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Original research

Optimization of wheat-bitter yam composite flour for nutrient-enhanced cake production: Rheological, nutritional, and sensory properties

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A B S T R A C T

The possibility of producing cake from the composite formulation of flour from wheat, white and yellow bitter yam was investigated. The flours from each of these sources were combined using response surface methodology (RSM), from which cake was respectively produced. The results revealed that the composited flour samples exhibited variation in the chemical compound constituents in terms of intensity and identity through the use of Fourier Transform Infrared (FTIR) spectroscopy. The pasting variables of the composited flour samples showed a general reduction in the values of peak viscosity, breakdown, final viscosity, and peak time, when compared to the respective values of the control (100% wheat flour). The apparent viscosity of cake batter was generally higher (293.4–393.5 Pa.s) in the composited flour than that of the control (283.3 Pa.s). The inclusion of white and yellow bitter yam flour in cake making formulation gave higher concentrations of ash, fat, protein, and fiber; when compared to the respective values of the control sample. The inclusion also led to variation in the crust and crumb color and *in vitro* starch digestibility of cake. In terms of sensory quality rating, the cake from the control (100% wheat flour) was rated the highest with respect to all sensory variables while cake from WWY-B (Blend of 78.9% wheat flour, 11.2% white bitter yam flour and 9.9% yellow bitter yam flour) was rated the second best which implied that an acceptable cake could be produced from the composited flour from wheat, white and yellow bitter yam.

Keywords: Batter; Sensory; Baking; Viscosity; FTIR.

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1. Introduction

Cake has been observed to be one of the highest consumed bakery products, but commonly used in festivals and felicitous celebrations (Felisberto et al., 2015). The basic ingredients for cake making are normally soft wheat flour and variable proportions of fat, sugar, eggs, milk, baking powder and emulsifier, among others (Barakat, 2021). The wheat flour in cake making serves as a structure builder as it is involved in forming the crumb and crust structure and is considered a toughened (Hassan et al., 2016).

In developing countries, there is a generally accepted desire to make use of alternative crops to wheat grains in the development of food products for human consumption (Haruna et al., 2017). The target is always towards such food products that do not require flour with an extensive gluten network, which include cookies, crackers, cakes and tortillas (Zhang et al., 2023). The desire to make use of alternative crops apart from wheat grains might have arisen from such factors as untoward soil conditions in many developing countries that restrict wheat production; effort to minimize foreign reserve wastage on wheat importation; and the inclination towards allowing the local industry to make use of new ingredients as a way of diversifying its production through the use of alternative crops (Oliete et al., 2010). Hence, various efforts have been made to substitute wheat flour with flours from other botanical sources, which include cereals, root and tuber crops (Barakat, 2021).

An important underutilized tuber crop in some of the developing countries that qualifies to be used as an alternative crop in the production of flour-based food products is bitter yam (*Dioscorea dumetorum*). This tuber crop has been observed to contribute to the household diet mainly in times of famine (Cemaluk et al., 2014). Bitter yam is said to have originated in tropical Africa and occurs in both wild and cultivated forms, while its cultivation and

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consumption are mainly in West and Central Africa especially Nigeria, Ghana, Guinea, Mali and Cameroon (Adedayo et al., 2013). The wild varieties are not normally consumed by people due to their toxicity, but when used for processing, they need to be subjected to special detoxification processing steps (Alozie et al., 2009). The cultivated varieties of bitter yam (white and yellow types) are edible but generally bitter due to the presence of such chemical compounds as saponin and diosbulbin D (Obidiegwu et al., 2020).

The underutilization of bitter yam has been attributed to such factors as hard-to-cook defect, which makes the crop unattractive to some consumers (Egbuonu and Nzewi, 2016) and its non-suitability for preparing other common yam-based traditional dishes, such as pounded yam and 'amala' (yam-based doughmeal), among others. The techno-functional application of flour from both white and yellow bitter yam may be found in the baking industry, where fairly high temperatures (> 80 °C) are frequently encountered, including bread, biscuit and cake production. This is due to their relative high peak gelatinization and pasting temperatures around 83–87 °C (Oyeyinka et al., 2018). In terms of the protein content of bitter yam, it was found to be around 7 g/100g while its amino acid profile revealed the presence of virtually all the amino acids but limiting in lysine, methionine, and cystine (Alozie et al., 2009). However, the general suggestion that has been given over the years towards enhancing the utilization of crops such as roots and tubers in developing countries is to explore ways of diversifying their usages (Obioma et al., 2023).

In Nigeria, the fundamental focus of incorporating flour from locally available alternative sources, as against wheat flour, in the production of flour-based food products, is to find a way of reducing dependence on imported wheat grains, bringing down the foreign exchange spending, and enhancing the utilization of locally-available alternative flour sources (Kurumeh et al., 2019). It is in line with this fundamental focus, therefore, that various efforts had been made to diversify the usage of bitter yam including an attempt to prepare 'amala' (yam-based doughmeal) from bitter yam flour (Abiodun and Akinoso, 2015); production of noodles from composite flour of bitter yam and wheat (Akinoso et al., 2016); production of starch from white bitter yam (Oyeyinka et al., 2018); and production of sugar syrup from bitter yam using exogenous enzymes (Okafor and Chukwu, 2019), among others. None of these research efforts has examined the combined usage of composite flour from wheat, white and yellow bitter yam in food product formulation. The objective of this present study, therefore, was to examine the suitability level of the composited flour from wheat, white and yellow bitter yam towards cake production concerning the quality characteristics of the composited flour samples and the bakery product (cake) emanating from them.

2. Materials and Methods

2.1. Sources of materials

The tubers of white and yellow bitter yam (*Dioscorea dumetorum*) were obtained from a local farm at Ilara-Mokin town, Ondo State, Nigeria; while the wheat flour was purchased from the King's market, Akure, Ondo State, Nigeria. All the chemicals used for various analyses were of analytical grade.

2.2. Methods

2.2.1. Preparation of flour from tubers of white and yellow bitter yam

Flour was respectively prepared from the tubers of white and yellow bitter yam using the method as described by Eke-Ejiofor and Owuno (2012). The freshly obtained yam tubers were washed, peeled, re-washed and sliced into a thickness of 5 mm. The yam slices were then blanched in hot water (90 ± 3 °C) containing 2.5% (w/v) sodium metabisulphite for 5 min and drained. The blanched slices were spread on drying trays and dried at 55 °C for 48 h in an air draught oven (Plus11, Sanyo Gallenkamp PLC, UK). The dried slices were cooled and milled into flour using a hammer mill (Jacobson Machine Works INC., Minneapolis, Minn, 55427, USA). The flour obtained was sieved using a sieve with an aperture of 300 µm followed by packaging in high density polyethylene bags and stored at 4 °C until subsequent usage.

2.2.2. Preliminary evaluation of water absorption capacity of the flour samples

Water absorption capacity (WAC) of the flour samples was determined using the method as described by Onwuka (2005). Ten milliliters of distilled water was added to one gram of flour sample weighed into a dry centrifuge tube and stirred well. The resulting suspension was centrifuged at 3500 rpm for 30 min. The supernatant was measured into a 10 mL graduated cylinder. Water absorbed was calculated as the difference between the initial volume of water added to the sample and the volume of the supernatant. WAC is expressed as grams of water bound per gram of the sample on a dry weight basis (Eq. (1)).

$$\text{WAC}=\frac{\text{Weight of water absorbed (g)}\times\text{density of water}}{\text{Sample weight (g)}} \quad (1)$$

2.2.3. Determination of oil absorption capacity of the flour samples

The determination of oil absorption capacity (OAC) of the flour samples was carried out using the method as described by Onwuka (2005). Ten milliliters of refined corn oil was added to 1 g of sample weighed into a dry centrifuge tube and stirred well. The resulting suspension was centrifuged at 3500 rpm for 30 min. The supernatant was measured into a 10 mL graduated cylinder. Oil absorbed was calculated as the difference between the initial volume of oil added to the sample and the volume of the supernatant. OAC is expressed as grams of oil bound per gram of the sample on a dry weight basis (Eq. (2)).

$$\text{OAC}=\frac{\text{Weight of oil absorbed (g)}\times\text{density of oil}}{\text{Sample weight (g)}} \quad (2)$$

2.2.4. Determination of foaming capacity and stability of the flour samples

The foaming capacity (FOC) and stability (FOS) of each flour sample was determined according to the method of Onwuka (2005). One gram of flour sample was weighed into a measuring cylinder previously dried in an oven at 50 °C for 1 h. Sixty milliliters of distilled water was then added to the sample to facilitate the dispersion of the flour and the volume was noted (volume before

Table 1. Surface responses of the flour blends intended for cake preparation.

	Blending proportion of the independent variables (%)			Physicochemical properties of the dependent variables (%)*			
Sample runs	Wheat flour	White bitter yam flour	Yellow bitter yam flour	Water absorption capacity (WAC)	Oil absorption capacity (OAC)	Foaming capacity (FOC)	Foaming stability (FOS)
Run-1	99.5	0.5	0.0	138.0 ± 7.2	141.0 ± 1.9	10.4 ± 1.5	6.9 ± 0.5
Run-2	79.5	0.0	20.5	98.5 ± 2.2	116.7 ± 2.8	30.7 ± 1.1	18.4 ± 1.1
Run-3	78.9	11.2	9.9	100.3 ± 1.9	122.5 ± 1.6	21.8 ± 3.3	17.3 ± 2.2
Run-4	89.0	1.0	10.0	123.3 ± 5.2	130.3 ± 8.6	40.6 ± 2.3	35.5 ± 0.7
Run-5	68.5	16.3	15.2	111.6 ± 3.9	122.7 ± 1.6	23.8 ± 1.6	24.8 ± 2.8
Run-6	78.9	11.2	9.9	113.3 ± 2.8	136.6 ± 2.8	30.7 ± 1.1	29.4 ± 1.4
Run-7	88.9	11.1	0.0	108.4 ± 1.6	122.8 ± 1.5	14.8 ± 0.8	20.3 ± 1.7
Run-8	70.4	5.4	24.2	110.6 ± 1.5	125.2 ± 1.3	25.6 ± 2.2	22.7 ± 2.2
Run-9	68.6	25.0	6.4	120.0 ± 4.2	150.0 ± 1.8	22.04 ± 2.1	21.8 ± 0.9
Run-10	62.0	13.0	25.0	105.3 ± 2.9	116.6 ± 1.7	21.4 ± 1.6	19.5 ± 1.9
Run-11	78.9	11.2	9.9	100.3 ± 1.9	122.5 ± 1.6	21.8 ± 3.3	17.3 ± 2.2
Run-12	79.5	0.0	20.5	98.5 ± 2.2	116.7 ± 2.8	30.7 ± 1.1	18.4 ± 1.1
Run-13	77.7	22.3	0.0	119.2 ± 3.3	108.6 ± 1.5	23.2 ± 1.4	20.4 ± 3.4
Run-14	62.0	13.0	25.0	105.3 ± 2.9	116.6 ± 1.7	21.4 ± 1.6	19.5 ± 1.9
Run-15	60.0	25.0	15.0	120.0 ± 5.3	161.4 ± 2.8	41.7 ± 1.8	34.6 ± 1.4
Run-16	78.9	11.2	9.9	100.3 ± 1.9	122.5 ± 1.6	21.8 ± 3.3	17.3 ± 2.2

* Results are mean value of triplicate determination ± standard deviation.

shaking). The suspension was mixed and properly shaken to foam and the total volume after 30 s was recorded (volume after shaking). The volume of foam obtained was calculated from the difference between the volume after shaking and the volume before shaking. The foam volume after 1 hour at room temperature was recorded to determine the foaming stability. The foaming capacity and foaming stability were calculated using the following expression (Eqs. (3) and (4)).

$$\text{Foaming Capacity (FOC)} = \frac{\text{Volume after shaking} - \text{Volume before shaking}}{\text{Volume before shaking}} \times 100 \quad (3)$$

$$\text{Foaming Stability (FOS)} = \frac{\text{Volume of the foam after one hour}}{\text{Initial volume of the foam}} \times 100 \quad (4)$$

2.3. Experimental design for the formulation of composite flours

The composite formulation of flour from wheat, white and yellow bitter yam was performed by using the response surface methodology (RSM) (Design-Expert, version 8.0.3.1, Stat-Ease Inc., Minneapolis, U.S.A) while the central composite design was selected. The ranges used for the independent variables were wheat flour (60.0–100 g/100g), white bitter yam flour (0–25 g/100g), and yellow bitter yam flour (0–25 g/100g) while the dependent variables were water and oil absorption capacities, foaming capacity and foaming stability; and this resulted in initial sixteen experimental runs. The basis for choosing the ranges for the independent variables was out of the desire to make the combined flour from bitter yam not to be more than 40%. Thereafter, each experimental run was subsequently analyzed for the dependent variables (water and oil absorption capacities, foaming capacity and foaming stability) and this is presented in Table 1. The four runs (run-4, run-6, run-9, and run-15) that exhibited greater concentrations of most of these dependent variables were eventually selected as the working samples. The selected four flour blends from the composite formulation are as follows: WWY-A (blend of 88.9% wheat flour, 1.0% white bitter yam flour and 10.0% yellow bitter yam flour); WWY-B (blend of 78.9% wheat flour, 11.2% white bitter yam flour and 9.9% yellow bitter yam flour); WWY-C (Blend of 68.6% wheat flour, 25% white bitter yam flour and 6.4% yellow bitter yam flour); and WWY-D (blend of 60% wheat flour, 25% white bitter yam flour and 15% yellow bitter yam flour). The sample used as the control was 100% wheat flour (WWF).

2.4. Evaluation of structural changes in the composited flour samples using Fourier transform infrared (FTIR) spectroscopy

The influence of flour blending on the structural changes in the flour samples were studied using Fourier transform infrared (FTIR) spectroscopy (Shimadzu IR affinity-I 8000 FTIR spectrometer, Japan). The study was carried out under dry air at room temperature (29 ± 2 °C) using potassium bromide (KBr) pellets. One milligrams (1 mg) sample was mixed with 300 mg of KBr supplied with FTIR unit. The samples were pressed directly on to attenuated reflectance KBr crystal into the sampling unit. Spectra were scanned in the frequency range of 4000 and 400 cm^{-1} at the resolution of 4 cm^{-1} and a maximum source aperture (Bhat and binti-Yahya, 2014; Zhao et al., 2014).

2.5. Evaluation of pasting characteristics of the composited flour samples

Each composited flour sample from wheat, white and yellow bitter yam was subjected to pasting analysis using rapid visco analyser (model RVA 4; Newport Scientific Limited, Warriewood, Australia). A sample of 4.0 g from each flour blend (14% moisture-basis) was transferred into a canister and approximately 25 ± 0.1 mL distilled water was added. The slurry so obtained was heated to 50 °C and stirred at 160 rpm for 10 S for thorough dispersion. The slurry was held at 50 °C for up to 1 min followed by heating to 95 °C over about 7.3 min and held at 95 °C for 5 min, and finally cooled to 50 °C over about 7.7 min. The parameters calculated from the pasting curve include the pasting temperature, peak viscosity, time to peak, breakdown, holding strength or trough, setback, and final viscosity (Bolade and Adeyemi, 2012).

2.6. Preparation of batter and cake production

The ingredient formulation towards batter preparation and subsequent cake production is shown in Table 2. The method of

Kinton et al. (2008) was adopted for batter preparation and production of cake. The margarine and sugar were creamed manually for 15 min in a stainless steel bowl until light and fluffy. The liquid eggs were beaten for 3 min and added to the creamed mixture gradually. Each prepared flour sample was respectively added gradually into the mixture. The baking powder, milk powder and vanilla essence were later added and mixed thoroughly until a soft consistency batter was formed. The batter was transferred to a 15-cm greased baking pan and baked in a pre-heated oven at 200 ℃ for 30 min and further 20 min at a reduced temperature of 170 ℃. Batter from each flour blend was baked separately. A skewer was inserted into the center of the cake to ascertain it was cooked properly. The well-cooked cake was allowed to cool in the tin for three minutes before turning out on wire racks for further cooling and subsequent analysis. Control cake sample was baked using 100% wheat flour.

Table 2. Ingredient formulation for batter preparation towards cake production.

Sample	Wheat flour (g)	White bitter yam flour (g)	Yellow bitter yam flour (g)
WWF	300.00	0.00	0.00
WWY-A	266.91	3.00	30.09
WWY-B	236.76	33.57	9.67
WWY-C	205.71	75.00	9.29
WWY-D	180.00	45.00	75.00

Note: Equal amount of the following ingredients was used in the preparation: margarine (230 g), sugar (150 g), liquid egg (240 mL), baking powder (10 g), vanilla flavor (10 mL), milk powder (5 g), and water (360 mL).

WWF= (100% wheat flour); WWY-A = (Blend of 89.0% wheat flour, 1.0% white bitter yam flour and 10.0% yellow bitter yam flour); WWY-B = (Blend of 78.9% wheat flour, 11.2% white bitter yam flour and 9.9% yellow bitter yam flour); WWY-C = (Blend of 68.6% wheat flour, 25.0% white bitter yam flour and 6.4% yellow bitter yam flour); WWY-D = (Blend of 60.0% wheat flour, 25.0% white bitter yam flour and 15.0% yellow bitter yam flour).

2.7. Measurement of density of cake batter

The modified method of Gomez et al. (2007) was used to determine the density of cake batter. The cake batter was filled into an aluminum cup immediately after removal from the mixing bowl, leveled off using a rubber spatula and weighed (W_1), noting the initial weight of the cup. The weight of the distilled water filled into the same aluminum cup was also taken (W_2). The batter density was calculated as the ratio of the batter weight (W_1) to the volume of the distilled water (W_2/ρ) filled into the same cup. The density (ρ) of the distilled water was taken as 1 g/cm^3 (Eq. (5)).

$$\text{Bulk Density} = \frac{\text{Weight of batter (W1)} \times \text{Density of distilled water } (\rho)}{\text{Weight of distilled water (W2)}} \times 100 \quad (5)$$

2.8. Measurement of apparent viscosity of cake batter

The procedure of Lakshminarayan et al. (2006) was used to measure the apparent viscosity of cake batter. A rotational viscometer (RION Viscotester Model VT-04F, Japan) was equipped with a L4 spindle and was used for measuring the apparent viscosity of each batter sample at a speed of 20 rpm at room temperature. The measurements were performed in duplicates.

2.9. Evaluation of physical characteristics of cake obtained from the composited flour of wheat, white and yellow bitter yam

The physical characteristics of the cakes were measured using the method outlined by Zoulias et al. (2002). The cake was of oval shape while the physical parameters measured included height, weight, volume and specific volume. The heights of the cake samples were measured at the center vertically at three different points. The weight was determined with weighing balance. Cake volume was calculated using the formula for oval shape (ellipsoid in 3–dimensions) below. The specific volume was evaluated by the ratio between the cake volume and its weight (Eqs. 6 and 7).

$$\text{Cake volume} = (4/3) \times \pi \times a \times b \times c \quad (6)$$

$$\text{Specific volume of cake} = \frac{\text{Cake volume}}{\text{Cake weight}} \quad (7)$$

where "a", "b", and "c" represent the lengths of the semi-major axes of the ellipsoid. "π" is the mathematical constant (approximately 3.14).

2.10. Determination of proximate composition of cake samples obtained from the composited flour

The proximate composition of the cakes was determined using the AOAC methods (AOAC, 2012). The parameters evaluated were moisture content, protein, total ash, fat, crude fiber, and carbohydrate (by difference).

2.11. Determination of color characteristics of cake samples prepared from the composited flour

The color characteristics of cake samples (crust and crumb) prepared from the composited flour were respectively measured using a color measuring instrument (Minolta, Model CR310, Osaka, Japan) and the values expressed on the L*, a*, b* tristimulus scale. The L* value signifies lightness, where L* = 0 is completely black and L* = 100 is completely white. The a* values represent red to green with (+a*) and (-a*) depicting red and green, respectively. The b* values also represent yellow to blue, with (+b*) representing yellow and (-b*) representing blue. The instrument was initially calibrated using a white reference standard, white duplicating paper sheet, 80g/m^2 (L*=93.41, a*= +1.32, b*= +0.08). The color intensity, expressed as chroma (C), was calculated from $(a^2+b^2)^{1/2}$ (Palatnik et al., 2015). The browning index (BI) of cake samples was evaluated from the L*, a*, b* tristimulus scale and used to describe the brown color characteristics of the sample (Maskan, 2001) (Eqs. 8 and 9).

$$\text{Browning Index (BI)} = \frac{[100(x-0.31)]}{0.17} \quad (8)$$

Where, x is:

$$X = \frac{(a*+1.75L*)}{(5.645L*+a*-3.012b*)} \quad (9)$$

2.12. Determination of selected mineral contents of cakes from the composited flours and their molar ratios

The mineral elements were determined using dry ash methods as described by AOAC (2012). One gram of sample was weighed into crucibles and ashed in the muffle furnace at 550 °C for 6 hours until all the carbon was burnt off. After ashing, the crucibles were transferred into the desiccator to cool and re-weighed. Each sample was quantitatively transferred into volumetric flasks by carefully washing the crucibles with 1mL nitric acid and 1 mL hydrochloric acid. All washings were transferred to individual volumetric flasks, repeating the washing procedure twice. The solutions were diluted to volume (100 mL) with distilled water and were used for individual mineral determination using the appropriate standards and blank. The content of calcium, magnesium, phosphorus and zinc were determined using Atomic Absorption Spectrophotometer (Buck Scientific, Model 210, USA).

Flame photometer was used to determine the concentrations of sodium and potassium. The standard solutions were prepared separately using sodium chloride and potassium chloride for sodium and potassium determinations respectively. The standard solutions were measured from the flame photometer and the value obtained was plotted against the strength of various solutions. The sodium and potassium content were determined from the flame photometer. The values were plotted in the respective standard curve to extrapolate the actual values of the concentration of the elements.

Phosphorus was determined using the spectrophotometric method as described by AOAC (2012). The dry ash of each sample obtained was digested by adding 5 mL of 2 M hydrochloric acid to the ash in the crucible and heated to dryness on a heating mantle. The 5 mL of the 2 M hydrochloric acid was added again, heated to boil and filtered through a Whatman No.1 filter paper into a 100 mL volumetric flask. Ten milliliters of the filtrate solution was pipetted into 50-mL standard volumetric flask and 10 mL of Vanadate – molybdate yellow was added and the flask was made up to mark with distilled water, stoppered and left for 10 minutes for full yellow development. The concentration of phosphorus was obtained by taking the absorbance of the solution on a Spectronic 21D (Milton Roy Model, USA) spectrophotometer at a wave length of 470 nm.

2.13. In vitro starch digestibility of cake from the composited flour

In vitro starch digestibility of cake samples was determined using pancreatic amylase and alpha-glucosidase (Lin et al., 2022). Fifty milligrams of the sample was dispersed in 1 mL of 0.2 M phosphate buffer of pH 6.9. Twenty milligrams of the enzyme was dissolved in 50 mL of the same buffer, and 0.2 mL of both the sample and enzyme were added. One milliliter of 3,5-dinitrosalicylic acid (DNSA reagent) was thereafter added while the mixture was heated for 5 min in a boiling waterbath. After cooling, the absorbance of the solution was read at 540 nm against the blank containing buffer while maltose was used as a standard.

2.14. Sensory quality ratings of cake samples obtained from the composited flour

Sensory quality ratings of the cakes samples produced from the composited flour were carried out by the method as described by Giami and Barker (2004). A 40-member taste panel was used and members were regular consumers of cake and were neither sick at the time of evaluation nor allergic to cake. Necessary precaution was taken to prevent carry-over of flavor, by ensuring that panelist rinsed their mouth with water after each stage of sensory evaluation. A well-structured questionnaire was used to assess cake attributes (color, handfeel, taste, aroma and overall acceptability) and were rated using a nine-point Hedonic scale to measure the degree of desirability in the following order: 9= extremely desirable, 8= very much desirable, 7= moderately desirable, 6= slightly desirable, 5= neither desirable nor desirable, 4= slightly undesirable, 3= moderately undesirable, 2= very much undesirable and 1= extremely undesirable (Iwe, 2002). Mean scores for color, handfeel, taste, aroma and overall acceptability and degree of difference were analyzed by analysis of variance (ANOVA). Post-hoc evaluation and separation of mean values were done using Duncan's test.

2.15. Statistical analysis

All determinations in this study were carried out in triplicates except that of Fourier transform infrared (FTIR) spectroscopy. In each case, a mean value and standard deviation were calculated. Analysis of variance (ANOVA) was also performed and separation of the mean values was by Duncan's Multiple Range Test at $P < 0.05$ using IBM-SPSS Statistics, version 21; on a personal computer.

3. Results and Discussion

3.1. Influence of composited flour from wheat, white and yellow bitter yam on the structural changes as depicted by Fourier transform infrared (FTIR) spectroscopy

The effect of compositing flour from wheat, white and yellow bitter yam on the structural changes is presented in Fig. 1 (A-E). The spectra of the flour samples were scanned in the wavenumber region of 4000–400 cm^{-1} and all the flour samples exhibited almost similar spectra for major important peaks corresponding to wavenumbers in the functional group region (4000–1200 cm^{-1}) although there were occasional shifts in the wavelength regions for some of the spectral peaks. The spectral peaks identified within the functional group region with wavelength of 4000–1200 cm^{-1} include –OH group manifested at 3600–3200 cm^{-1} wavelength region and –C–H bonds of the $–CH_2$ or $–CH_3$ alkyl groups manifested at 2929.7 cm^{-1} wavelength region. The presence of –OH group suggests water availability within the flour samples while the presence of –C–H bonds suggests lipid availability (Ismail et al., 1997; Ikram et al., 2021). The FTIR spectra of WWF (100% wheat flour) revealed a location of its peak at 2113.4 cm^{-1} wavelength while other composited flour samples also revealed the presence of their spectral peaks at 2210.3–2109.7 cm^{-1} wavelength region. All these peaks are essentially suggesting the presence of unsaturated fatty acids in the lipids present (Thompson, 2018) but the peaks were more visible than in the control sample (WWF) due to the inclusion of white and yellow bitter yam flour.

The FTIR spectra of WWF (100% wheat flour) revealed two peaks located at 1982.9 and 1919.6 cm^{-1} respectively but these peaks were absent in other composite flour samples containing different inclusion levels of white and yellow bitter yam flour. The functional group that has been assigned to the wavenumber region of 2000–1900 cm^{-1} was the cumulated double bonds of the ($>C=C=CH_2$) unit of conjugated aliphatic and aromatic compounds (Larkin, 2011). Therefore, the absence of these peaks in all composited flour samples implied that the inclusion of white and yellow bitter yam flour in the composite formulation might have caused drastic reduction of the functional group.

In all the flour samples, there was no observed spectral peak within the wavenumber regions of 1900–1700 cm^{-1}. This implies that there was absence of C=O bonds particularly of esters, ketones and aldehydes origins (Thompson, 2018). However, the peak located at 1640.0 cm^{-1} in all the flour samples signifies the presence of C=O stretching vibrational bond of amides origin. It had earlier been observed that the wavenumber region assigned to C=O stretching vibration of amide-I bond was 1700–1600 cm^{-1} (Ismail et al., 1997; Thompson, 2018). It essentially suggests the presence of proteins in the flour samples and the appreciable quantity of protein in the bitter yam might have contributed enormously to the presence of peptides in the composited flour samples (Alozie et al., 2009). The peak located at 1543.1 cm^{-1} in sample WWF (100% wheat flour) could also be found in all other composite flour samples. The functional group assigned to the wavenumber region of 1560–1530 cm^{-1} was C─N stretching and ─N─H bending vibrations of the amide-II origin (Stuart, 2004). The presence of these functional groups is an indication of the presence of proteins in the flour samples.

The location of a spectral peak at 1420.1 cm^{-1} in sample WWF (100% wheat flour) was also present in other composited flour samples except in WWY-D (blend of 60% wheat flour, 25% white bitter yam flour and 15% yellow bitter yam flour) with a wavenumber position shift to 1408.9 cm^{-1}. The peak at 1420.1 cm^{-1} might have originated from CH_2 bending vibration of the O=C─CH_2 and CH_2─C≡N units of aliphatic and aromatic compounds of protein with assigned wavenumber region of 1445–1405 cm^{-1} (Larkin, 2011). The wavenumber position shifts to 1408.9 cm^{-1} as observed in WWY-D (blend of 60% wheat flour, 25% white bitter yam flour and 15% yellow bitter yam flour) may be attributed to the weakening of the bonds within the functional groups as a result of relatively high quantity of white and yellow bitter yam flour in the sample.

The spectral peak located at 1341.8 cm^{-1} wavelength as observed in sample WWF (100% wheat flour) fell within 1370–1330 cm^{-1} wavelength region assigned to the presence of aromatic nitrogen-containing compounds (Stuart, 2004). The spectral peaks of other composited flour samples also fell within this wavelength region but with shifts in the wavelength positions. The inclusion of white and yellow bitter yam flour might have caused these shifts in the wavelength positions with the implication of leading to the weakening of the chemical bonds in the flour molecules (Thompson, 2018).

The 'fingerprint' region of the infrared spectra for the flour samples is said to be 1300–900 cm^{-1} (Thompson, 2018) while the wavenumber region of 1200–800 cm^{-1} had been observed to be assigned to the presence of polysaccharides in flour particularly that from wheat (Ikram et al., 2021). The peak located at 1244.9 cm^{-1} in sample WWF (100% wheat flour) was also present in the FTIR spectra of all other composite flour samples. The spectral peaks exhibited by the flour samples fell within 1300–1220 cm^{-1} wavelength region assigned to aliphatic compound containing CH_2 in the Cl-CH_2 unit (Larkin, 2011). Similarly, the identical peaks present in all the flour samples is essentially a reflection of the functional group being structurally similar (Thompson, 2018).

The peak at 931.8 cm^{-1} was observed in both WWF (100% wheat flour) and WWY-B (Blend of 78.9% wheat flour, 11.2% white bitter yam flour and 9.9% yellow bitter yam flour) while a shift in the wavenumber position to 928.1 cm^{-1} was noticed in samples WWY-A, WWY-C, and WWY-D. The peak located at 931.8 cm^{-1} essentially denotes a lone hydrogen wagging vibration of an aromatic compound having an assigned wavenumber region of 935–810 cm^{-1} (Larkin, 2011). The shift in the position of wavenumber to 928.1 cm^{-1} as observed in other three composited flour samples might have been caused by the inclusion of white bitter yam flour to a level as high as 25% or the inclusion of yellow bitter yam flour to a level not less than 10.03%. This inclusion level might have caused an interplay of factors such as resonance, electron withdrawing and

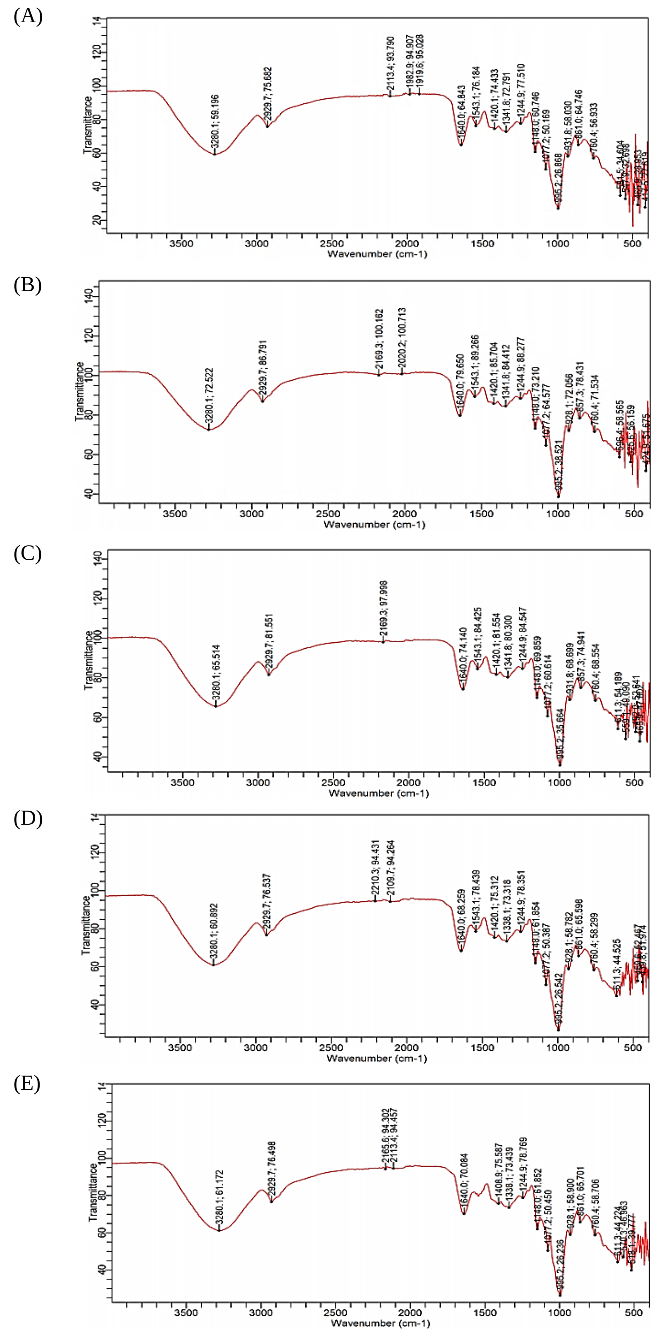

Fig. 1. FTIR spectra of flour samples. (A)=WWF (100% wheat flour); (B)=WWY-A (Blend of 89.0% wheat flour, 1.0% white bitter yam flour and 10.0% yellow bitter yam flour); (C)=WWY-B (Blend of 78.9% wheat flour, 11.2% white bitter yam flour and 9.9% yellow bitter yam flour); (D)=WWY-C (Blend of 68.6% wheat flour, 25.0% white bitter yam flour and 6.4% yellow bitter yam flour); (E)=WWY-D (Blend of 60.0% wheat flour, 25.0% white bitter yam flour and 15.0% yellow bitter yam flour).

Table 3. Pasting characteristics of composited flour from wheat, white and yellow bitter yam.

Source of flour sample	Pasting variables*						
	Peak viscosity (cP)	Trough (cP)	Breakdown (cP)	Final viscosity (cP)	Setback (cP)	Peak time (min)	Pasting temperature (°C)
WWF	1231 ± 4[a]	695 ± 1[a]	535 ± 2[a]	1294 ± 3[a]	599 ± 2[b]	5.67 ± 0.02[b]	87.21 ± 0.12[b]
WWY-A	1102 ± 3[b]	672 ± 1[b]	431 ± 2[b]	1288 ± 2[b]	616 ± 2[a]	5.87 ± 0.02[a]	89.45 ± 0.09[a]
WWY-B	693 ± 2[e]	389 ± 2[e]	305 ± 1[e]	844 ± 1[e]	455 ± 1[d]	5.53 ± 0.01[c]	89.65 ± 0.13[a]
WWY-C	1006 ± 3[c]	599 ± 2[c]	407 ± 2[c]	1214 ± 2[c]	615 ± 2[a]	5.53 ± 0.01[c]	85.61± 0.16[c]
WWY-D	848 ± 2[d]	528 ± 2[d]	321 ± 1[d]	1091 ± 2[d]	563 ± 2[c]	5.41± 0.01[d]	87.31 ± 0.11[b]

*Results are mean values of triplicate determination ± standard deviation. Mean values within the same column having the same letter are not significantly different at $p < 0.05$. cP = centiPoise. WWF= (100% wheat flour); WWY-A = (Blend of 89.0% wheat flour, 1.0% white bitter yam flour and 10.0% yellow bitter yam flour); WWY-B = (Blend of 78.9% wheat flour, 11.2% white bitter yam flour and 9.9% yellow bitter yam flour); WWY-C = (Blend of 68.6% wheat flour, 25.0% white bitter yam flour and 6.4% yellow bitter yam flour); WWY-D = (Blend of 60.0% wheat flour, 25.0% white bitter yam flour and 15.0% yellow bitter yam flour).

donating effects, steric interactions, and/or hydrogen bonding within the functional groups of the flour molecules (Thompson, 2018).

The peak located at 861.0 cm^{-1} was observed in WWF (100% wheat flour), WWY-C, and WWY-D; while a shift in the wavenumber position to 857.3 cm^{-1} was observed for samples WWY-A and WWY-B. The peak at 861.0 cm^{-1} essentially signifies two adjacent hydrogen wagging vibration of an aromatic compound with an assigned wavenumber region of 880–795 cm^{-1} (Larkin, 2011). The shift in wavenumber position to 857.3 cm^{-1} as observed in the two composite flour samples (WWY-A and WWY-B) may be attributed to the inclusion of white bitter yam flour in the range of 1.0–11.19% and the yellow bitter yam flour in the range of 9.89–10.03%. This inclusion level might have caused significant bond weakening within the functional group as a weaker bond within a molecule will require the absorption of infrared radiation at lower frequencies or wavenumbers which usually results in molecular vibration (Thompson, 2018). Obviously, the inclusion of white and yellow bitter yam flour in composite formulation with wheat flour, towards cake production, had caused noticeable adjustments or modifications in the FTIR spectra of the composite flour samples.

3.2. Pasting characteristics of composited flour from wheat, white and yellow bitter yam

The influence of compositing flour from wheat, white and yellow bitter yam on the pasting characteristics is presented in Table 3. The peak viscosity of WWF (100% wheat flour) was 1231 cP, higher than those of the composite flour samples which ranged between 848 and 1102 cP. The peak viscosity is an indicator of the rate of water absorption by the starch granules in the flour samples during heating which usually leads to the swelling of such granules (Ocheme et al., 2018). Thus, the reduced peak viscosity in the composited flour samples was an indication that the inclusion of white and yellow bitter yam flour had essentially led to decreased water absorption by the starch granules coupled with decreased granule swelling.

There was also a general decrease in the values of trough, breakdown and final viscosities of the composite flour samples when compared to that of WWF (100% wheat flour). The reduced breakdown viscosity as observed in the samples was an indication of enhanced paste stability during processing of the composite flour samples (Abah et al., 2020). The presence of white and yellow bitter yam flour in the composite formulation might have contributed to the reduced breakdown viscosity values with the implication of enhanced paste stability. The final viscosity of WWF (100% wheat flour) was 1294 cP while those of other composite flour samples ranged between 844 and 1288 cP. The reduction in the final viscosity values was indicative of their reduced ability to form a viscous paste or gel after cooking and cooling (Imoisi et al., 2020). It was also an indication of reduced aggregation of the amylose molecules in the paste (Wang et al., 2023). Thus, the inclusion of white and yellow bitter yam flour in the composite formulation might have contributed to the reduced aggregation of the amylose molecules in their respective pastes and hence their reduced final viscosities.

The setback of WWF (100% wheat flour) was 599 cP while those of composited flour samples ranged between 455 and 616 cP with significant differences at $p < 0.05$. The setback is essentially an indicator of retrogradation tendency of possible gel obtainable from flour after its cooking and cooling (Chen et al., 2024). The highest setback viscosity was observed in WWY-A (Blend of 89% wheat flour, 1.0% white bitter yam flour and 10% yellow bitter yam flour) while the lowest setback value was obtained in WWY-B (Blend of 78.9% wheat flour, 11.2% white bitter yam flour and 9.9% yellow bitter yam flour). The sample with the highest setback viscosity implied that it would offer the highest retrogradation tendency in its gel while that of lowest setback value would offer the least retrogradation tendency. The reason for the variations in the setback values of the composite flour samples is not clear but it seems to be an interplay of the degree of white and yellow bitter yam flour included in each formulation.

The peak time for WWF (100% wheat flour) was 5.67 min while that of other composite flour samples ranged between 5.53 and 5.87 min. The peak time denotes the time taken to attain peak viscosity, a stage through which any flour or starch must pass during cooking (Ohizua et al., 2017). Thus, the lower peak time as exhibited by most of the composite flour samples was an indication that the samples would behave differently during cooking as samples with lower peak time would take a shorter period to attain peak viscosity and this also has a strong implication on fuel usage. The pasting temperature for WWF (100% wheat flour) was 87.21 °C while that of other flour samples ranged from 85.61 to 89.65 °C. The pasting temperature is an indicator of the temperature at which the starch granules in a sample begin to gelatinize when subjected to thermal application (Akoja and Coker, 2018). The inclusion of white and yellow bitter yam flour in the composite formulation generally led to an increase in the pasting temperature and was an indication of an increased gelatinization temperature of the starch granules in the composited flour samples. The sample WWY-C (blend of 68.57% wheat flour, 25% white bitter yam flour and 6.43% yellow bitter yam flour) that exhibited the lowest pasting temperature (85.61 °C) essentially implied that the inclusion of the specified quantity of white and yellow bitter yam flour in the composite formulation would lead to the reduction in the gelatinization temperature of the sample, and hence the reduction in the cooking time.

3.3. Density and apparent viscosity of cake batter produced from the composited flour

The density and apparent viscosity of cake batter is presented in Table 4. The density of cake batter from WWF (100% wheat flour) was 0.75 g/cm^3 while the batter from other composited flour samples exhibited lower density values (0.72–0.73 g/cm^3) with no significant differences at $p < 0.05$. The density of cake batter is usually regarded as a reflection of the amount of air incorporated in the batter and are inversely related to each other (Allais et al., 2006). A cake batter with high air incorporated is regarded as having a tendency of exhibiting lower batter density (Gomez et al., 2010).

In the case of apparent viscosity of cake batter, the control sample (WWF) exhibited the lowest value of apparent viscosity of 283.3 Pa.s while the cake batter from the composited flour samples exhibited higher values (286.7–393.5 Pa.s) with significant differences at $p < 0.05$. These higher apparent viscosity values may be attributed to the presence of white and yellow bitter yam flour which possessed starches of different viscoelastic properties (Otegbayo et al., 2024) and which might have contributed to the higher apparent viscosity of cake batter. It had similarly been observed that the viscosity of cake batter could serve as a controlling factor for the final cake volume (Dizlek and Altan, 2021).

Table 4. Density and apparent viscosity of cake batter produced from composited flour samples.

Source of samples	Density (g/cm^3)	Apparent viscosity (Pa.s)
WWF	0.75 ± 0.00^a	283.3 ± 5.8^{cd}
WWY-A	0.73 ± 0.01^a	313.1 ± 5.6^b
WWY-B	0.72 ± 0.01^a	293.4 ± 8.3^c
WWY-C	0.73 ± 0.10^a	393.5 ± 7.6^a
WWY-D	0.73 ± 0.01^a	286.7 ± 6.6^c

Results are mean values of triplicate determination ± standard deviation. Mean values within the same column having the same letter are not significantly different at $p < 0.05$. WWF= (100% wheat flour); WWY-A = (Blend of 89.0% wheat flour, 1.0% white bitter yam flour and 10.0% yellow bitter yam flour); WWY-B = (Blend of 78.9% wheat flour, 11.2% white bitter yam flour and 9.9% yellow bitter yam flour); WWY-C = (Blend of 68.6% wheat flour, 25.0% white bitter yam flour and 6.4% yellow bitter yam flour); WWY-D = (Blend of 60.0% wheat flour, 25.0% white bitter yam flour and 15.0% yellow bitter yam flour).

3.4. Physical characteristics of cake produced from the composited flour

The physical characteristics of cake produced from the composited flour samples are presented in Table 5. The cake was of oval shape and the height (8.17 cm) of cake from the control (WWF) was higher than those from the composited flour samples which exhibited 6.23–7.70 cm height. The attainment of greater height in cake could be a function of the amount of gas incorporated within the cake batter prior to baking as well as the rising rate of bubbles within the cake batter. Therefore, lower apparent viscosity of the cake batter could encourage higher rising rate of bubbles in the batter and hence greater cake height (Yang et al., 2022).

The weight of cake from the control sample (700.2 g) was lower than those from cake produced from the composited flour samples which exhibited a range of 750.5–850.7 g in weight. This occurrence could be related to the presence of white and yellow bitter yam flour in the formulation in which their starch granule size and weight might have contributed to the overall weight of the final cake (Houngbo et al., 2024).

The volume of cake obtained from the control sample (WWF) was observed to be the highest (1534 cm^3) among the cake samples. The cake obtained from the composited flour samples exhibited a lower volume range of 1273–1386 cm^3 with significant differences at $p < 0.05$. The lower cake volume as observed with cake from the composited flour may be attributed to their respective high apparent viscosity, which has the capacity of activating a relative difficulty in batter expansion prior to baking. This difficult expansion may be as a result of greater force that might be required to overcome internal network structure of cake batter with a higher cohesiveness (Yang et al., 2022). The cake volume is a parameter that can be used to assess the external view of cake and hence it is regarded as a factor for quality evaluation by its consumers (Renzetti and van der Sman, 2022).

3.5. Proximate composition of cakes from the composited flour

Table 6 shows the proximate composition of cakes produced from the composited flour samples. It was observed that the inclusion of white and yellow bitter yam flour in cake making drastically elevated the concentration of ash, fat, protein, and fiber in the cake samples except for the carbohydrate content that got reduced. The breakdown of the proximate composition of cakes from the composited flour samples, on dry weight basis, is as follows: ash (1.66–2.55 g/100 g) as against 1.22 g/100 g for the control; fat (39.95–42.21 g/100 g) as against 38.12 g/100 g for the control; protein (9.54 –12.68 g/100 g) as against 6.43 g/100 g for the control; and fiber (0.77–1.28 g/100 g) as against 0.50 g/100 g for the control. The carbohydrate content of the control (53.73 g/100 g) was, however, higher than those from the composited flour samples (41.82–47.52 g/100g). The implication of this observation is that the inclusion of white and yellow bitter yam flour in cake making has a high tendency for nutrient enrichment in the final cake produced.

3.6. Color characteristics of crust and crumb of cake samples from the composited flour

Table 7 shows the color characteristics of crust and crumb of cake samples obtained from the composited flour. The lightness index (L*-value) of the cake crust from WWF (100% wheat flour) was 56.12 while those from other composited flour samples were of lower values (41.24–56.05) with significant differences at $p < 0.05$. The implication of this observation is that the crust color of the control sample was lighter than others and this was similarly reflected in the browning index of the samples. The cake crust from the composited flour samples was more brownish (88.5–121.8) than that from the control sample (63.9). The color of cake crust is usually attributed to certain reactions occurring during the baking period and these include Maillard and caramelization reactions (Fernandez-Pelaez et al., 2021). The intensity of color formation in baked products has generally been observed to be dependent on such factors as ingredient composition, baking temperature and duration (Goranova et al., 2022).

In the case of cake crumb from the composited flour samples, the same trends were observed for the lightness index (L*-value) and the browning index. The L*-value for the cake crumb of the control sample (WWF) was 66.63 while those from the composited flour samples exhibited lower values (61.44–64.22). Similarly, the browning index of the cake crumb from the control sample (WWF)

Table 5. Physical characteristics of cake produced from composited flour samples.

Source of samples	Height (cm)	Weight (g)	Volume (cm3)	Specific Volume (cm3/g)
WWF	8.17 ± 0.15[a]	700.2 ± 2.6[d]	1534 ± 39[a]	2.19 ± 0.06[a]
WWY-A	7.70 ± 0.20[b]	800.1 ± 1.8[b]	1337 ± 20[bc]	1.67 ± 0.11[bc]
WWY-B	7.47 ± 0.12[b]	750.5 ± 1.4[c]	1273 ± 45[c]	1.69 ± 0.09[bc]
WWY-C	6.23 ± 0.12[d]	750.8 ± 2.7[c]	1349 ± 71[bc]	1.80 ± 0.06[b]
WWY-D	6.67 ± 0.12[c]	850.7 ± 2.3[a]	1386 ± 55[b]	1.63 ± 0.09[c]

Table 6. Proximate composition of cakes produced from composited flour samples (dry weight basis).

Source of sample	Proximate composition (g/100 g)					
	Moisture	Ash	Fat	Protein	Fiber	Carbohydrate
WWF	19.55 ± 0.67[b]	1.22 ± 0.15[d]	38.12 ± 0.58[c]	6.43 ± 0.03[d]	0.50 ± 0.01[c]	53.73 ± 0.31[a]
WWY-A	21.21 ± 0.80[a]	1.66 ± 0.11[c]	40.0 ± 1.01[ab]	9.54 ± 0.03[c]	1.28 ± 0.02[a]	47.52 ± 1.05[b]
WWY-B	21.27 ± 0.66[a]	2.55 ± 0.18[a]	40.43 ± 1.16[ab]	11.19 ± 0.03[b]	0.77 ± 0.01[b]	45.06 ± 1.58[b]
WWY-C	18.22 ± 0.35[c]	1.60 ± 0.28[c]	39.95 ± 1.15[bc]	11.21 ± 0.04[b]	1.25 ± 0.00[a]	45.99 ± 1.75[b]
WWY-D	19.43 ± 0.53[b]	2.02 ± 0.11[b]	42.21 ± 1.11[a]	12.68 ± 0.14[a]	1.27 ± 0.01[a]	41.82 ± 1.02[c]

Table 7. Color characteristics of crust and crumb portion of cakes produced from composited flour samples.

Source of Cake	Crust				Crumb			
	L*	a*	b*	Browning index	L*	a*	b*	Browning index
WWF	56.12 ± 0.10[a]	11.02 ± 0.01[e]	22.24 ± 0.02[e]	63.9 ± 0.5[e]	66.63 ± 0.17[a]	5.00 ± 0.01[e]	19.70 ± 0.06[d]	39.9 ± 0.3[e]
WWY-A	56.05 ± 0.24[a]	15.64 ± 0.03[b]	28.23 ± 0.03[a]	88.5 ± 0.2[d]	64.22 ± 0.16[b]	7.42 ± 0.02[d]	22.12 ± 0.05[b]	49.9 ± 0.6[d]
WWY-B	41.24 ± 0.05[c]	14.96 ± 0.02[d]	26.31 ± 0.01[d]	121.8 ± 0.4[a]	61.44 ± 0.24[e]	8.36 ± 0.01[a]	24.24 ± 0.10[a]	59.2 ± 0.7[a]
WWY-C	49.22 ±0.05[b]	17.41 ± 0.02[a]	27.82 ± 0.09[b]	105.7 ± 0.3[b]	63.36 ± 0.08[c]	8.28 ±0.02[b]	24.17 ± 0.01[a]	56.8 ± 0.4[b]
WWY-D	49.23 ± 0.04[b]	15.27 ± 0.02[c]	26.84 ± 0.06[c]	98.6 ± 0.2[c]	62.87 ± 0.38[d]	7.52 ± 0.03[c]	21.75 ± 0.10[c]	50.5 ± 0.3[c]

Tables 5, 6 and 7: Results are mean values of triplicate determination ± standard deviation. Mean values within the same column having the same letter are not significantly different at $p < 0.05$. WWF= (100% wheat flour); WWY-A = (Blend of 89.0% wheat flour, 1.0% white bitter yam flour and 10.0% yellow bitter yam flour); WWY-B = (Blend of 78.9% wheat flour, 11.2% white bitter yam flour and 9.9% yellow bitter yam flour); WWY-C = (Blend of 68.6% wheat flour, 25.0% white bitter yam flour and 6.4% yellow bitter yam flour); WWY-D = (Blend of 60.0% wheat flour, 25.0% white bitter yam flour and 15.0% yellow bitter yam flour).

was 39.9 while those from the composited flour samples exhibited higher browning index (49.9–59.2). The presence of white and yellow bitter yam flour in the cakes obtained from the composited flour samples had, most probably, played enormous role in the brown color intensity in both the crust and crumb of the cakes. Another factor that may be attributed to the higher browning index in cake crust and crumb as obtained from the composited flour samples is the presence of carotenoids in yellow bitter yam. The carotenoids naturally have a yellow pigmentation and its concentration in yellow bitter yam had been found to be in the range of 5.21–26.61 µg/g (Alamu et al., 2016). Therefore, the contribution of yellow pigmentation to the composite formulation in the flour samples might have played a contributory role to the higher browning index of both the crust and crumb portions of the cakes.

3.7. Selected mineral content of cakes produced from the composited flour

Table 8 shows the selected mineral content of cakes obtained from the composited flour samples. The degree of mineral abundance in cakes obtained from the composited flour is as follows: K > Na > Ca > Mg > Zn > P. Similarly, the inclusion of white and yellow bitter yam flour in cake making formulation generally led to an increase in the concentration of Na and P while these was a decrease in Ca and Zn. The presence of these minerals in cakes essentially imposes certain nutritional significance. Sodium has been observed to be involved in blood pressure regulation (Xi et al., 2015); potassium is a major intracellular electrolyte also involved in blood pressure control, muscle contraction, and nerve transmission, among others (Kong et al., 2017). Calcium is an essential mineral contributing to building and protection of bones and teeth, muscle contraction and relaxation, helps in blood clotting, nerve impulse transmission, hormone secretion and enzyme activation (Sukumaran et al., 2021).

3.8. In vitro starch digestibility of cakes from the composited flour

Fig. 2 shows the *in vitro* starch digestibility of cakes prepared rom the composited flour samples. The cake from the control (WWF, 100% wheat flour) exhibited an *in vitro* starch digestibility value of 8.26 mg/g, being the lowest compared to cakes from the composited flour samples which exhibited a higher value range of 8.65–10.17 mg/g. The implication of this observed trend is that the inclusion of white and yellow bitter yam flour in cake making formulation has the tendency of elevating the *in vitro* starch digestibility values. The *in vitro* starch digestibility is essentially an index for assessing the rate of starch hydrolysis in carbohydrate-rich food products like cake, when ingested. Certain factors that had been identified to influence *in vitro* starch digestibility in food products include

Table 8. Selected mineral content of cakes produced from composited flour samples.

Source of Cake	Selected mineral content (mg/100 g)					
	Na	K	Ca	Mg	P	Zn
WWF	66.6 ± 5.8[c]	212.4 ± 6.5[c]	71.9 ± 6.1[a]	22.5 ± 2.9[b]	2.2 ± 0.6[bc]	2.6 ± 0.5[a]
WWY-A	92.6 ± 6.7[a]	227.4 ± 6.2[b]	65.9 ± 5.5[ab]	20.3 ± 2.1[b]	2.3 ± 0.2[bc]	2.4 ± 0.3[ab]
WWY-B	57.4 ± 6.5[d]	176.1 ± 5.6[de]	56.4 ± 5.1[b]	22.4 ± 2.3[b]	3.8 ± 0.7[a]	1.5 ± 0.2[c]
WWY-C	72.6 ± 3.7[c]	186.5 ± 5.8[d]	66.3 ± 2.8[a]	23.1 ± 3.1[b]	2.1 ± 0.2[c]	2.3 ± 0.4[ab]
WWY-D	81.5 ± 3.8[b]	242.7 ± 6.3[a]	45.9 ± 2.7[c]	35.3 ± 3.1[a]	2.7 ± 0.2[b]	3.1 ± 0.3[a]

Table 9. Sensory quality rating of cakes produced from composited flour samples.

Source of samples	Color	Aroma	Taste	Hand-feel	Overall acceptability
WWF	7.9 ± 0.8[a]	7.5 ± 0.7[a]	7.7 ± 0.4[a]	7.5 ± 0.5[a]	8.1 ± 0.8[a]
WWY-A	7.0 ± 0.5[b]	6.9 ± 0.5[ab]	7.3 ± 0.5[ab]	7.1 ± 0.4[b]	7.3 ± 0.5[b]
WWY-B	7.4 ± 0.7[ab]	6.9 ± 0.4[ab]	7.3 ± 0.5[ab]	7.2 ± 0.3[b]	7.5 ± 0.4[b]
WWY-C	7.4 ± 0.6[ab]	7.1 ± 0.6[ab]	6.8 ± 0.3[b]	6.6 ± 0.3[c]	7.1 ± 0.5[bc]
WWY-D	7.1 ± 0.4[b]	6.8 ± 0.1[b]	6.9 ± 0.2[b]	6.3 ± 0.4[c]	6.7 ± 0.2[c]

Tables 8 and 9: Results are mean values of triplicate determination ± standard deviation. Mean values within the same column having the same letter are not significantly different at $p < 0.05$. WWF= (100% wheat flour); WWY-A= (Blend of 89.0% wheat flour, 1.0% white bitter yam flour and 10.0% yellow bitter yam flour); WWY-B= (Blend of 78.9% wheat flour, 11.2% white bitter yam flour and 9.9% yellow bitter yam flour); WWY-C= (Blend of 68.6% wheat flour, 25.0% white bitter yam flour and 6.4% yellow bitter yam flour); WWY-D= (Blend of 60.0% wheat flour, 25.0% white bitter yam flour and 15.0% yellow bitter yam flour).

botanical origin of the starch involved due to morphological and structural differences (Lin et al., 2023); extent of starch gelatinization during baking (Zhang et al., 2021) and the degree of non-digestible constituents in the food material (Xie et al., 2024).

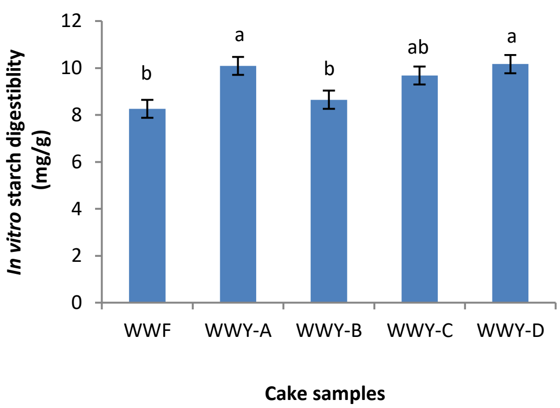

Fig. 2. *In vitro* starch digestibility of cakes prepared from the composited flour samples. WWF= (100% wheat flour); WWY-A= (Blend of 89.0% wheat flour, 1.0% white bitter yam flour and 10.0% yellow bitter yam flour); WWY-B= (Blend of 78.9% wheat flour, 11.2% white bitter yam flour and 9.9% yellow bitter yam flour); WWY-C= (Blend of 68.6% wheat flour, 25.0% white bitter yam flour and 6.4% yellow bitter yam flour); WWY-D= (Blend of 60.0% wheat flour, 25.0% white bitter yam flour and 15.0% yellow bitter yam flour).

3.9. Sensory quality rating of cakes from the composited flour

Table 9 shows the sensory quality rating of cakes produced from the composited flour samples. It was observed that cake from the control (WWF, 100% wheat flour) was rated the highest in terms of all the sensory variables (color, aroma, taste, hand-feel, and overall acceptability). The second best-rated cake was from WWY-B (Blend of 78.9% wheat flour, 11.2% white bitter yam flour and 9.9% yellow bitter yam flour). The implication of this observation is that an acceptable cake making is possible with the inclusion of white and yellow bitter yam flour with wheat flour at a specific graded level of the flour components.

4. Conclusion

This study has essentially established that the composite formulation of flour from wheat, white and yellow bitter yam for the purpose of cake making is possible. However, such formulation must be done at a specific graded level of the flour components. In particular, sample WWY-B (Blend of 78.9% wheat flour, 11.2% white bitter yam flour and 9.9% yellow bitter yam flour) demonstrated a promising combination that could serve as an alternative to cake obtained from 100% wheat flour. The benefit of white and yellow bitter yam flour inclusion in cake making, especially in the tropical developing countries, is related to the conservation of scarce foreign reserves being used for importing wheat grains into these countries. The composite formulation could therefore lead to a drastic reduction in the level of wheat importation as well as enhancing the local production of white and yellow bitter yam crop regarded as under-utilized varieties in these countries. It could also serve as a form of expansion of diversified utilization for the yam variety.

Conflict of interest

The authors declare that there is no conflict of interest.

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