulp Yoghurt

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Abstract: The effects of fermentation time on proximate composition and sensory properties of baobab (Adansonia digitata) fruit pulp-fortified yoghurt were studied in the present research. Baobab fruits underwent processing to extract the pulp and were incorporated at 10% (w/v) into milk before fermentation at different times (0-15 hours). Moisture, ash, protein, fat, fibre, and carbohydrate contents were determined using standard analytical techniques. Sensory evaluation was done using a 9-point hedonic scale. The results showed that fermentation time significantly, at ($p < 0.05$), influenced proximate parameters: moisture within the range of 76.53-78.96%, protein within the range of 6.78-8.16%, ash within the range of 0.50-0.64%, fat within the range of 3.71-4.40%, fibre within the range of 0.31-0.67%, and carbohydrates within the range of 8.38-10.72%. Protein content steadily increased with the time taken for fermentation, while values of moisture and carbohydrate oscillated. Sensory properties, namely, colour, taste, flavour, odour, mouthfeel, and overall acceptability, however, were not significantly different, at $p > 0.05$, across all fermentation periods. This study indicated that the incorporation of baobab pulp into yoghurt will not affect its sensory quality negatively and will improve its nutritional value. The nutritional characteristics of yoghurt containing baobab are those of a functional and nutrient-rich dairy product that is suitable for wider consumer acceptance.

Keywords: *Baobab, Fermentation, Yoghurt, Pulp.*

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Introduction

Adansonia digitata L. (Malvaceae) is a multipurpose tree termed African baobab by both the English and the French (Kaboré *et al.*, 2011). The tree belongs to the Malvaceae family with great ecological tolerance which makes it valuable in both hot and dry cultivating conditions (Buchmann *et al.*, 2010). This beneficial tolerance is attributed to the thick fire-resistant bark, shedding of leaves, as well as possession of a trunk that can absorb water in the rainy season and contracts in the dry season. The genre *Adansonia* was coined from Adanson Micheal, (1727– 1806) a French botanist name, who discovered a specimen on the islands of Sor, Senegal, while the term digitate (digitals of the hand or hand-like) was about the shape of the leaves of the African baobab tree (Kamatou *et al.*, 2011) with a usual range of 5–7 leaflets. However, concerning physiological attributes, several other names have been ascribed to the African baobab, including "magic tree", "chemist tree", "symbol of the earth", "monkey bread of Africa" (Vermaak *et al.*, 2011) "dead rat tree", "cream of tartar", etc. (Rahul *et al.*, 2015).

African baobab is indigenous to the Savannah regions of Africa (16° N and 26° S), whilst several others have been identified in other tropical regions of the world (Darr *et al.*, 2020). African baobab is an angiosperm - having flowers and producing seeds covered by a carpel, they are pachycauls, with thick stems. Records have shown that the African baobab tree is the oldest and largest surviving angiosperm (Patrut *et al.*, 2018) where some of them including the Panke of Zimbabwe (a sacred tree in Matabeleland North), Chapman of Botswana (a historic African baobab tree), are now dead. Initial growth of the African baobab tree is characterized by single stems which consequently develops to several other stems as a result of its characteristic ability to produce stems periodically.

The nutritional profile of baobab pulp has garnered interest from the global health community, particularly for its potential to combat malnutrition in developing countries. Studies have shown that baobab fruit pulp contains ten times the vitamin C of oranges, making it one of the richest sources of this essential vitamin (Singh *et al.,* 2021). In traditional African medicine, the baobab fruit pulp is used to treat various ailments, including dysentery, malaria, smallpox, and gastrointestinal disorders. The pulp's high antioxidant content helps reduce inflammation and supports immune function (Ogundare *et al.,* 2021). Additionally, the seeds, leaves, and bark of the baobab tree have medicinal uses, with the seeds being used as an anti-inflammatory agent and the leaves being consumed for their antipyretic properties (Iruene *et al.,* 2021).

Yoghurt, a fermented dairy product, is widely consumed for its probiotic properties and nutritional value. Combining baobab pulp with yoghurt can enhance the product's nutritional profile by adding vitamins, minerals, and antioxidants, making it a functional food with numerous health benefits (Momanyi *et al.,* 2020). The fermentation process involved in yoghurt production is carried out by lactic acid bacteria (LAB), primarily *Lactobacillus bulgaricus* and *Streptococcus thermophilus*. These microorganisms ferment lactose, the sugar in milk, into lactic acid, which acts as a preservative by lowering the pH and inhibiting the growth of spoilage organisms (Iruene *et al.,* 2021). The LAB used in yoghurt production also contribute to the product's health benefits by improving gut health, enhancing immune function, and providing relief from lactose intolerance (Kaimba *et al.,* 2020).

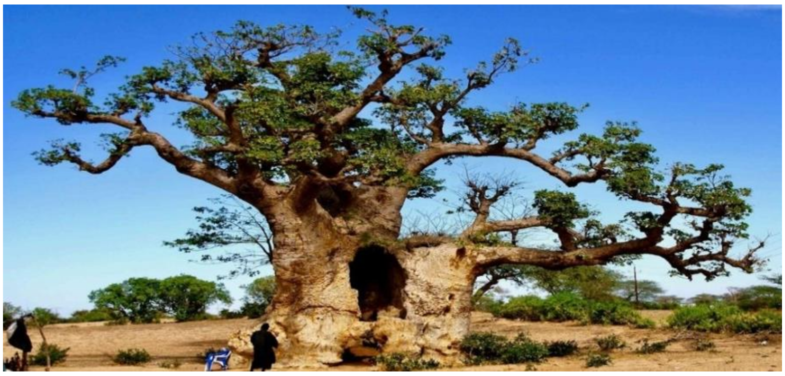

Figure 1. African Baobab Tree (Darr *et al.,* 2020)

Material and Methods

Sample Collection and Preparation

Baobab fruits were collected from mature baobab trees located in the arid regions of northern Nigeria. The fruits were carefully selected based on their size, color, and absence of physical damage. Once collected, the fruits were transported to the laboratory for further processing. In the laboratory, the fruits were washed thoroughly with clean water to remove any dirt or contaminants. The hard outer shells of the baobab fruits were cracked open using a mallet, and the pulp was extracted. The pulp was then separated from the seeds and fibers using a clean, sterile sieve. The sieved pulp was collected in sterile containers and stored at -20°C until further use as previously described by Mounjouenpou *et al.* (2018).

Yoghurt Production

The baobab pulp was used as an ingredient in the yoghurt production process as previously described by Adelekan *et al.* (2020) and Stadlmayr *et al.* (2020) with little modification. Fresh cow milk was obtained from a local dairy farm and was pasteurized by heating it to 85°C for 15 minutes to eliminate any pathogenic microorganisms. After pasteurization, the milk was cooled to 45°C, the optimal temperature for the growth of yoghurt starter cultures. Starter cultures containing *Lactobacillus bulgaricus* and *Streptococcus thermophilus* were added to the cooled milk. The inoculated milk was then divided into two batches. In the first batch, 10% (w/v) of baobab pulp was added to the milk, while the second batch served as the control without any baobab pulp. Both batches were incubated at 45°C for 6 hours to allow fermentation to occur.

Proximate Analysis

Proximate analysis was performed to determine the nutritional composition of the baobab pulp yoghurt. The analysis included the determination of moisture content, ash content, protein content, fat content, and carbohydrate content. Standard analytical methods were used for these determinations.

Determination of Moisture content

The moisture content was determined by drying a known weight of the yoghurt sample in an oven at 105°C until a constant weight was achieved. The moisture content was calculated as the percentage of weight loss as previously described Zumunta and Umar, (2020).

$$\text{Percentage moisture} = \frac{\text{Loss of weight due to drying}}{\text{weight of sample}} \; x\frac{100}{1}$$

Similarly and more clearly, the percentage moisture content was calculated using the formula:

$$\%\text{Moisture} = \frac{W2-W3}{W2-W1} \; x\frac{100}{1}$$

Where W1 = wt of dish, W2= Wt of dish +sample, W3= Wt of dish + sample after drying.

Determination of Ash content

The ash content was determined by incinerating a known weight of the yoghurt sample in a muffle furnace at 550°C until all organic matter was burnt off. The remaining inorganic residue was weighed, and the ash content was expressed as a percentage of the original sample weight (Gemede *et al.,* 2016).

$$\%\ \text{Ash content} = \frac{\text{weight of ash}}{\text{weight of sample}} \; x\frac{100}{1}$$

Determination of crude protein content:

The protein content was determined using the Kjeldahl method. The sample was digested with concentrated sulfuric acid, and the resulting digest was distilled with sodium hydroxide. The liberated ammonia was collected in boric acid and titrated with a standard acid. The protein content was calculated using a conversion factor of 6.25 (i.e 100/16) an approximate crude protein value as multiple of nitrogen percent (Muthai *et al.*, 2019).

Determination of Lipid content

The fat content was determined using the Soxhlet extraction method adopted from Idris *et al.* (2020). A known weight of the yoghurt sample was extracted with petroleum ether in a Soxhlet apparatus. The solvent was evaporated, and the remaining lipid (ether extract) was weighed. The lipid content was expressed as a percentage of the original sample weight.

Determination of crude fiber content

The carbohydrate content of the food was contained in two fractions: the crude fiber (CF) and the nitrogen-free extractives (NFE). The crude fiber was determined by subjecting the residual food from ether extraction to successive treatments with boiling acid and alkali of defined concentration. The organic residue obtained from these treatments was identified as the crude fiber (Msalilwa *et al.*, 2020).

Determination of carbohydrate contents

The carbohydrate content of the food was divided into two fractions: the crude fiber (CF) and the nitrogen-free extractives (NFE). The crude fiber was determined by subjecting the residual food from ether extraction to successive treatments with boiling acid and alkali of defined concentration; the organic residue obtained was considered the crude fiber (Alba *et al.*, 2020). The nitrogen-free extractives (carbohydrate) were calculated by subtracting the sum of the amounts of moisture, ash, crude protein, ether extract (% lipid), and crude fiber (expressed in g/kg) from 1000. The difference was designated as the nitrogen-free extractives. This fraction is a heterogeneous mixture of all components not determined in the other fractions, including sugars, fructans, starch, pectins, organic acids, and pigments (Babiker *et al.*, 2020).

Sensory Evaluation

Sensory evaluation was conducted to assess the acceptability of the baobab pulp yoghurt as previously described by Titilayo and Musliu, (2016). The samples were evaluated using fifteen (10) trained panelists from staff and students of Aliko Dangote University of Science and Technology, Wudil. The selection of the panel members was based on their ability to differentiate samples even with slight change. The sensory analyses were performed in individual booths with controlled temperature and lighting conditions. The panelists were given approximately 20 mL of each sample in disposable plastic cups, coded with three-digit random numbers. They also received biscuits and water to clean their palates. The sensory attributes evaluated were colour, taste, flavour, odour, mouthfeel and general acceptability. These were rated using a 9-point hedonic scale (1: like extremely, 9: dislike extremely). Panelists were requested to fill in the sensory evaluation form.

Results

Proximate composition

The effect of fermentation time on proximate composition of yoghurt supplemented with baobab fruit pulp is shown in Table 1, moisture content varied from 76.53 to 78.96 with highest found during 3 hour fermentation time, while 6 hour fermentation time recorded the lowest value. Ash content, representing the mineral composition varied from 0.50 to 0.64%, the highest was recorded during 6 hour fermentation. Fat content was stable, ranging from 3.71 to 4.40%, the highest value was recorded during 12 hour fermentation. Crude fiber content ranged from 0.31% during 9 hour fermentation to 0.67 which was found at 3 hour fermentation time. The carbohydrate content varied from 8.38 to 10.72%. On the other hand, crude protein content showed different trend with other parameters and was found to increase from 6.78% to 8.16% at 0 and 15 hour fermentation respectively.

Sensory analysis

Table 2 shows the results of effect of fermentation time on sensory attributes of yoghurt supplemented with baobab fruit pulp. The sensory parameter ranges from 2.31 to 3.31, 2.69 to 3.31, 3.08 to 3.38, 4.08 to 4.62, 2.92 to 3.38 and 2.92 to 3.23 for colour taste, flavour, odour, mouthfeel and general acceptability respectively. Fermentation time from 0 hour to 15 hours did not cause any difference ($p<0.05$) for all sensory attributes evaluated.

Table 1. Effect of fermentation time on proximate composition of yoghurt supplemented with baobab pulp

		Parameters (%)					
S/N	**Fermentation time (hours)**	**Moisture**	**Ash**	**Proteins**	**Fat**	**Fibre**	**Carbohydrates**
1	0	78.48 ± 0.25^{a}	0.58 ± 0.03^{bc}	6.78 ± 0.00^{b}	3.88 ± 0.00^{bc}	0.49 ± 0.01^{b}	9.79 ± 0.00^{c}
2	3	78.96 ± 0.45^{a}	0.50 ± 0.00^{d}	7.20 ± 0.14^{ab}	3.71 ± 0.00^{c}	0.67 ± 0.00^{a}	8.96 ± 0.01^{e}
3	6	76.79 ± 0.48^{b}	0.64 ± 0.02^{a}	7.46 ± 0.81^{ab}	4.01 ± 0.57^{b}	0.38 ± 0.02^{cd}	10.72 ± 0.0^{a}
4	9	77.49 ± 0.20^{ab}	0.60 ± 0.00^{b}	7.68 ± 0.02^{ab}	4.23 ± 0.01^{a}	0.31 ± 0.01^{d}	9.69 ± 0.01^{d}
5	12	78.31 ± 0.17^{a}	0.55 ± 0.00^{c}	7.88 ± 0.07^{ab}	4.40 ± 0.05^{a}	0.49 ± 0.01^{b}	8.38 ± 0.01^{f}
6	15	76.53 ± 0.00^{b}	0.63 ± 0.00^{a}	8.16 ± 0.03^{a}	3.99 ± 0.05^{b}	0.42 ± 0.00^{c}	10.27 ± 0.01^{b}

Values are means ± SD. Means having similar superscript letter in a column are not significantly different ($p < 0.05$).

Table 2. Effect of fermentation time on sensory evaluation of yoghurt supplemented with baobab pulp

Fermentation time (hours)						
Parameters	**0**	**3**	**6**	**9**	**12**	**15**
Colour	6.38±1.76[a]	6.85±1.41[a]	6.85±1.63[a]	6.92±1.61[a]	7.15±1.34[a]	7.69±1.32[a]
Taste	7.00±1.41[a]	7.31±1.49[a]	7.23±1.54[a]	7.23±1.54[a]	6.77±2.05[a]	6.69±2.36[a]
Flavour	6.62±1.94[a]	6.92±1.80[a]	6.62±1.89[a]	6.46±2.30[a]	6.31±2.21[a]	6.69±2.46[a]
Odour	5.38±1.98[a]	5.77±1.83[a]	5.38±2.06[a]	5.62±2.22[a]	5.92±1.66[a]	5.77±2.39[a]
Mouthfeel	6.77±1.09[a]	6.85±1.07[a]	7.00±1.53[a]	7.08±1.32[a]	6.69±1.89[a]	6.62±2.22[a]
General Acceptability	6.77±1.48[a]	6.92±1.55[a]	7.00±1.68[a]	7.38±1.19[a]	6.85±2.23[a]	6.77±2.39[a]

Values are means ± SD. Means having similar superscript letter in a row are not significantly different ($p < 0.05$).

Discussion

Moisture content is an important factor that affect the keeping quality of fermented products (Mshelia *et al.*, 2024), according to Matin *et al.* (2018), higher moisture content supports the growth of microorganisms and subsequent decrease in shelf life and quality of yoghurt. The findings of these study reveals moisture content ranges between 76.53% - 78.96% at corresponding fermentation time of 15 and 3 hours respectively, these values are significantly different at ($p < 0.05$). The findings is not an agreement with the finding reported by Mwangi (2023) of moisture content value ranging from 84 to 87% and significantly higher than the value reported in the present study; it is obvious that addition of fruit pulp will correspond to the decrease in moisture, as there is an inverse relationship between moisture and dry matter content. However, the moisture content of the samples was below the standard limit of moisture content for most commercial yoghurt which Eke et al (2013) is between 80-85%. This finding corroborate with Wairimu *et al.*, (2022) who observed a decrease in moisture content in yoghurt produced from goat milk supplemented with baobab fruit pulp, and authors attributed the decrease due to absorption of moisture by high solid content in the pulp. Zumunta and Umar 2020, reported the moisture ranging from 75.72 – 77.52% and it is in agreement to the present study, and it was found the ratio of fruit pulp was 3:1 which is close to the ratio used in the present study.

Present study showed that as fermentation time increase correspond to the increase in protein content 6.78-8.16 and it was generally observed that there is increase in the protein content with the corresponding increase in the fermentation time (Table 1). Mwangi (2023) reported protein content from 2.14 to 4.8% which is lower to the values obtained in the present study, the higher protein content may be due to the fact that in the present study, the ratio of the milk to baobab fruit pulp was 1:2 (baobab pulp to powdered milk), while in their formulation the ratio is between 1-2% baobab fruit pulp. This shows that fruit pulp is rich in protein with potentials of producing rich protein products (Mwangi, 2023). Protein content reported by Zumunta and Umar (2020) is in agreement with present study. The agreement may be attributed to the ratio of fruit pulp and milk was almost the same. Lower protein was reported by Mshelia *et al.*, (2024) in yoghurt produced from milk supplemented with baobab fruit and the different may be due to the level of fruit pulp.

The finding of the ash content reported in this study (Table 4.4) reveals the ranges values of 0.50-0.63% at corresponding fermentation time of 3 and 15 hours respectively. The values are lower than the values reported by Zumunta and Umar (2020) of 0.67 – 0.95%. The values obtained were within the acceptable limit of (0.4-0.95%). Also, the findings of this study reveals the fat content ranges between 3.71-4.40% at corresponding fermentation time of 3 and 12 hours respectively. The value was lower than the value reported by Mwangi, (2023) of 33.33%. The total carbohydrate content obtained of these study, ranges between 8.38-10.72% at corresponding fermentation time 12 and 6 hours respectively, which is lower than the value reported by Zakari *et al*. (2017) of 15.37%, according to Kabore *et al*. (2011) the decrees in the total carbohydrate content was likely due to the use of the nutrient especially the metabolites, the simple sugars is a source of energy and also the use of carbohydrate to provide carbon needed for the synthesis of the other absorbable compounds which in turn increase the availability of the nutrient in the fermentation samples. Zumunta and Umar, (2020) reported fibre content ranged from 0.67 – 0.95% and were higher than the values of the present study Mwangi, (2023) reported a values in the carbohydrate content which significantly ($p<0.05$) lower than the value reported in the present study. However, it is in agreement with those values reported by Zumunta and Umar, (2020). Fermentation involves the utilization of carbohydrate (milk sugar) there by reducing the total carbohydrates content during fermentation. However, the present study reported a fluctuation at 6 and 15 hour fermentation time.

A ten member of trained consumer finalist was used to assess the baobab pulp yoghurt produce in this study. The panelist scored on a 9 point hedonic scale on how the either liked or disliked the appearance, texture, color, ordour, mouthfeel, and general acceptability of the baobab pulp yoghurt sample. Preference in terms of the color of the yoghurt pulp sample it was generally observed that the preference increases with respect to color as the fermentation time increases. This may be attributed to the increase in the activities of the metabolites of the yoghurt pulp sample during fermentation period. Preference for the tastes varies according to the results (Table 4.7). The highest value for the preference for the taste (7.31) was recorded during 3hours fermentation time, while the lowest value (6.69) was recorded during the 15hours fermentation time. This could be attributed to the physiological individual differences in terms of the teste buds. Also the differences observed and recorded in terms of flavor and odour. The result of the mouthfeel as shown in the table reveals that the highest preference was recorded at 9hours fermentation time (7.08), while the lowest preference of 6.62 was recorded at 15hours fermentation time, this can also be attributed to the fact that mouthfeel and perceptions differ between individuals. The general acceptability of the baobab pulp yoghurt shows no significant difference across various attributes at ($p < 0.05$). The sensory attributes evaluated in the present study did not show any significant difference ($p>0.05$) across the fermentation time. The sensory score were in agreement with value on yoghurt produced from Zebu milk with addition of 2% baobab fruit pulp as reported by Olorunnisomo, 2015. This shows that fermentation did not affect the sensory attributes. Finding contradict with those revealed by Mshelia *et al.,* (2024), Baobab fruit pulp has a pleasant favour and is unique due to its high percentage organic acids such as citric, tartaric, malic, succinic and ascorbic acids. However, the fermentation period employed did not cause any changes which may affect one of the parameters. Yoghurt is fermented milk consumed worldwide (Aluko, 2017).

The appearance of yoghurt is an important quality parameter that is directly affected by additives (Wajs *et al.,* 2003). Appearance is also one of the quality attribute and it attracts the consumer acceptance. Different plants parts were used to improve the acceptability of yoghurt according to Külcü *et al.,* (2021), the use of different herbs, spices or fruit to enrich yoghurt is receiving attention among consumers. Swiader *et al.,* (2020) used green tea in yoghurt at the ratio of 1 - 8% and the preliminary study showed that 2% green tea was found to be the best in sensory parameters in comparison with the others. Bchir *et al.*, 2019 observed that the supplementation of 20 % of frozen seeds into yoghurt received highest score by the panelist compared with other yogurts. Additionally, It was reported that higher the concentration of Mentha pulegium powder in yogurt samples significantly affected the scores (Külcü *et al.,* 2021).

Conclusion

Results from the present study show that adding baobab fruit pulp to yoghurt and changing the time of fermentation significantly affected nutritional composition but maintained acceptable sensory characteristics. The proximate results indicated increased protein and ash content with extended fermentation, suggesting increased nutrient concentration as a result of the microbial activity. Moisture, carbohydrate, fat, and fibre contents changed, reflecting metabolic activities during yoghurt fermentation. Despite these changes, all proximate contents were within acceptable limits as reported in earlier works. Sensory evaluation indicated that fermentation time did not significantly influence consumer perception of yoghurt colour, taste, flavour, odour, mouthfeel, and general acceptability. This suggests that the addition of baobab pulp to yoghurt does not detract from its sensory acceptability and is thus suitable for consumer markets. Baobab, on account of its pleasant natural flavour and nutrient richness, imparts additional functional benefits with no negative sensory effects.

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