Nutritional Composition and Sensory Attributes of '*Apula*' Produced From Maize (*Zea mays*), African Yam Bean (*Sphenostylis stenocarpa* Hochst ex A. Rich) and Date (Phoenix dactylifera) Fruit Flours

Ameh, U. E.[1,2], Ocheme, B.O.[1], Michael, U.[3], Makun, H.A[2], Idoko, F.A.[4,2]

[1]*Department of Food Science and Technology, Federal University of Technology, Minna, Niger State*
[2]*Africa Centre of Excellence for Mycotoxin and Food Safety, Federal University of Technology, Minna, Niger State*
[3]*Department of Animal Production, Federal University of Technology, Minna, Niger state*
[4]*Department of Food Science and Technology, Kaduna Polytechnic, Kaduna, Nigeria.*

*__Correspondence Author:__ pg4412911.ameh@st.futminna.edu.ng, __Phone Number:__ 08032864369

ABSTRACT

Background: *with the level of malnutrition, it is important to produce breakfast meal that can meet the nutrient needs, and also suitable for people that are at high risk of sugar related health issues.*

Objective: *The study assessed the nutritional composition and sensory attribute of Apula based meal produced from maize, African yam bean and date fruit*

Method: *Breakfast meal were formulated from white maize, African yam beans, date fruit as into sample ATAYB, AFAYB and AGAYB, Sample AP (100% maize flour) served as the control. The Nutritional composition were determined and sensory evaluation carried out.*

Result: *Findings shows that the Proximate composition varied significantly ($p<0.05$) based on fermentation, germination and toasting methods. Moisture content, ash content, fat content, fibre content, protein content and carbohydrate for the various formulations ranged between (6.01 and 8.51%), (1.95 and 4.87%), (2.17 and 3.88%), (3.18 and 5.12%), (9.73 and 23.02%) and (58.82 and 74.23%) respectively. Vitamin values obtained ranged as follow, Beta-carotene (0.06 and 0.38), thiamine (2.10 and 2.38) and nacin (0.34 and 2.38). Mineral content, calcium, Magnesium, phosphorous and potassium were significantly ($p<0.05$) higher in the formulated samples than in the control. Sensory evaluations showed higher preference score for enriched Apula, particularly for formulations incorporating germinated AYB and date fruit flours in terms of taste, texture, appearance, Aroma and overall acceptability.*

Conclusion: *Toasting, fermentation and germination increased the nutritional value of Apula, leading to improved mineral, vitamin bioavailability and enhanced overall Acceptability of the sensory parameters, mostly for the germinated and fermented formulation.*

Keywords: Maize, African Yam bean, processing method, Date flour, nutritional qualities

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INTRODUCTION

Apula is a traditional breakfast staple in Nigeria, predominantly made from cereal grains such as maize, although sorghum and millet are also commonly utilized as alternatives. This food is prepared through processes that include roasting, milling, and dehulling. The steps not only contribute to its unique flavour and appealing texture but also play a significant role in its digestibility (1). As a carbohydrate-rich meal, *Apula* serves as a substantial energy source;

however, it is limited in protein content, which presents a nutritional gap for populations relying heavily on it as a dietary staple (2).

The African yam bean (AYB) is an underutilized legume with a remarkably high protein content ranging between 19% and 30%, alongside a rich supply of essential micronutrients such as potassium, magnesium, and zinc (3). These nutrients are critical for energy production, immune support, and overall physiological functioning (4). Furthermore, AYB's protein profile rivals that of other legumes, including chickpeas and common beans, making it a highly promising candidate for combating protein deficiencies in cereal-heavy diets. In addition, its high dietary fiber content promotes gut health, offering complementary benefits when paired with other traditional staples (5)

Date fruits, often referred to as "nature's candy," are highly valued for their exceptional nutritional composition. They are rich in natural sugars, dietary fiber, and an array of vitamins and minerals, including potassium and magnesium (6). Dates are also a notable source of antioxidants, which help to protect against cellular damage, strengthen the immune system, and support overall health (7). Incorporating date palm into *Apula* not only enhances its nutritional value but also improves its taste and reduces the reliance on added sugars, an advantage for individuals managing dietary sugar intake (8).

Additionally, processing techniques such as germination have proven effective in increasing the bioavailability of nutrients in cereals and legumes. Germination initiates water absorption, which activates enzymes that release bound nutrients and produce bioactive compounds like phenolics. This natural process significantly enhances the accessibility of proteins and minerals, thus improving the overall nutrient profile of the food (9). When applied to *Apula*, germination can boost its nutritional density, addressing concerns in populations with limited access to diverse food sources (9).

Fermentation, another transformative process, has long been employed to improve the sensory and nutritional qualities of food. By synthesizing essential nutrients and breaking down anti-nutritional factors like phytates, fermentation enhances protein digestibility and facilitates better nutrient absorption. Introducing fermentation into the preparation of *Apula* could transform it into a more nutritionally balanced food option, particularly for those dependent on cereal-based diets (10).

Toasting, a widely used technique for processing cereals and legumes, offers significant benefits by enhancing digestibility, flavour, and shelf life (11). By denaturing proteins and reducing anti-nutritional factors, toasting preserves the food's nutritional integrity while making it more appealing to consumers (12). Incorporating toasting into the production of *Apula* is likely to result in a product that retains its traditional essence while catering to modern nutritional demands This study assessed the nutritional composition and sensory attributes of '*Apula*' produced from maize, african yam bean and date fruit flours.

MATERIALS AND METHODS

Procurement of raw materials

White maize (Zea mays) African yam beans (Sphenostylis sternocarpa), date fruit, and plastics were purchased from the central market in Kaduna, Kaduna State, Nigeria.

Production of toasted maize flour

The maize flour was prepared following the method outlined by (13). First, the maize grains were cleaned by sorting, handpicking, and washing. Then, the grains were boiled in a water bath at 93°C for 15 minutes and drained for 20 minutes. After this, the grains were dried in an oven at 50°C for 10 hours. The grains were then toasted for 1 hour at 80°C. Finally, the toasted grains were ground into flour, sieved through a 100μm mesh, and packaged in sealed containers before being stored in a refrigerator prior to further analysis.

Production of fermented AYB flour

One kilogram of African yam bean (AYB) grains was washed and soaked separately in 200 ml of tap water in a plastic container. The grains were left to ferment for 3 days at room temperature. After fermentation, the grains were washed and dried in a hot air oven at 60°C for 12 hours. Once dried, the AYB was milled using an attrition mill and sieved through a 425 μm mesh to produce a fine fermented AYB flour. The flour was packaged in plastic containers and stored at 4°C until needed for analysis.

Production of germinated AYB flour

One kilogram of AYB grains was washed and soaked in tap water (1:3 weight-to-volume ratio) for 12 hours. After soaking, the grains were spread on trays lined with jute bags and kept moist in a dark wooden cupboard, spraying water

on them each morning and evening for 3 days to allow sprouting. Once sprouted, the grains were dried in an oven at 60°C for 12 hours. The rootlets were removed, and the grains were dry milled using an attrition mill. The flour was sieved through a 425 μm mesh to obtain a fine germinated AYB flour, which was packaged in plastic containers and stored at 4°C before analysis.

Production of date fruit flour

Date fruit flour was prepared using a method based on (14), with some modifications from (15). First, the dates were cleaned with a wet cloth and deseeded. Then, the dates were cut into small pieces and dried in a vacuum oven at 75°C for 24 hours, followed by further drying in an electric cabinet dryer at 80°C for 12 hours. After drying, the dates were cooled and ground into powder using a mixer grinder. The powder was sieved through a 0.35 mm mesh filter.

Production of '*Apula*' from the flour blends of maize, African yam bean and date flour blends, the samples of maize meal was created by combining the flours in different ratios: maize, AYB, and date palm fruit in the following proportions: 75:15:10, 70:20:10, 65:25:10, 60:30:10, and 55:35:10.

Proximate analysis

The standard method of (16) was used to determine the proximate content of the samples. The hot air oven method was used to determine the moisture content; Protein was determined using the Kjeldahl method of protein analysis. Fat was determined by the Soxhlet method of fat extraction, while ash was obtained by weighing 5g of the sample into a tarred porcelain crucible. The crucible and its content were then transferred into a muffle furnace set at 550 C for 6 hours until ash content was obtained. The crude fibre was determined, 2g grams of the sample was weighed and placed in 200mL of 1.25% H_2SO_4 (sulfuric acid) and boiled for 30 minutes. The solution was then filtered through linen or muslin cloth fixed to a funnel and washed with boiling water until all the acid is removed. The residue was then transferred back into 200mL of boiling NaOH (sodium hydroxide) and boiled for another 30 minutes. Afterward, it was washed with 1% HCl (hydrochloric acid) boiling water to remove any remaining acid. The final residue was drained and transferred into a silica ash crucible, which was dried in the oven to a constant weight and cooled. The percentage of crude fiber was calculated using the appropriate formula.

Determination of mineral and vitamin analysis

Mineral's determination was carried out in a dilute solution of the ashed samples according to the method outlined in AOAC (7). Potassium and sodium were determined by flame photometry, phosphorus by colorimetric method, while Atomic Absorption Spectrophotometer (Buck Scientic, Model 210 was used for iron, calcium, iodine, Zinc, Copper, Manganese and Magnesium. Water soluble vitamins such as thiamine, riboflavin, niacin, pantothenic acid, pyridoxine and folic acid were determined using the AOAC method of analysis, while vitamin C was also determined. Each analysis was carried out in duplicates.

Sensory evaluation of *Apula* with African yam bean and date palm flour blends

A structured score sheets was used to collect information from 20 trained panelists on the sensory characteristics of the formulated *Apula* based maize meal. The samples were coded as MF, ATAYB, AFAYB and AGAYB and were presented to the panelists familiar with the product, who were staff and students recruited from the Faculty of Agriculture, Department Food Nutrition and Home Science, Kogi State University, Anyigba. The panelists were seated comfortably at the sensory unit of the department, and each panelist was served with a separate cup of the prepared *Apula* sample and teaspoon served at the same temperature (30 C) in line with method described by (17).

Statistical Analysis

Data was analysed using Statistical Package for Social Sciences (SPSS, Version 20) software. The results were expressed as mean ± standard deviation, and the test for statistical significance was carried out using a one-way analysis of variance (ANOVA). Significant means were separated using Duncan's New Multiple Range Test (DNMRT), and differences were considered significant at $p<0.05$.

RESULTS

Proximate composition of *Apula* enriched with African Yam bean and date palm flour blends

Findings from the proximate analysis shows that sample AP (8.51%) was significantly ($p<0.05$) had the highest value in moisture content. The ash content of the samples increases significantly ($p<0.05$) with the increase in the quantity of AYB and date fruit flour in the formulation. Sample AGAYB5 had the highest (4.40%) ash content. The fat content decreases with the increase in the

quantity of AYB and date fruit flour used in the formulation. Sample ATAYB5 with highest percentage of fat which was significant ($p<0.05$) higher compared to other samples. Fibre content of the *Apula* based meal also increased across all the samples while the protein content of the meal increased with increase in the amount of AYB and date fruit flour ratio in the Formulation.

Table 1: Proximate composition (%) of *Apula* with african yam bean and date palm flour blends (dry basis)

Samples	Moisture	Protein	Crude fat	Ash	Crude Fiber	CHO
AP	8.51±0.01^{a}	9.73±0.01^{e}	3.57±0.01^{a}	1.95±0.01^{c}	2.01±0.01^{c}	74.23±0.01^{a}
ATAYB1	6.46±0.01^{b}	12.34±0.01^{d}	3.68±0.01^{a}	2.13±0.01^{bc}	2.85±0.01^{c}	72.54±0.01^{a}
ATAYB2	6.24±0.01^{b}	13.00±0.01^{d}	3.70±0.01^{a}	2.30±0.01^{bc}	3.59±0.01^{b}	71.17±0.01^{a}
ATAYB3	6.19±0.01^{b}	14.67±0.01^{c}	3.76±0.01^{a}	2.45±0.01^{bc}	3.98±0.01^{b}	68.95±0.01^{b}
ATAYB4	6.10±0.01^{b}	14.89±0.01^{c}	3.88±0.01^{a}	2.65±0.01^{bc}	4.47±0.01^{a}	68.01±0.01^{b}
ATAYB5	6.01±0.01^{b}	16.20±0.01^{b}	3.96±0.01^{a}	2.80±0.01^{bc}	5.12±0.01^{a}	65.91±0.01^{b}
AFAYB1	7.67±0.01^{a}	11.33±0.01^{d}	2.17±0.01^{c}	3.41±0.01^{b}	3.17±0.01^{b}	72.25±0.01^{a}
AFAYB2	7.44±0.01^{a}	14.89±0.01^{c}	2.17±0.01^{c}	3.56±0.01^{b}	3.45±0.01^{b}	68.49±0.01^{b}
AFAYB3	7.09±0.01^{a}	19.98±0.01^{a}	2.13±0.01^{c}	4.43±0.01^{a}	3.44±0.01^{b}	62.95±0.01^{b}
AFAYB4	7.76±0.01^{a}	12.0±0.01^{a}	2.10±0.01^{c}	4.52±0.01^{a}	3.65±0.01^{b}	69.97±0.01^{b}
AFAYB5	7.34±0.01^{a}	23.02±0.01^{a}	2.10±0.01^{c}	4.87±0.01^{a}	3.85±0.01^{b}	58.82±0.01^{b}
AGAYB1	7.22±0.01^{a}	12.0±0.01^{d}	2.99±0.01^{b}	2.22±0.01^{bc}	3.18±0.01^{b}	72.39±0.01^{a}
AGAYB2	7.87±0.01^{a}	14.98±0.01^{c}	2.82±0.01^{b}	2.13±0.01^{bc}	3.53±0.01^{b}	68.67±0.01^{b}
AGAYB3	7.65±0.01^{a}	15.63±0.01^{c}	2.80±0.01^{b}	2.41±0.01^{bc}	3.68±0.01^{b}	67.83±0.01^{b}
AGAYB4	7.98±0.01^{a}	16.97±0.01^{b}	2.78±0.01^{b}	2.42±0.01^{bc}	3.76±0.01^{b}	66.09±0.01^{b}
AGAYB5	7.98±0.01^{a}	17.88±0.01^{b}	2.65±0.01^{b}	4.40±0.01^{a}	3.89±0.01^{b}	63.20±0.01^{b}

Values represent the mean ± standard deviation (SD) based on three separate determinations. Means with different superscripts within the same column indicate significant differences ($p < 0.05$). M: Maize, AYB: African yam bean, DF: Date fruit flour Flour formulation above is each for toasted, fermented and germinated African yam bean.

AP: 100% Maize flour (control), **ATAYB**: *Apula* with Toasted African yam bean and Date fruit flour, **ATAYB1:** 75%M+15%AYB: 10%DF, **ATAYB2:**70%M+20%AYB: 10%DF, **ATAYB3:** 65%M+25%AYB: 10%DF, **ATAYB4:** 55%M+35%AYB: 10%DF, **ATAYB5:** 50%M+40%AYB:10%DF**, AFAYB**: *Apula* with fermented African yam bean and Date fruit flour, **AFAYB1:** 75%M+15%AYB: 10%DF, **AFAYB2:**70%M+20%AYB: 10%DF, **AFAYB3:** 65%M+25%AYB: 10%DF, **AFAYB4:** 55%M+35%AYB: 10%DF, **AFAYB5:** 50%M+40%AYB:10%DF, **AGAYB**: *Apula* with Germinated African yam bean and Date palm fruit flour, **AGAYB1:** 75%M+15%AYB: 10%DF, **AGAYB2:**70%M+20%AYB: 10%DF, **AGAYB3:** 65%M+25%AYB: 10%DF, **AGAYB4:** 55%M+35%AYB: 10%DF, **AGAYB5:** 50%M+40%AYB:10%DF

Mineral Content of *Apula* with African yam bean and Date Palm Flour Blends

In terms of mineral content, sample AGAYB was significantly difference ($p<0.05$) from other samples and contained the highest value of iodine (1.81mg/100g), calcium (39.93mg/100g) and potassium (142.34mg/100g) content, while magnesium was significantly ($p<0.05$) higher in sample AGAYB (196.56mg/100g), while ATAYB had the least value (64.33mg). Sample AGAYB had the highest value for phosphorus content (221.34mg), while sample ATAYB had the least value (10.34mg/100g). The control sample MF had the least value for iron (0.34mg/100g). Calcium, potassium and iodine were significantly ($p<0.05$) higher in the formulated products compared to the control sample. All the formulated product was significantly ($p<0.05$) higher in phosphorus compared to the control sample.

Vitamin Content of *Apula* with African yam bean and Date Palm Flour Blends

The vitamin content of the samples revealed that Beta carotene (0.39mg /100g), Niacin (Vit B3) (1.39mg/100g), Vitamin B1 (2.45mg/100g), and Vitamin C (12.98mg/100g) were significantly ($p<0.05$) higher in sample AFAYB, AGAYB and AFAYB, respectively, and were significantly ($p<0.05$) higher than control sample (MF) except in vitamin B3. Vitamin C content of the *Apula* based meal was significantly ($p<0.05$) lower in the control sample than the formulated *Apula* samples.

Table 2: Mineral Composition (mg/100g) of *Apula* with African yam bean and Date Palm Flour Blends (AYB was toasted, fermented and germinated)

Sample	Calcium	Iodine	Iron	Magnesium	Phosphorus	Potassium
AP	5.56±0.01^{d}	0.04±0.01^{b}	0.34±0.01^{b}	64.33±0.01^{e}	10.34±0.01^{d}	60.56±0.01^{a}
ATAYB1	15.23±0.01^{cd}	1.23±0.01^{a}	1.09±0.01^{ab}	128.88±0.01^{d}	188.03±0.01^{cd}	101.23±0.01^{d}
ATAYB2	19.18±0.01^{c}	1.32±0.01^{a}	1.21±0.01^{a}	146.32±0.01^{c}	192.34±0.01^{c}	120.11±0.01^{c}
ATAYB3	20.76±0.01^{c}	1.41±0.01^{a}	1.31±0.01^{a}	156.45±0.01^{bc}	196.23±0.01^{bc}	122.75±0.01^{c}
ATAYB4	26.23±0.01^{bc}	1.48±0.01^{a}	1.32±0.01^{a}	159.78±0.01^{bc}	199.90±0.01^{bc}	125.58±0.01^{c}
ATAYB5	27.85±0.01^{bc}	1.59±0.01^{a}	1.38±0.01^{a}	166.09±0.01^{a}	208.54±0.01^{b}	130.54±0.01^{bc}
AFAYB1	16.89±0.01^{cd}	1.31±0.01^{a}	1.21±0.01^{a}	136.56±0.01^{d}	189.45±0.01^{c}	102.57±0.01^{d}
AFAYB2	19.02±0.01^{c}	1.33±0.01^{a}	1.22±0.01^{a}	166.98±0.01^{b}	196.45±0.01^{bc}	109.57±0.01^{d}
AFAYB3	25.67±0.01^{bc}	1.51±0.01^{a}	1.39±0.01^{a}	166.98±0.01^{b}	195.34±0.01^{bc}	129.57±0.01^{bc}
AFAYB4	32.98±0.01^{b}	1.69±0.01^{a}	1.44±0.01^{a}	175.67±0.01^{ab}	202.34±0.01^{b}	130.60±0.01^{bc}
AFAYB5	34.87±0.01^{b}	1.71±0.01^{a}	1.51±0.01^{a}	181.09±0.01^{a}	221.34±0.01^{a}	138.62±0.01^{b}
AGAYB1	18.67±0.01^{c}	1.36±0.01^{a}	1.24±0.01^{a}	138.78±0.01^{d}	190.45±0.01^{c}	107.62±0.01^{d}
AGAYB2	22.24±0.01^{c}	1.42±0.01^{a}	1.29±0.01^{a}	167.04±0.01^{b}	196.34±0.01^{bc}	124.23±0.01^{c}
AGAYB3	27.15±0.01^{bc}	1.59±0.01^{a}	1.40±0.01^{a}	175.43±0.01^{ab}	199.45±0.01^{bc}	134.26±0.01^{b}
AGAYB4	39.11±0.01^{a}	1.79±0.01^{a}	1.53±0.01^{a}	186.45±0.01^{a}	204.34±0.01^{b}	132.27±0.01^{b}
AGAYB5	39.93±0.01^{a}	1.81±0.01^{a}	1.61±0.01^{a}	196.56±0.01^{a}	218.34±0.01^{a}	142.34±0.01^{a}

Values represent the mean ± standard deviation (SD) based on three separate determinations. Means with different superscripts within the same column indicate significant differences ($p < 0.05$). M: Maize, AYB: African yam bean, DF: Date fruit flour Flour formulation above is each for toasted, fermented and germinated African yam bean

AP: 100% Maize flour (control), **ATAYB**: *Apula* with Toasted African yam bean and Date fruit flour, **ATAYB1:** 75%M+15%AYB: 10%DF, **ATAYB2:**70%M+20%AYB: 10%DF, **ATAYB3:** 65%M+25%AYB: 10%DF, **ATAYB4:** 55%M+35%AYB: 10%DF, **ATAYB5:** 50%M+40%AYB:10%DF**, AFAYB**: *Apula* with fermented African yam bean and Date fruit flour, **AFAYB1:** 75%M+15%AYB: 10%DF, **AFAYB2:**70%M+20%AYB: 10%DF, **AFAYB3:** 65%M+25%AYB: 10%DF, **AFAYB4:** 55%M+35%AYB: 10%DF, **AFAYB5:** 50%M+40%AYB:10%DF, **AGAYB**: *Apula* with Germinated African yam bean and Date palm fruit flour, **AGAYB1:** 75%M+15%AYB: 10%DF, **AGAYB2:**70%M+20%AYB: 10%DF, **AGAYB3:** 65%M+25%AYB: 10%DF, **AGAYB4:** 55%M+35%AYB: 10%DF, **AGAYB5:** 50%M+40%AYB:10%DF

Table 3: Vitamins Composition of *Apula* with African yam bean and Date Pal Flour Blends (AYB was toasted, fermented and germinated)

Samples	Beta-Carotene (µg/100g)	Niacin (mg/100g)	Thiamine (mg/100g)	Vitamin C (µg/100g)
AP	0.06±0.03^{b}	0.34±0.02^{b}	2.34±0.03^{a}	0.00±0.01^{b}
ATAYB1	0.23±0.01^{a}	1.23±0.03^{a}	2.10±0.01^{a}	12.98±0.02^{a}
ATAYB2	0.38±0.02^{a}	1.32±0.01^{a}	2.34±0.03^{a}	12.45±0.01^{a}
ATAYB3	0.36±0.01^{a}	1.34±0.03^{a}	2.35±0.04^{a}	12.64±0.03^{a}
ATAYB4	0.33±0.01^{a}	1.32±0.01^{a}	2.34±0.01^{a}	12.78±0.01^{a}
ATAYB5	0.35±0.05^{a}	1.36±0.04^{a}	2.38±0.02^{a}	12.45±0.03^{a}
AFAYB1	0.39±0.01^{a}	1.34±0.03^{a}	2.33±0.03^{a}	12.87±0.01^{a}
AFAYB2	0.38±0.02^{a}	1.33±0.03^{a}	2.35±0.04^{a}	12.96±0.02^{a}
AFAYB3	0.37±0.01^{a}	1.31±0.01^{a}	2.21±0.01^{a}	12.98±0.01^{a}
AFAYB4	0.38±0.05^{a}	1.29±0.01^{a}	2.24±0.01^{a}	12.98±0.01^{a}
AFAYB5	0.37±0.01^{a}	1.29±0.02^{a}	2.22±0.01^{a}	12.09±0.04^{a}
AGAYB1	0.37±0.04^{a}	1.32±0.01^{a}	2.25±0.04^{a}	12.78±0.01^{a}
AGAYB2	0.38±0.01^{a}	1.33±0.02^{a}	2.39±0.01^{a}	12.56±0.03^{a}
AGAYB3	0.35±0.02^{a}	1.39±0.01^{a}	2.39±0.02^{a}	12.65±0.01^{a}
AGAYB4	0.31±0.02^{a}	1.39±0.03^{a}	2.45±0.01^{a}	12.98±0.02^{a}
AGAYB5	0.38±0.03^{a}	1.31±0.02^{a}	2.38±0.04^{a}	12.56±0.01^{a}

Values represent the mean ± standard deviation (SD) based on three separate determinations. Means with different superscripts within the same column indicate significant differences ($p < 0.05$). M: Maize, AYB: African yam bean, DF: Date palm fruit flour Flour formulation above is each for toasted, fermented and germinated African yam bean. **ATAYB**: *Apula* with Toasted African yam bean and Date fruit flour,

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Sensory Properties of *Apula*

The result of the mean sensory scores is presented in Table 5. The result showed the scores for overall acceptability revealed that the control (6.9) was not the most accepted sample. Sample ATAYB" and AFAYB and AGAYB were the most accepted in terms of overall acceptability with (7.5 and 7.6 respectively). The acceptability was significantly ($P<0.05$) than the control samples. Acceptability in all the parameters increases with increase in the addition AYB and date fruit flour.

Table 4: Sensory Attribute of *Apula* with African yam bean and Date Palm Flour Blends (AYB was toasted, fermented and germinated)

Samples	Appearance	Taste	Texture	Aroma	Overall acceptability
AP	7.5 ± 0.01^{b}	6.6 ± 0.01^{bc}	6.3 ± 0.01^{d}	6.7 ± 0.01^{b}	6.9 ± 0.01^{bc}
ATAYB1	7.8 ± 0.03^{a}	6.9 ± 0.02^{ab}	7.5 ± 0.05^{bc}	7.0 ± 0.04^{a}	7.3 ± 0.06^{ab}
ATAYB2	7.2 ± 0.08^{c}	6.8 ± 0.01^{b}	7.9 ± 0.01^{a}	6.9 ± 0.09^{ab}	7.5 ± 0.01^{a}
ATAYB3	7.5 ± 0.06^{ab}	6.6 ± 0.01^{a}	7.5 ± 0.01^{a}	7.0 ± 0.01^{a}	7.2 ± 0.01^{ab}
ATAYB4	7.5 ± 0.01^{a}	6.8 ± 0.01^{b}	6.4 ± 0.01^{d}	6.9 ± 0.01^{ab}	6.9 ± 0.03^{bc}
ATAYB5	7.1 ± 0.01^{c}	6.7 ± 0.01^{b}	7.7 ± 0.09^{ab}	6.8 ± 0.05^{ab}	7.1 ± 0.01^{b}
AFAYB1	7.1 ± 0.01^{c}	6.7 ± 0.01^{b}	7.7 ± 0.09^{ab}	6.8 ± 0.05^{ab}	7.1 ± 0.01^{b}
AFAYB2	7.5 ± 0.03^{ab}	7.0 ± 0.01^{ab}	6.4 ± 0.09^{d}	7.2 ± 0.05^{a}	7.3 ± 0.01^{ab}
AFAYB3	7.7 ± 0.01^{a}	7.3 ± 0.01^{a}	7.1 ± 0.09^{c}	7.2 ± 0.05^{a}	7.5 ± 0.01^{a}
AFAYB4	7.2 ± 0.01^{c}	7.0 ± 0.08^{ab}	7.6 ± 0.09^{ab}	7.1 ± 0.05^{a}	7.5 ± 0.01^{b}
AFAYB5	7.1 ± 0.01^{c}	6.7 ± 0.01^{b}	7.7 ± 0.09^{ab}	6.8 ± 0.05^{ab}	7.1 ± 0.01^{b}
AGAYB1	7.4 ± 0.01^{b}	7.2 ± 0.01^{a}	7.7 ± 0.09^{ab}	6.8 ± 0.05^{ab}	7.3 ± 0.01^{ab}
AGAYB2	7.0 ± 0.01^{c}	7.2 ± 0.03^{a}	7.5 ± 0.09^{bc}	7.0 ± 0.05^{a}	7.6 ± 0.01^{b}
AGAYB3	7.1 ± 0.01^{c}	6.7 ± 0.01^{b}	7.7 ± 0.09^{ab}	6.8 ± 0.05^{ab}	7.1 ± 0.01^{b}
AGAYB4	6.7 ± 0.01^{d}	6.7 ± 0.01^{b}	5.8 ± 0.09^{e}	6.8 ± 0.05^{ab}	6.7 ± 0.01^{c}
AGAYB5	7.1 ± 0.01^{c}	6.7 ± 0.01^{b}	7.7 ± 0.09^{ab}	6.8 ± 0.05^{ab}	7.1 ± 0.01^{b}

Values represent the mean ± standard deviation (SD) based on three separate determinations. Means with different superscripts within the same column indicate significant differences ($p < 0.05$). M: Maize, AYB: African yam bean, DF: Date fruit flour. Flour formulation above is each for toasted, fermented and germinated African yam bean.

AP: 100% Maize flour (control), **ATAYB**: *Apula* with Toasted African yam bean and Date fruit flour, **ATAYB1:** 75%M+15%AYB: 10%DF, **ATAYB2:**70%M+20%AYB: 10%DF, **ATAYB3:** 65%M+25%AYB: 10%DF, **ATAYB4:** 55%M+35%AYB: 10%DF, **ATAYB5:** 50%M+40%AYB:10%DF, **AFAYB**: *Apula* with fermented African yam bean and Date fruit flour, **AFAYB1:** 75%M+15%AYB: 10%DF, **AFAYB2:**70%M+20%AYB: 10%DF, **AFAYB3:** 65%M+25%AYB: 10%DF, **AFAYB4:** 55%M+35%AYB: 10%DF, **AFAYB5:** 50%M+40%AYB:10%DF, **AGAYB**: *Apula* with Germinated African yam bean and Date palm fruit flour, **AGAYB1:** 75%M+15%AYB: 10%DF, **AGAYB2:**70%M+20%AYB: 10%DF, **AGAYB3:** 65%M+25%AYB: 10%DF, **AGAYB4:** 55%M+35%AYB: 10%DF, **AGAYB5:** 50%M+40%AYB:10%DF

DISCUSSION

Apula based meal is rich in carbohydrate and other minerals, study has suggested that adding AYB and date fruit flour to the meal helps to improve the nutritional qualities of the product. Moisture content is a critical factor influencing the stability, shelf life, and microbial susceptibility of flour-based products. The *Apula* (AP) sample has a moisture content of 8.51%, while the AYB and date flour blends (ATAYB and AFAYB) demonstrate slightly varying moisture levels from 8.01% to 8.98%. Lower moisture content, particularly in ATAYB5 at 8.01%, implies a reduced likelihood of microbial spoilage, thereby enhancing shelf stability (9). The Protein content is essential for nutritional quality, especially in regions with protein deficiency. *Apula* has a baseline protein content of 9.73%, while AYB-based formulations show considerable enhancements, ranging up to 23.02% in AFAYB5. This significant protein increase indicates that AYB fortification effectively enhances the protein quality of *Apula*, making it suitable for addressing protein-energy malnutrition. AYB's high lysine and tryptophan content complements the traditionally deficient amino acid profile of *Apula*, suggesting a more balanced amino acid profile in AYB-blended flours (18). The fat content is notably low across samples, with *Apula* containing 3.57% and AYB variants from 2.10% to 3.96%. Low-fat content is advantageous for consumers requiring reduced fat intake, such as those managing cardiovascular diseases (19). Ash content reflects the mineral concentration within the samples, directly correlating with nutritional and functional attributes. *Apula*'s ash content is 1.95%, but AYB-enhanced samples demonstrate an increase, with values reaching 4.87% in AFAYB5. This increase implies a higher mineral composition, including calcium, magnesium, and phosphorus, which are

essential for bone health and metabolic functions (11). Fiber plays a critical role in gastrointestinal health and impacts the glycaemic index of foods. *Apula* shows a lower crude fiber content of 2.01%, whereas AYB-enriched samples exhibit higher levels, particularly in ATAYB5 (6.12%). Increased fiber is beneficial for consumers aiming to improve digestive health and control blood glucose levels (10). *Apula* flour alone contains a low beta-carotene level (0.06 μg/100g), but the addition of AYB and date palm fruit flour significantly enhances the beta-carotene content, with values reaching up to 0.39 μg/100g. This increase is primarily attributed to the natural beta-carotene found in dates, which are known for their carotenoid content (20). Consuming such enriched flour products could provide a dietary source of beta-carotene, which the body can convert to vitamin A as needed, supporting visual health and immunity. The rise in beta-carotene levels in these blends suggests that they could be effective in addressing vitamin A deficiencies, especially in regions where vitamin A deficiency is prevalent. Consuming such enriched flour products could provide a dietary source of beta-carotene, which the body can convert to vitamin A as needed, supporting visual health and immunity. Increased niacin content is beneficial for metabolic processes. It can aid in the reduction of oxidative stress by enhancing the activity of NAD-dependent enzymes, which play a role in antioxidant defenses (22). Increased vitamin C in the blends enhances their potential as a functional food ingredient, as vitamin C is crucial in combating oxidative stress, promoting healthy skin, and supporting immune defenses (4).

Significant variations were observed in the sensory perception scores for parameters such as texture, appearance, and overall acceptability. These differences underscore the appeal of the *Apula* blends based on consumer preferences as measured by the Hedonic scale. The results indicate that the toasted, fermented, and germinated flour blends were well-received, achieving positive acceptance levels across all tested attributes. Among the samples, those containing AFAYB consistently outperformed the 100% maize flour (AP) in sensory evaluations. Specifically, the appearance of the samples received scores ranging from 6.9 to 7.8, indicating a generally appealing visual quality. For texture, scores varied between 5.8 and 7.9, reflecting a broad range of responses but overall positive perceptions. The overall acceptability scores fell within the range of 6.7 to 7.6, signifying a favourable reception by the evaluators. Notably, samples ATAYB2, AFAYB2, and AGAYB2 achieved higher scores for both aroma and overall acceptability, highlighting their superior sensory qualities. These results suggest that blending techniques such as toasting, fermenting, and germination, along with the inclusion of AFAYB, enhance the sensory appeal of the products, making them competitive alternatives to traditional maize flour.

CONCLUSION

The enrichment of the traditional Nigerian breakfast dish, *Apula*, with African yam bean (AYB) and date fruit flours significantly boosts its nutritional value and sensory appeal. The inclusion of AYB, rich in protein and essential micronutrients, combined with the natural sugars, dietary fiber, vitamins, minerals, and antioxidants from date fruit, creates a composite flour blend that effectively addresses nutritional deficiencies. Processing techniques such as germination, fermentation, and toasting further improve nutrient bioavailability and sensory qualities. These improved *Apula* formulations not only provide a nutritionally superior alternative to traditional maize flour but also show potential as functional food ingredients to enhance food security, nutrition, and public health in Nigerian communities. The study showed that the germinated samples with 55% male, 35%AYB and 10% date flour was the most preferred and higher in nutritional values. The favourable sensory evaluations indicate strong consumer acceptance, opening doors for wider adoption and commercialization of these nutritionally fortified traditional foods

INFORMED CONSENT

Before the sensory evaluation, each panellist was informed about the objective of the study. Verbal consent from the panellist was obtained after the aim of the study was explained to them.

DECLARATION OF CONFLICT OF INTEREST

The authors alone are responsible for the design, data collection, writing and funding of this research and no declared no conflicts of interest.

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