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Full Length Research Paper

Aroma profile of gowe, a traditional malted fermented sorghum beverage from Benin

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Spontaneous fermented gowé was characterized by specific flavor produced by different enzymatic activities of microorganisms involved. Gowé was also produced by controlled fermentation using strains of *Lactobacillus fermentum* and *Weissella confusa* singly or in combination with *Kluyveromyces marxianus* and *Pichia anomala* after an accelerated saccharification. Investigation using Likens-Nikerson extraction method and gas chromatography-mass spectrometry (GC-MS) analysis revealed that the volatile compounds identified in the product obtained by spontaneous and controlled fermentation were composed of alcohols, aldehydes, acids, esters, hydrocarbons, furan, phenol and piperidine. The use of the starter cultures preceded by an accelerated saccharification led to a drastic reduction in the volatile components concentration for the inoculated samples. A principal component analysis performed revealed an important concentration of volatile acids in the inoculated samples.

Key words: Sorghum, fermentation, starter culture, volatile compound.

INTRODUCTION

Gowé is a fermented cereals beverage mostly made of a blend of malted and non-malted red sorghum flour. Previous studies had reported the various changes observed in the physico-chemical, proximate and microbiological characteristics during the production process (Vieira-Dalodé et al., 2007). A decrease of the pH with a concomitant increase of the titratable acidity and organic acid content were observed. The identification of the microbiota involved in *gowé* fermentation showed that the dominant microorganisms were mainly lactic acid bacteria (LAB) and yeasts. Several functions have been attributed to these microorganisms involved in the fermentation. The LAB and yeasts identified in kenkey, a Ghanaian fermented maize dough product, play an important role in the distinct aroma profile (Halm et al., 1993). Flavor and

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texture improvement has often been mentioned as beneficial effects for fermented foods and beverages (Jespersen, 2002). Beside the demand for safe food, there is always the need to eat foods that taste good. Consumers' behavior and perception of food quality are some parameters which must be taken into account (Cayot, 2007). Aroma characteristics are of most importance for the consumer perception of food quality and acceptability.

Several studies have been done to characterize the aroma profile of fermented and non-fermented products (Halm et al., 1993; Lasekan et al., 1997; Annan et al., 2003a, b, c; Gran et al., 2003; Mugula et al., 2003; Mamede et al., 2005; Cayot, 2007; Ho et al., 2006; Komthong et al., 2007). Volatile compounds identified were produced during various steps of the production process as a result of fermentation by lactic bacteria and yeasts, enzymatic activities, lipid oxidation or maillard reactions (Feillet, 2000). Malting and fermentation involved in the production of gowé contribute to its specific taste and aroma enhancing consumer's acceptance (Adinsi et al., 2014). The organoleptic acceptance, such as aroma improvement of fermented product had led to the use of starter cultures in the fermentation of maize dough for kenkey production (Annan et al., 2003a, b). These authors reported how *Lactobacillus fermentum, Saccharomyces cerevisiae* and *Candida krusei* can be used as starter cultures to modify the aroma profiles of fermented maize dough. The use of *Lactobacillus fermentum* and *Weissella confusa* previously identified as the predominant lactic acid bacteria during the natural fermentation process of gowé in association with *Kluyveromyces marxianus* and *Pichia anomala* the predominant yeasts (Vieira-Dalodé et al., 2007) as starter cultures for a controlled fermentation, may have an effect on the volatile compounds of the product. An accelerated saccharification process was performed before the use of the starter cultures for *gowé* fermentation. The main objective of the present work is to identify the different volatile compounds characterizing gowé aroma and to evaluate the combined effect of saccharification and use of starter cultures on the volatile compounds, during gowé fermentation.

MATERIALS AND METHODS

The red variety of sorghum [*Sorghum bicolor* (L) Moench] for the production of gowé was purchased from a local market in Cotonou. The strains of lactic acid bacteria and yeasts used as starter cultures were isolated from gowé obtained by spontanaous fermentation and identified as the predominant species during the production process.

Samples preparation

Two different processing methods were used. The first one followed the spontaneous fermentation process described by Vieira-Dalodé et al. (2007). Samples of product were taken at 0, 4, 8 and 12 h during primary fermentation and at 12 h of the secondary fermentation. A modified technology was used during the second process. The modification involved the production of a gruel (23 to 25% D.W.) made from the malted sorghum flour diluted in water. The gruel was kept at 40°C for 2 h in a water bath. This treatment initiated an accelerated saccharification. The saccharified product was mixed with a non-malted sorghum flour. The LAB (*L. fermentum* and *W. confusa*) and yeast (*K. marxianus* and *P. anomala)* selected were used singly or in combination (one LAB + one yeast) as inoculum enrichment to inoculate the mixture as described by Vieira-Dalodé et al. (2008). Sampling was done at 0, 12 and 24 h of fermentation. At each sampling time, samples (100 g) were taken, freeze dried and kept at -20°C for further determination of volatile compounds.

Determination of volatile compounds

Volatile compounds extraction

The Likens-Nickerson simultaneous distillation and extraction was used to determine the volatile organic compounds in gowé according to the method used by Annan et al. (2003a). Extraction was done using a micro-scale steam distillation low-density solvent extraction device (micro-SDE, Chrompack, Middelburg, the Netherlands). The extraction procedure was conducted using 10 g of freeze dried sample diluted in 400 ml distilled water to obtain 2.5% slurries of samples (w/v) in a 1 L conical flask. One (1 ml) of internal standard (50 ppm, 4-methyl-1-pentanol in H_2O) was added to the slurry in an Erlenmeyer flask. Six (6 ml) of a mixture of pentane and diethyl ether (1:1) were placed in 9 ml pear-shaped solvent flask. The conical and the pear shaped flasks were connected to the Likens-Nickerson distillation extraction apparatus and the solutions were brought to boil. Extraction of volatile compounds was carried out for 30 min, from the beginning of condensation of vapors on the walls of the condenser. The pear shaped flask containing entrapped volatiles in solvent was removed and placed in freezer to freeze out the aqueous portion in solution. The solvent extract was poured off, dried over in 2 g of Na_2SO_4 and concentrated to about 100 mg by gently blowing N_2 gas over the surface. The concentrated extract was analyzed for volatile compounds using the gas chromatograph-mass spectrophotometer (GC-MS). Separation and identification of volatile compounds in extracts of *gowé* samples were carried out on Hewlett-Packard G1800 GCD System (GC-MS, Hewlett-Packard, Palo Alto, CA, USA). The instrument was equipped with a Hewlett-Packard DB-WAX column (30 m × 0.25 µm i.d., × 0.25 mm film thickness).

Identification of volatile compounds

Two microlitres extracts were injected (split ratio 1: 20) using the temperature programme: 10 min at 40°C, increased to 240°C at 6°C min^{-1} and held constant at 240°C for 30 min. Identification of aroma compounds was determined in the total ion mode scanning a mass to charge ratio (m/z) of range between 25 and 550. Further identification was obtained by probability based matching with mass spectra in the G1033A NIST PBM Library (Hewlett-Packard). The quantity of an individual compound was estimated by comparing its total ion relative peak area with that of the 4-methyl-1-pentanol internal standard. The volatile organic compounds taken into account were those having a quality identification mark or quality Index (QI: degree of agreement between mass spectrum of sample and mass spectrum in database on scale of 0 to 100) above 70%.

Statistical analysis

Principal component analysis (PCA) was performed using statistica

7 (StatSoft, Tulsa, Uk, USA).

RESULTS

Aroma compounds during *gowé* production by natural fermentation

Gowé was characterized by 61 volatile compounds, composed of 9 alcohols, 17 aldehydes, 5 acids, 14 esters, 12 hydrocarbons, 1 furan, 2 phenol and 1 piperidine (Table 1).

Alcohols

Nine types of alcohol were identified. Ethanol was the most abundant alcohol found throughout the process. Its concentration increased from 0.94 g kg^{-1} at 0 h of the primary fermentation to a peak of 2.2 g kg^{-1} at 12 h of the secondary fermentation. It decreased below the initial value after 24 h of the secondary fermentation. The concentrations of the other alcohols identified were lower and varied between 0.88 and 19.12 mg kg^{-1}. 1-Pentanol was found from 0 h of the primary fermentation to 24 h of the secondary fermentation. Its concentration was very low at the end of the process. With the exception of heptanol, all the identified alcohols could be found at 24 h of the secondary fermentation.

Aldehydes

Seventeen aldehydes were found through the fermentation process. Hexanal could be identified during primary fermentation and at 12 h of secondary fermentation but not at 24 h. The concentration of hexanal decreased from 76.18 mg kg^{-1} at 0 h of the primary fermentation to 15.93 mg kg^{-1} at 12 h of the secondary fermentation. Most of the aldehydes were identified during the primary fermentation. During the secondary fermentation only 3 aldehydes could be found namely hexanal, furfural and 2-4- Decadienal, which was the only one found at the end of the second fermentation.

Esters

Fourteen esters were found and several could be identified from the primary fermentation to 12 h of the secondary fermentation. Ethyl linoleate was the ester with the highest concentration increasing from 39.09 at 0 h to 1664.70 mg kg^{-1} at 12 h of the secondary fermentation. The second abundant ester was ethyl linoleate which increased from 18.42 to 702.85 mg kg^{-1}. At 12 h of the secondary fermentation, ethyl linoleate was the volatile compound in highest concentration after ethanol. No ester was detected at the end of the fermentation process.

Hydrocarbons

A total of 12 hydrocarbons were identified with p-xylene and 1-3 dimethyl benzene being found during the primary and the secondary fermentation. They were the two compounds found in high concentration after 12 h of the secondary fermentation.

Acids

Five acids were detected during the fermentation process. Hexadecanoic acid, oleic acid and 9-12 octadecadienoic acids were found in concentrations that increased from 0 h of the primary fermentation to 12 h of the secondary fermentation. Acetic acid was identified in increasing amount from 12 h of the primary fermentation to the end of the process. Butanoic acid was identified only at the end of the process after 24 h of the secondary fermentation.

Other compounds

Phenols, furans and piperidine were the other volatiles compound identified but they were not detected at the end of the process.

Aroma compounds during gowé production after saccharification and use of starter cultures

A total of 94 compounds were identified during the fermentation process after saccharification and the use of the starter cultures. The volatile compounds identified in the saccharified and inoculated samples were composed of alcohols, aldehydes, acids and esters, hydrocarbons, furan and phenol as in the spontaneous fermentation. The concentrations of the compounds were drastically reduced compared to the spontaneous fermentation (Table 2).

DISCUSSION

Flavors and taste are important quality characteristics of traditional foods. Fermented foods are particularly appreciated for their pleasant flavor and taste (Holzapfel, 2002). Traditional gowé is a naturally fermented product characterized by specific taste and flavors well known by the consumers. Several groups of volatile compounds could be identified during the production of gowé including alcohols, aldehydes, esters, hydrocarbon and acids. Most of the volatiles could be identified from 0 h of fermentation and may have been initiated during the steps preceding fermentation such as steeping and germination of sorghum kernels. Most of the volatile compounds of the different groups were observed during

Table 1. Volatiles compounds (mg kg^{-1}) during *Gowé* production by spontaneous fermentation.

Compounds	Quality index	Primary fermentation			Secondary fermentation	
		0 h	8 h	12 h	12 h	24 h
Alcohols						
Ethanol	***	940.50	1056.70	1483.08	2196.75	906.42
2-methylpropan-1-ol	**	Nd	Nd	5.69	Nd	5.37
3-methyl butan-1-ol	**	Nd	Nd	Nd	Nd	15.66
1-pentanol	**	13.16	15.12	19.12	3.19	1.71
Hexanol	**	Nd	Nd	5.45	9.94	5.04
Heptanol	**	Nd	Nd	5.18	Nd	Nd
1-octanol	**	2.96	3.32	5.31	Nd	2.73
Mequinol	**	Nd	Nd	Nd	Nd	1.45
Benzyl alcohol	***	Nd	Nd	Nd	Nd	0.88
Total		**956.62**	**1075.14**	**1523.83**	**2209.88**	**939.26**
Aldehydes						
3-methyl butanal	**	Nd	7.61	20.78	Nd	Nd
Hexanal	***	76.18	56.86	55.36	15.93	Nd
Heptanal	***	20.50	14.64	8.11	Nd	Nd
Trans2-heptanal	***	Nd	ND	13.68	Nd	Nd
Nonanal	***	9.30	8.08	8.81	Nd	Nd
Octanal	**	11.54	Nd	Nd	Nd	Nd
2-octenal	***	Nd	7.87	14.60	Nd	Nd
3- propanal	**	1.39	ND	Nd	Nd	Nd
Furfural	***	Nd	Nd	Nd	4.22	Nd
Benzaldehyde	***	1.82	0.78	2.16	Nd	Nd
2-nonenal	***	13.45	11.76	10.48	Nd	Nd
2-decenal	***	6.87	8.56	12.09	Nd	Nd
2,4-nonadienal	***	4.03	5.54	6.04	Nd	Nd
2-undecenal	***	Nd	ND	13.44	Nd	Nd
2,4-decadienal	***	23.21	32.50	47.24	Nd	6.54
Octadecanal	***	Nd	Nd	2.39	Nd	Nd
Total		**168. 92**	**154.2**	**215.18**	**20.15**	**7.94**
Esters						
Ethyl lactate	**	Nd	Nd	Nd	9.61	Nd
Ethyl octanoate	***	Nd	Nd	3.96	5.93	Nd
Ethyl tetradecanoate	***	5.11	3.24	4.36	Nd	Nd
Ethyl palmitate	**	Nd	Nd	0.87	Nd	Nd
Methyl hexadecanoate	***	Nd	Nd	1.75	Nd	Nd
Ethyl hexadecanoate	***	Nd	23.46	56.66	111.04	Nd
9-Ethyl hexadecanoate	***	Nd	ND	Nd	43.14	Nd
9-methyl octadecenoate	***	10.39	ND	Nd	Nd	Nd
Ethyl oleate	***	18.42	65.555	397.27	702.85	Nd
9-12-methyl octadecenoate	***	19.90	21.10	29.26	Nd	Nd
Ethyl linoleate	***	39.09	567.68	787.72	1664.70	Nd
9-12-15ethyl octadecatrienoate	***	Nd	Nd	30.96	85.87	Nd
Dibutyl phthalate	***	10.51	Nd	Nd	Nd	Nd
9-methyl octadecenoate	***	39.33	Nd	Nd	Nd	Nd
Total	***	**142.75**	**681.03**	**1312.81**	**2623.14**	-
Hydrocarbons						
P-xylene	***	14.34	8.15	7.78	14.45	8.09

Table 1. Contd.

1,3 dimethyl benzene	***	7.97	10.20	15.98	20.84	Nd
2-heptacene	**	12.50	6.30	Nd	Nd	Nd
3-ethyl 2 methyl 1,3 hexadiene	***	28.97	22.65	23.99	Nd	Nd
Octyl cyclopropane	**	Nd	Nd	Nd	Nd	4.41
1-methylene	**	Nd	Nd	Nd	Nd	4.15
Trans trans-2-4-decadiene	***	Nd	12.70	47.24	Nd	Nd
Cyclododecane	***	Nd	Nd	Nd	4.69	Nd
1-dodecene	***	Nd	Nd	Nd	Nd	2.92
1-octadecene	***	Nd	Nd	2.30	Nd	Nd
Heptacosane	***	Nd	Nd	4.87	Nd	Nd
Docosane	***	Nd	Nd	1.95	Nd	Nd
Total		**63.78**	**60.0**	**104.11**	**39.98**	**19.57**
Acids						
Acetic acid	**	Nd	Nd	1.57	2.84	4.53
Butanoic acid	***	Nd	Nd	Nd	Nd	21.44
Hexadecanoic acid	***	144.20	97.45	Nd	1036.59	Nd
Oleic acid	***	Nd	Nd	185.01	327.27	Nd
9-12 octadecadienoic acid	***	39.33	154.6	423.94	845.79	Nd
Total		**183.53**	**252.05**	**608.95**	**2209.65**	**25.97**
Phenol, Furans						
2 pentyl furan	***	23.22	14.32	Nd	Nd	Nd
2 methoxy phenol	***	Nd	ND	10.72	Nd	Nd
Phenol	***	2.77	9.56	42.20	20.82	Nd
Total		**25.99**	**23.88**	**52.92**	**20.82**	
Others						
Piperidine	***	Nd	Nd	3.04	Nd	Nd

QI (Quality index): degree of agreement between mass spectrum of sample and mass spectrum in database on scale of 0 to 100; ***: quality index > 90, **: quality index between 80 and 90. N: analysis was not done. Nd: compound was not detected.

Table 2. Volatiles compounds (Total amount $mgkg^{-1}$) of Gowé produced after saccharification using starter cultures.

Compounds	C	Lf	Wc	Km	Pa	WK	WP	LK	LP
Alcohols	1.4	0.47	0.82	1.55	2.58	0.96	1.51	0.88	0.85
Aldehydes	1.97	0.37	0.30	0.99	0.66	0.52	1.02	0.96	0.69
Esters	15.25	7.01	5.57	15.61	11.21	12.17	12.32	10.13	11.88
Hydrocarbons	0.59	0.27	0.18	0.47	1.58	1.11	0.88	0.74	0.52
Acids	10.43	9.52	8.07	6.89	6.43	8.15	10.48	8.78	9.21
Phenol/furans	0.24	0.19	Nd	0.06	0.83	Nd	0.13	Nd	Nd

L: *lactobacillus fermentum ;* W *: Weissella confusa ;* C: control ; K *: Kluyveromyces marxianus ;* P *: Pichia anomala; ;* WK , WP: Starters composed of *W. confusa* and *K. marxianus* or *P. anomala.* LK, LP: starters composed of *L. fermentum* and *K. marxianus* or *P. anomala.*

the primary fermentation stage where an increase of the lactic acid bacteria and yeast counts could be observed. After 12 h of the primary fermentation a hot gruel of non-malted sorghum flour was added resulting in a decrease in the number of the compounds identified. Alcohols were produced throughout the fermentation process and were identified from 0h of the primary fermentation. Alcohols are produced from fermentation by yeasts which had their numbers increasing during the primary fermentation. Ethanol, the main alcohol produced was found to occur in

increasing amounts as fermentation progressed. During spontaneous fermentation of maize dough for Kenkey production in Ghana, ethanol was the most abundant alcohol found (Annan et al., 2003a). Ethanol was a flavor compound found in Amasi, a Zimbabwean naturally fermented raw milk product (Gran et al., 2003).

Most of the aldehydes were found during the primary fermentation. Several steps such as milling into flour and kneading carried out during gowé processing could lead to aldehyde production. During milling into flour, lipoxygenase enzymes in plant cell lysosomes react with linolenic and linoleic acids in the presence of oxygen to produce aldehydes such as hexanal (Gray et al., 1999). The intensity of kneading may have an effect on the concentration of some aldehydes (Cayot, 2007). Hexanal was the aldehyde found in the highest amount at 0h of fermentation when the malted sorghum flour was kneaded and left to ferment. Hexanal has also been identified in several cereal based fermented products such as kenkey (Annan et al., 2003a) and sorghum malt beverage (Lasekan et al., 1997). Ethanol was the alcohol found in the highest concentration during gowé production. This corresponded with the formation of several ethyl esters. Esters are mainly produced by yeast during alcoholic fermentation in reactions between alcohol and acetyl-CoA catalysed by enzymes (Mamede et al., 2005). Ethyl oleate and ethyl linoleate were observed to be in increasing amounts from 0 to12 h of the secondary fermentation when gowé is ready to be cooked. The different volatile acids identified were mainly hexadecanoic acid, oleic acid and 9 to 12 octadecadienoic acid. Their concentrations increased considerably after 12 h of the secondary fermentation.

Gowé is generally cooked after 24 h of fermentation (12 h of the secondary fermentation). The characteristic volatiles at this stage were mainly ethanol, ethyl linoleate and hexadecanoic acid.

The use of starter cultures for gowé fermentation produced volatile compounds similar to what was observed in the spontaneously fermented gowé but in significantly decreased amounts. This may have been due to the accelerated saccharification process where the product was kept at 40°C for 2 h. Most of the volatile compounds increased with the fermentation time when the yeasts were used in single or in association with the LAB. The ability of selected microorganisms to modify taste, flavors and other characteristics of fermented products has been studied by several authors (Annan et al., 2003b, c; Mugula et al., 2003; Zorba et al., 2003; Gran et al., 2003; Ouoba et al., 2005; Azokpota, 2005). Fermentation of maize dough involving yeasts induced higher concentrations of compounds related to yeasts fermentation products such as alcohols and esters (Annan et al., 2003c). The fermentation of gowé with *K. marxianus* and *P. anomala* used singly led to a relatively higher concentration of alcohol. The use of *L. fermentum* singly in the fermentation of maize dough gave lower concentration of alcohol than when used in combination with yeasts (Annan et al., 2003). Lower concentrations of aldehydes, esters and hydrocarbons were observed when the LAB were used singly in the saccharified and inoculated product. Lower concentrations of volatile compounds were observed when LAB were used to ferment sourdough bread compared to sourdough fermented with yeasts (Hansen and Hansen, 1994). Annan et al. (2003b, c) found that the concentrations of most volatile organic acids were the lowest in fermentation of maize dough with only *L. fermentum* added as a starter culture.

A principal component analysis was performed on the volatile compounds produced by traditional and starter fermented gowe. The aroma compounds obtained after 24 h of fermentation exhibited two volatile profiles groups. The first two principal components accounted for 94.89% (PCI) and 5.04% (PC2) of the variation in the data, respectively. The PC1 reflects the content of acids on the left of the plot (Figure 1). The high concentrations of volatile acids (6.43 to 10.48 mg/kg) are in correlation with the starters used, lactic acid bacteria used singly or in association with a yeast. Fermentations of Ghanaian maize dough with *L. fermentum* with *C. krusei* were characterized by similar trend, higher concentration of acetic acid and low concentrations of most volatiles produced (Annan et al., 2003b). This high production of acids was not observed when the yeasts were used singly. The other volatile compounds were found on the right and were composed by compounds mainly identified in the traditional product. Gowe obtained by natural flora fermentation (control) was characterized by particularly high levels of phenol, furans (20.82 mg/kg), esters (255.54 mg/kg) and aldehyde (20.15 mg/kg) and low level of acid (2.84 mg/kg). These compounds were also detected in the inoculated samples but in low concentration. Using principal component analysis for comparison, the aroma profiles of gowe fermented with the yeasts *K. marxianus* and *P. anomala* and lactic acid bacteria *L. fermentum* used singly or in association with one of the yeasts can be separated from that of naturally fermented gowe.

Conclusion

Gowé obtained by spontaneous fermentation of sorghum flour is characterised by several volatile compounds developed with the activities of the different lactic acid bacteria and yeasts involved. The use of *L. fermentum* and *W. confusa* in association with *K. marxianus* and *P. anomala* as inoculum enrichment for a controlled fermentation of gowé modified the profile of volatile compounds and the volatiles acids were the best component detected in the inoculated products. The observed reduction in the concentration of the volatile compounds compared to the spontaneous fermentation

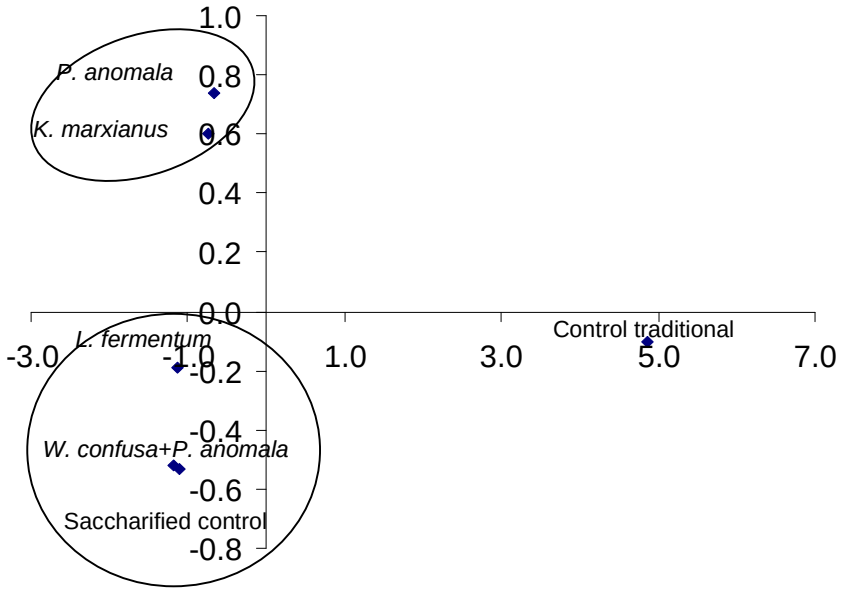

Figure 1a. Grouping of types of inoculated gowé related to the starter used.

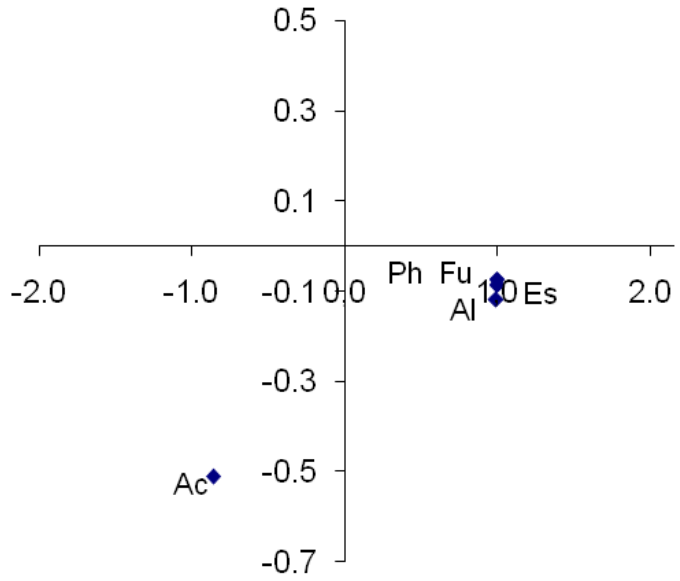

Figure 1b. Volatile compounds identified in different groups of inoculated gowé. Ac: acids, Al: aldehydes, Es: esters, Fu: furan, Ph: Phenols.

may be due to the saccharification process realised before inoculation. A standardized production process was aimed with the use of starter cultures. The products inoculated with lactic acid bacteria showed a high concentration of acids. These volatile acids may confer to the gowé obtained some qualities and specific flavors sought by the consumers. Analysis by GC-sniffing can provide further knowledge about the contribution of the identified compounds to the characteristic aroma of cooked *gowé*.

Conflict of interests

The authors have not declared any conflict of interest.

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Composition and sensory properties of plantain cake

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Nutrient composition, organoleptic attributes and overall acceptability of plantain cake were evaluated. Plantain fingers in stages 2 (URP) and 5 of ripeness (RP) used in this study were washed, peeled, sliced into small pieces, sun-dried for five days and milled separately into flour. Commercial wheat flour (WF_{100}) served as the control. Each sample was sieved and analyzed for functional properties and nutrients and combined in different proportions. The wheat flour (WF) was substituted by plantain flour (URP and RP) at 25, 50 and 75% for cake making, respectively. The combinations derived were 25%URP and 75%W ($URP_{25}W_{75}$), 50%URP and 50%W ($URP_{50}W_{50}$), 75%URP and 25%W ($URP_{75}W_{25}$), 25%RP and 75%W ($RP_{25}W_{75}$), 50%RP and 50%W ($RP_{50}W_{50}$), 75%RP and 25%W ($RP_{75}W_{25}$). Each combination was used in baking cake. The proximate composition and sensory evaluation of the cakes were determined. The URP flour had the least protein content (2.73%) while WF_{100} had the highest (3.04%). The RP had the lowest fat (0.30%) and highest ash (2.33%) contents. The URP flour had more foaming stability/capacity and emulsion capacity but less oil absorption capacity and least gelation concentration than RP flour. The W_{100} cake had 26.41% protein followed by the $RP_{25}W_{75}$ (23.99%) and $URP_{25}W_{75}$ (23.91%) cakes. The $URP_{25}W_{75}$ cake had significantly ($p<0.05$) more fibre and fat contents (9.44 and 12.32%, respectively) than the rest of the samples. Vitamin B_2 (mg/100 g) in $URP_{50}W_{50}$, (2.29) $RP_{25}W_{75}$ (2.05) $RP_{50}W_{50}$ (2.05) and W_{100} (2.09) cakes were comparable. All the cake samples had similar folate and calcium contents. There were differences in iron, potassium, magnesium and zinc contents of the cakes. The $URP_{50}W_{50}$ was rated best plantain-based cake in terms of texture (7.80) and acceptability (7.82). This study forms a basis for new product development for the biscuit food industry.

Key words: Functional properties, Plantain flour, wheat flour, plantain-cake, proximate composition, sensory evaluation.

INTRODUCTION

There is increased advocacy on the consumption of functional foods by world human nutrition due to different health problems related with food consumption such as diabetes and coronary heart diseases (WHO/FAO, 2003). Food professional/industries might face challenges of producing food products containing functional ingredients in order to meet the nutritional requirements of individuals with health challenges. This is because of the effect of

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added sugar and lipids in the industrial production of foods products. Alternative source of food production was advocated by Oke and Adeyemi (1991) in tackling food crises. The prospect of blending tubers, roots and plantain with cereals and legumes for the production of household food products is receiving considerable attention (Nnam, 2002; Onoja and Obizoba, 2009). This might make the products to be nutritious, relatively cheap and affordable to the rural poor to stem-off hunger and malnutrition.

Baked products provide an excellent opportunity to incorporate food-grade fractions from grains, legumes or other indigenous food sources. High cost of wheat flour in non-wheat producing countries such as Nigeria poses a problem to bakery industries and consumers of baked products (Chinma et al., 2012). Nigeria is currently one of the world's largest importers of United State wheat flour (United States Department of Agriculture, 2014). The present high cost of baked products in Nigeria presents the need to further study on incorporation of indigenous food sources for baking, as this will help reduce total dependence on wheat flour.

Plantain is the common name for herbaceous plants of the genus *Musa*. Plantain (*Musa paradisiaca*) is an important staple food in Central and West Africa. It is a basic food crop and cheap source of energy in Nigeria (Faturoti et al*.,* 2007; Adeniyi et al*.,* 2006). Several food consumption surveys in Nigeria identified plantain among the major starchy staples (Odenigbo, 2012; Okeke et al*.,* 2008; Ogechi et al*.,* 2007). According to FAO (2005), over 2.11 million metric tons of plantains are produced in Nigeria annually. However, about 35-60% post-harvest losses had been reported and attributed to lack of storage facilities and inappropriate technologies for food processing (Olorunda and Adelusola, 1997).

An average plantain has about 220 calories and is a good source of potassium and dietary fiber (Randy et al*.*, 2007). It is rich in carbohydrate, dietary fiber, irons, vitamins, and minerals. This nutritious food is ideal for diabetics, children, and pregnant women. It can also be a good supplement for marasmus patients. Plantain contains small amount of serotonin which has the ability to dilate the arteries and improve blood circulation. Its regular consumption helps to cure anemia (low blood level) and maintain a healthy heart (USDA Nutrient Database, 2010). A diet of unripe plantain is filling and can also be a good inclusion in a weight loss diet plan (Oke et al*.*, 1998).

Plantain is widely grown in the Southern states of Nigeria and it is used both in Nigeria and many African countries as a cheap source of calories, excellent for weight control, slow in the release of energy after consumption with a low glycermic index (Mendosa, 2008), high in potassium and good for diabetic patients (Akubor, 2003?). Plantain is also a good source of Iron, and β – Carotene (Pro-Vitamin A) as reported by Ogazi (1988?). It contains 32% carbohydrate, 1% protein, 0.02 fat, 60% water, some vitamins and mineral elements (Kure et al*.,* 1998). With the progressive increase in the consumption of bread and related baked products in Nigeria, the composite flour program if adopted has the potential to add value to indigenous crops like plantain and at the same time conserve foreign exchange spent on wheat importation. The aim of the study therefore is to evaluate the effect of substitution on the functional properties of the wheat/ plantain composite flour and the proximate/sensory properties of wheat/plantain bread.

Plantain is rich in dietary fibre (8.82%), resistant starch (16.2%), and low in protein and fat (Ayodele and Erema, 2011). Dietary fibre in human diets lowers serum cholesterol, reduces the risk of heart attack, colon cancer, obesity, blood pressure, appendicitis and many other diseases (Rehinan et al., 2004). On the other hand, resistant starch assists in preventing and managing type 2-diabetes (Jideani and Jideani, 2011). Resistant starch has interesting functional properties for use in foods including: formation of products with high fibre content and low volume with improved sensory properties like texture and appearance (Nugent, 2005). Considering the health benefits of plantain, its incorporation as composite blend in the preparation of cake will help in enhancing the nutritional and health status of consumers, reduce total dependence on wheat flour and incidence of certain chronic non communicable disease.

The possibility of producing bakery products from wheat/plantain composite flour has been assessed (Bamidele et al., 1990; Mepba et al., 2007; Idoko and Nwajiaku, 2013). The water absorption capacity and dough development time of the composite flour decreased with increasing levels of supplementation with plantain (Bamidele et al., 1990). The percentage of wheat flour required to achieve a certain effect in composite flours depends heavily on the quality and quantity of wheat gluten and the nature of the product involved. Akubor (1998) has shown that plantain flour has a good potential for use as a functional agent in bakery products on account of its high water absorption capacity.

Aurore et al*.* (2009) used colour index according to the commercial peel colour to define 8 ripening stages of banana. At stages 1-3, banana is not usually eaten like fruit, because it is green, very hard, astringent, and rich in starch. At stage 8, it is overripe and muddy. Plantain can be utilized at all stages of ripening, and its nutritive value depends on their ripeness, variety, climatic conditions and soil of crop production (Baiyeri et al*.,* 2011; Ogazi, 1986). Baiyeri et al. (2011) reported increased ash and carbohydrate contents with ripeness, whereas at unripe stages, fat, protein and dry matter were relatively higher. With changes observed in composition of plantain due to ripening it becomes imperative to assess the use of wheat and plantain flour at different stages of ripeness in cake production. This study was undertaken to evaluate the composition of cake produced from different ratios of plantain (at stages 2 and 5 of ripeness) and wheat flours.

MATERIALS AND METHODS

Source and preparation of samples

The fresh plantains (*Musa paradisiaca*) used for this study were bought from Ogige market Nsukka in Enugu State, Nigeria. The plantain fingers were at stages 2 (unripe) and 5 (firm ripe) of ripeness using the colour index chart as described by Aurore et al. (2009).

Wheat flour and the cake ingredients (margarine, eggs, granulated sugar, vanilla and baking powder) were also bought from the local market.

The plantain fingers were washed, peeled, sliced, sun-dried for 96 h (during dry season) and milled into flour using Attrition Mill (Globe P 44, China). The flour samples were sieved through a 75µm sieve and stored in airtight plastic containers at room temperature (28±2°C).

Formulation of composite flour

The unripe plantain (stage "2" of ripeness) and firm ripe plantain (stage "5" of ripeness) flours were mixed with wheat flour separately at different proportions (25:75; 50:50 and 75:25) while 100% wheat flour was used as control. The flours were mixed using a B8 (Mega Best Industry Ltd, GuangDong, China) universal spiral mixer at 450 rpm for 20 min until uniform blends were obtained.

Cake making

The proportion of ingredients used consists of flour (100g), egg (100g), sugar (60g), vanilla (three drops), baking powder (1.7g), water (80 ml) and margarine (80g). The baking procedure described by Ceserani et al. (1995) was adopted.

Determination of functional properties of the flour samples

Determination of bulk density

The bulk density was determined using Onwuka (2005)'s method with slight modification. Fifty grams of each sample was measured into a clean 100 ml graduated measuring cylinder which was tapped gently several times until there was no further diminution. Its volume was recorded and the bulk density was calculated using the formula:

$$\text{Bulk density (g/cm}^3\text{)} = \frac{\text{Weight of sample (g)}}{\text{Volume occupied (cm}^3\text{)}}$$

Determination of foaming capacity and stability

Foaming capacity and stability were studied as described by Narayana and Narasinga (1982). Two grams of each flour sample was blended with 50 ml distilled water at 30±2°C. The whipped mixture was transferred into 100 ml graduated cylinder. The suspension was mixed and properly shaken to foam and the volume of the foam after 30 s was recorded. The foaming capacity was expressed as a percentage increase in volume. The foam volume was recorded 1 h after whipping to determine the foaming stability as a percentage of the initial foam volume.

Determination of water and oil absorption capacity

Water and oil absorption capacities were determined according to the method described by Okezie and Bello (1988). Briefly, 1.0 gram of each sample was mixed with 20 ml distilled water (for water absorption capacity) and 20 ml of oil (for oil absorption capacity) in a flask shaker and centrifuged at 2,000 rpm for 1h. Water/oil absorbed by samples was calculated as the difference between the initial and final volumes of water/oil. Means of triplicates determination were reported.

Determination of least gelation concentration

The least gelation concentration was determined using the method of Coffmann and Garciaj (1977). Sample suspensions of 2-20% were prepared in distilled water. Ten milliliter of each of the prepared dispersions was transferred into a test tube. It was heated in a boiling water bath for 1 h, followed by rapid cooling in a bath of cold water. The test tubes were further cooled at 4°C for 2 h. The least gelation concentration was determined as that concentration when the sample from the inverted test tube did not slip.

Determination of emulsion capacity

Emulsion capacity was determined using the procedure of Abbey and Ibeh (1988) with slight modification. One gram of each flour sample was dispersed in a beaker containing 5 ml distilled water and 5 ml of vegetable oil (corn oil) was added. The mixture was emulsified by centrifuging at 1,600 for 5 min. Emulsion capacity (%) was calculated as:

$$\frac{\text{(Initial vol. of oil – Final vol. of oil)}}{\text{(Weight of sample × density of oil)}} \times 100$$

Determination of emulsion stability

Emulsion stability was studied by the method described by Sathe and Salunkhe (1981) with slight modification. 0.5 g of the sample was blended with 25 ml of distilled water, then 25ml of vegetable oil was added while blended for 30 s at high speed. The emulsion prepared was allowed to stand in a graduated cylinder and volume of water separated at time intervals of 0.5, 1, 2, 3 … 12h was noted in each case as the emulsion stability. Triplicate measurements were made and average results taken.

Emulsion stability (%) was calculated as:

$$\frac{\text{Height of the emulsified layer}}{\text{Height of total content in the tube}} \times 100$$

Chemical analysis

Proximate composition

Proximate analysis of the samples was carried out using AOAC methods (AOAC, 1995). Moisture content was determined by air oven method at 105°C. The protein content of the sample was determined using micro-Kjeldahl method. Fat was determined by Soxhlet extraction method using petroleum ether as extracting solvent. The ash content was determined by weighing 5 g of charred sample into a tarred porcelain crucible. It was incinerated at 600°C for 6 hours in ash muffle furnace until ash was obtained. Crude fibre was determined by exhaustive extraction of soluble substances in a sample using H_2SO_4 and NaOH solution, after the residue was ashed and the loss in weight recorded as crude fibre. The carbohydrate content was determined by difference as follows:

Table 1. Functional properties of ripe, unripe plantain and wheat flours.

Flour	Packed bulk density (g/cm^3)	Foaming capacity (%)	Foaming stability (%)	Water absorption capacity (g/g)	Oil absorption capacity (g/g)	Emulsion capacity (%)	Emulsion stability (%)	Least gelation concentration (%)
Ripe plantain (RP)	0.64±0.09^a	11.52±0.30^a	54.78±1.64^a	2.77±0.45^c	2.59±0.41^b	2.30±0.33^a	3.34±0.44^a	35.00±0.51^b
Unripe plantain (URP)	0.79±0.06^b	17.47±0.23^b	58.14±3.50^b	2.71±0.04^b	2.56±0.42^a	4.00±0.48^c	2.74±0.30^a	30.01±0.06^a
Wheat	0.82±0.07^b	28.81±0.20^c	73.31±0.51^c	2.09±0.46^a	3.13±0.41^c	3.17±0.25^b	4.40±0.40^b	35.00±0.41^b

Mean values in the same column with different superscripts are significantly different at $p < 0.05$.

Table 2. Proximate composition (%) of the ripe, unripe plantain and wheat flours.

Flour	Moisture	Protein	Fibre	Fat	Ash	Carbohydrate
Ripe plantain (RP)	18.48±0.06^a	3.02±0.01^b	1.31±0.03^b	0.30±0.00^a	2.33±0.02^c	74.56±0.06^c
Unripe plantain (URP)	20.43±0.06^c	2.73±0.04^a	0.49±0.01^a	0.63±0.01^b	2.11±0.04^b	73.61±0.71^b
Wheat	20.22±0.72^b	3.04±0.01^b	1.48±0.04^c	1.28±0.01^c	1.11±0.07^a	72.87±0.77^a

Mean values in the same column with different superscripts are significantly different at $p < 0.05$.

% Carbohydrate = 100 – (% Moisture + % Ash + % Protein + % Fat + % Crude fibre).

Vitamins and mineral analyses

Provitamin A was determined using the method adopted from IVACG (1992) and vitamin B_1, B_2, vitamin C and folate were determined using the method of AOAC (1995).

Mineral compositions were determined using AOAC method (1995). The ash was digested with 3 cm^3 of 3M HCl and made up to the mark in a 100cm^3 standard flask with 0.36 M HCl before the mineral elements (calcium, zinc, magnesium, iron and potassium) were determined by atomic absorption spectrophotometer (PYE Unicam SP 2900, UK)

Determination of sensory properties

Thirty panelists consisting of staff and students of the Department of Home Science, Nutrition and Dietetics University of Nigeria Nsukka, Nigeria were selected for the sensory evaluation based on their familiarity with the quality of cake. Cakes prepared from the flour blends were coded and presented in white plastic plates. Water was provided to rinse mouth between evaluations. The samples were evaluated for texture, colour, taste, flavor and general acceptability. Panelists evaluated cake samples on a 9-point hedonic scale quality analysis (Ihekoronye and Ngoddy, 1985) with 9 = liked extremely, 8 = liked very much, 7 = liked, 6 = liked mildly, 5 = neither liked nor disliked, 4 = disliked mildly, 3 = disliked, 2 = disliked very much and 1 = disliked extremely .

Statistical Analysis

The data obtained were analyzed statistically by Statistical Package for Social Science (SPSS), version 18, using one way analysis of variance (ANOVA). Means were separated by calculating the least significant difference (LSD) at ($P \leq 0.05$). Data reported on the tables are average values of triplicate determinations.

RESULTS

Table 1 shows the functional properties of ripe plantain, unripe plantain and wheat flours. The bulk density of the flour samples ranged from 0.64 to 0.82 gm^3 for ripe plantain and wheat flour, respectively. However, there was no significant difference between the bulk density of wheat and unripe plantain flours. The foaming capacity, foaming stability and emulsion capacity of unripe plantain flour was found to be significantly higher than that of ripe flour ($p<0.05$). The ripe plantain and wheat flours had the highest least gelation concentration (35%) as compared to the unripe plantain flour (30.01%). The water absorption capacity of the ripe plantain (2.77g/g) and unripe plantain (2.71g/g) flours was significantly higher ($p<0.05$) than wheat (2.09g/g) flour.

Table 2 shows the proximate composition of the ripe, unripe plantain and wheat flours. The moisture content ranged from 18.48% for ripe to 20.43% for unripe plantain flours. Protein content ranged from 2.73 to 3.04% for unripe plantain and wheat flours, respectively. There was no significant difference in the protein content of wheat and ripe plantain flours. Wheat flour had the highest fibre (1.48%) and fat (1.28%) contents. Carbohydrate content ranged from 72.87 to 74.56% for wheat and ripe plantain flours, respectively. Ripe (2.33%) and unripe plantain (2.11%) flours had significantly higher ($p<0.05$) ash content when compared to the wheat flour (1.11 %).

Table 3 shows the proximate composition of cakes prepared from the wheat-plantain composite flour and wheat flour (control). Table 3 shows that the carbohydrate content of the cakes prepared from plantain and wheat flour blends were significantly higher than that

Table 3. Proximate composition (%) of the cake samples.

Cake samples	Moisture	Protein	Fibre	Fat	Ash	Carbohydrate
$URP_{25}W_{75}$	12.15±0.27[a]	23.91±0.42[d]	9.44±0.03[g]	12.32±0.03[g]	3.18±0.06[b]	39.00±0.23[b]
$URP_{50}W_{50}$	16.00±0.04[c]	21.41±0.01[c]	4.98±0.04[f]	4.23±0.28[a]	2.81±0.03[a]	50.57±2.86[g]
$URP_{75}W_{25}$	19.03±0.05[e]	18.91±0.35[a]	0.44±0.03[b]	7.53±0.05[b]	6.51±0.45[d]	47.58±3.47[e]
$RP_{25}W_{75}$	16.00±0.04[c]	23.00±0.01[d]	0.36±0.04[a]	8.70±0.04[d]	2.70±0.05[a]	49.24±0.03[f]
$RP_{50}W_{50}$	18.45±0.04[d]	21.56±0.04[c]	0.95±0.03[d]	8.53±0.02[c]	3.60±0.30[c]	46.91±0.33[d]
$RP_{75}W_{25}$	19.33±0.02[f]	19.14±0.04[b]	1.55±0.05[e]	11.34±0.28[f]	9.06±0.04[e]	42.58±0.64[c]
W_{100}	14.00±0.04[b]	26.41±0.04[e]	0.57±0.04[c]	10.69±0.02[e]	9.56±0.05[f]	38.77±0.08[a]

Mean values in the same column with different superscripts are significantly different at $p < 0.05$. Key: $URP_{25}W_{75=}$ (25% unripe plantain flour, 75% wheat flour), $URP_{50}W_{50=}$ (50% unripe plantain flour, 50% wheat flour), $URP_{75}W_{25=}$ (75% unripe plantain flour, 25% wheat flour), $RP_{25}W_{75=}$ (25% ripe plantain flour, 75% wheat flour), $RP_{50}W_{50\,=}$ (50% ripe plantain flour, 50% wheat flour), $RP_{75}W_{25=}$ (75% ripe plantain flour, 25% wheat flour), W_{100}=(100% wheat flour).

Table 4. Vitamin composition of the cake samples (per 100 g).

Cake samples	Pro-vit. A (µg)	Vit. B_1 (mg)	Vit. B_2 (mg)	Folate (µg)	Vit. C (mg)
$URP_{25}W_{75}$	928±0.01[d]	0.84±0.01[f]	2.29±0.01[c]	237±0.01[b]	15.60±0.01[c]
$URP_{50}W_{50}$	973±0.01[g]	0.67±0.01[d]	2.05±0.01[b]	235±0.01[a]	30.60±0.01[e]
$URP_{75}W_{25}$	950±0.01[f]	0.49±0.01[c]	1.98±0.01[a]	235±0.01[a]	45.60±0.01[g]
$RP_{25}W_{75}$	915±0.01[b]	0.22±0.01[b]	2.05±0.01[b]	238 ± 0.01[b]	14.40±0.01[b]
$RP_{50}W_{50}$	934±0.01[e]	0.69±0.01[e]	2.02±0.01[b]	237±0.01[b]	28.20±0.01[d]
$RP_{75}W_{25}$	924±0.01[c]	0.96 ±0.01[g]	1.98±0.01[a]	235±0.01[a]	42.00±0.01[f]
W_{100}	905±0.01[a]	1.01±0.01[a]	2.09±0.01[b]	235±0.01[a]	0.60±0.01[a]

Mean values in the same column with different superscripts are significantly different at $p < 0.05$. Key:$URP_{25}W_{75=}$ (25% unripe plantain flour, 75% wheat flour), $URP_{50}W_{50=}$ (50% unripe plantain flour, 50% wheat flour), $URP_{75}W_{25=}$ (75% unripe plantain flour, 25% wheat flour), $RP_{25}W_{75=}$ (25% ripe plantain flour, 75% wheat flour), $RP_{50}W_{50\,=}$ (50% ripe plantain flour, 50% wheat flour), $RP_{75}W_{25=}$ (75% ripe plantain flour, 25% wheat flour), W_{100}=(100% wheat flour).

prepared from 100% wheat flour. However, 100% wheat flour cake had the highest protein (26.41%) and ash (9.56%) content when compared to other cakes.

Table 4 shows the vitamin composition of the cake samples. The $URP_{50}W_{50}$, $RP_{50}W_{50}$, $RP_{75}W_{25}$ and $URP_{75}W_{25}$ cakes had significantly more pro-vitamin A, vitamin B_1 and vitamin C values. Cake prepared from 100% wheat flour was significantly low in pro-vitamin A (905 µg/100 g) and vitamin C (0.60 mg); high in vitamin B_1 (1.01 mg) and folate (235 µg/100 g).

The mineral composition of the cakes is presented in Table 5. The $URP_{75}W_{25}$ cake had significantly more potassium content (2310 mg/100 g) but less calcium (449 mg/100 g), iron (9.84 mg/100 g), magnesium (262 mg/100 g) and zinc (6.02 mg/100 g).

The sensory attributes of cakes prepared from the flours are presented in Table 6. The $URP_{50}W_{50}$ was rated best plantain-base cake in terms of texture (7.80) and acceptability (7.82). The $URP_{75}W_{25}$ cake was rated lowest in texture (6.76), appearance (6.24), taste (6.44), flavor (6.67) and overall acceptability (6.42). However, the plantain-base cakes compared favourably with the 100% wheat cake in most the sensory attributes.

DISCUSSION

The foaming capacity of the flours ranged from 11.52 - 28.81%. Wheat flour had the highest foaming capacity and stability. Foaming capacity is assumed to be dependent on the configuration and nature of protein molecules, as flexible proteins have good foaming capacity (Graham and Philips, 1976) (). Unripe plantain flour had higher foam stability (58.14%) and capacity (17.47 %) when compared to ripe plantain flour (54.78 and 11.52%, respectively). This may suggest the usefulness of the flour in improving textural and leavening characteristics. Akubor et al*.* (2000) reported that food ingredients with good foaming capacity and stability can be used in bakery products. The water absorption capacity of the flours ranged from 2.09 - 2.77 g/g with wheat flour having the lowest value (2.09 g/g). The major chemical composition that enhances the water absorption capacity of flours are carbohydrates and proteins, since they contain hydrophilic parts such as polar or charged chains (Lawal and Adebowale, 2004). The result of carbohydrate content of the plantain flours (Table 2) may have contributed to their water absorption capacity. The

Table 5. Mineral composition (mg/100 g) of the cakes.

Cake samples	Calcium	Iron	Potassium	Magnesium	Zinc
$URP_{25}W_{75}$	452 ± 0.01^{c}	12.09 ± 0.01^{e}	1764 ± 0.01^{d}	296 ± 0.01^{e}	8.65 ± 0.01^{e}
$URP_{50}W_{50}$	451 ± 0.01^{b}	10.96 ± 0.01^{c}	2037 ± 0.01^{f}	279 ± 0.01^{c}	7.47 ± 0.01^{d}
$URP_{75}W_{25}$	449 ± 0.01^{a}	9.84 ± 0.01^{a}	2310 ± 0.01^{g}	262 ± 0.01^{a}	6.02 ± 0.01^{a}
$RP_{25}W_{75}$	452 ± 0.01^{c}	12.39 ± 0.01^{f}	I286 ± 0.01^{b}	298 ± 0.01^{e}	8.70 ± 0.01^{f}
$RP_{50}W_{50}$	451 ± 0.01^{b}	11.54 ± 0.01^{d}	1559 ± 0.01^{c}	282 ± 0.01^{d}	7.44 ± 0.01^{c}
$RP_{75}W_{25}$	449 ± 0.01^{a}	10.44 ± 0.01^{b}	1834 ± 0.01^{e}	266 ± 0.01^{b}	6.18 ± 0.01^{b}
W_{100}	454 ± 0.01^{d}	13.21 ± 0.01^{g}	1012 ± 0.01^{a}	314 ± 0.01^{f}	9.97 ± 0.01^{g}

Mean values in the same column with different superscripts are significantly different at $p < 0.05$. Key: $URP_{25}W_{75=}$ (25% unripe plantain flour, 75% wheat flour), $URP_{50}W_{50=}$ (50% unripe plantain flour, 50% wheat flour), $URP_{75}W_{25=}$ (75% unripe plantain flour, 25% wheat flour), $RP_{25}W_{75=}$ (25% ripe plantain flour, 75% wheat flour), $RP_{50}W_{50\ =}$ (50% ripe plantain flour, 50% wheat flour), $RP_{75}W_{25=}$ (75% ripe plantain flour, 25% wheat flour), W_{100} = (100% wheat flour).

Table 6. Sensory attributes of the cake samples.

Cake samples	Texture	Appearance	Taste	Flavour	Overall acceptability
$URP_{25}W_{75}$	7.71±1.10^{b}	7.67±1.07^{d}	7.82±1.01^{b}	7.98±1.01^{a}	7.82±1.01^{abc}
$URP_{50}W_{50}$	7.80±1.22^{c}	7.56±1.18^{c}	7.73±1.30^{b}	7.76±1.17^{b}	7.82±1.39^{bcd}
$URP_{75}W_{25}$	6.76±1.71^{a}	6.24±1.77^{a}	6.44±1.96^{a}	6.67±1.89^{a}	6.42±2.15^{ab}
$RP_{25}W_{75}$	7.67±1.33^{b}	7.62±1.23^{d}	7.78±1.29^{b}	7.87±1.10^{b}	7.67±1.26^{abc}
$RP_{50}W_{50}$	8.04±0.98^{c}	6.98±1.74^{b}	7.69±1.04^{b}	7.71±1.06^{b}	7.56±1.01^{cd}
$RP_{75}W_{25}$	7.07±2.05^{a}	6.89±1.85^{d}	6.40±2.15^{a}	6.78±1.93^{a}	6.76±1.85^{a}
W_{100}	7.47±1.75^{b}	8.38±103^{e}	8.07±1.25^{b}	8.20±1.29^{c}	8.02±1.12^{d}

Mean values in the same column with different superscripts are significantly different at $p < 0.05$. Key: $URP_{25}W_{75=}$ (25% unripe plantain flour, 75% wheat flour), $URP_{50}W_{50=}$ (50% unripe plantain flour, 50% wheat flour), $URP_{75}W_{25=}$ (75% unripe plantain flour, 25% wheat flour), $RP_{25}W_{75=}$ (25% ripe plantain flour, 75% wheat flour), $RP_{50}W_{50\ =}$ (50% ripe plantain flour, 50% wheat flour), $RP_{75}W_{25=}$ (75% ripe plantain flour, 25% wheat flour), W_{100}=(100% wheat flour).

emulsion capacity ranged from 2.30 to 4.00% with unripe plantain having the highest value. Emulsion capacity plays a significant role in many food systems where protein has the ability to bind to fat such as in batter and dough (Sathe, 2001). There was significant difference in the least gelation concentration of unripe plantain flour and wheat flour. According to Sathe et al*.* (1982) the variation in the gelling properties of flours is attributed to the relative ratio of protein, carbohydrates and lipids that made up the flours and interaction between such components.

The moisture content of the flours ranged from 18.48 to 20.43%. Unripe plantain flour had the highest moisture value (20.43%) which is still low when compared to other studies (Idoko and Nwajiaku, 2013; Ketiku, 1973; Asiedu, 1987) that reported a range of 49.40 to 62.0%. Low moisture content enhances keeping quality/shelf-life. The fat content of wheat flour (1.28%) was higher than the plantain flours (0.30% and 0.63%). The fat content of the plantain flour in this study is similar to those reported in other studies (Odenigbo et al*.* 2013; Egbebi and Bademosi, 2011). However, Idoko and Nwajiaku (2013) reported higher values of fat for firm ripe (2.10%) and unripe plantain (2.30%) flour. This difference could be attributed to stage of ripeness, soil and climate condition under which the fruits were planted (Chandler, 1995; Baiyeri and Unadike, 2001).

This study showed that the protein contents of ripe and unripe plantain flours were 3.03 and 2.73%, respectively. This is in agreement with Egbebi and Bademosi (2011) who reported that protein content of ripe and unripe plantain flour varied from 2.18 - 3.15%. Ayodele and Erema (2011) also reported that plantain has low protein and fat contents. The increase in protein content of the plantain flour from unripe (2.73%) to ripe (3.03%) stage could be associated with amino acid uptake and incorporation into protein during fruit ripening (Brady et al*.,* 1970). The crude fibre content of the plantain flours (1.31 and 0.49% for ripe and unripe plantain, respectively) is an indication that when incorporated in human diet would help in lowering serum cholesterol, reduction of risk of heart attack, colon cancer, obesity, blood pressure, appendicitis and many other diseases as reported by Rehinan et al. (2004). The ash contents of both ripe (2.33%) and unripe plantain (2.11%) flours reported in this study are comparable with the work of

Odenigbo et al. (2013). Ash contents are indication of minerals that are contained in the flours. The carbohydrate content of the flours ranges from 72.87 - 74.56%, with ripe plantain having the highest value (74.56%). Carbohydrate is a source of energy for human daily activities.

The moisture content of the 100% wheat cakes was significantly lower than the composite cakes except $URP_{25}W_{75}$ cake. This could be due to the ability of the plantain flours to absorb more water than the wheat flour as shown in Table 1. Protein content of the cakes ranged from 18.91 - 26.41%. This shows that 100 g of the cake can provide more than one-third of recommended daily protein intake (IOM, 2005) of a healthy adult when consumed The protein content of the plantain base cakes increased with addition of wheat flour. This could be due to additive effect of wheat flour as it contains more protein than the plantain flour (Table 2). The fibre and fat content of the cakes varied between 0.36 – 9.44% and 4.23 – 12.32%, respectively with $URP_{25}W_{75}$ cake having the highest fibre and ash contents. The health benefits of fibre are enormous (Rehinan et al., 2004). The cakes had appreciable ash content which ranged from 2.81 – 9.56%. The plantain base cakes had more carbohydrate content than the 100% wheat cake. This is quite understandable as plantain flour had higher carbohydrate content than the wheat flour (Table 2).

The composite cakes contain significantly higher vitamins (pro-vitamin A, vitamin C, B_1, B_2 and folate) than 100% wheat cake. This demonstrates the beneficial effect of blending food in food product development. The result agrees with Akubor (2005) that nutritional enhancement is the advantage in the use of composite food products. The calcium and iron contents of cakes made from the composite flour varied from 449 – 454 mg and 9.84 – 12.39 mg, respectively. Calcium is essential for proper bone and teeth formation (Wardlaw and Kessel, 2002). The potassium, magnesium and zinc composition (mg/100g) of the composite cakes ranged from 1012 – 2310, 262 – 314 and 6.02 – 9.97, respectively. These minerals are quite beneficial to human health; potassium is crucial to heart function and plays a key role in skeletal and smooth muscle contraction, making it important for normal digestive and muscular function (Wardlaw and Kessel, 2002). Magnesium is an essential constituent of all cells and is necessary for the functioning of enzymes involved in energy utilization and it is present in the bone (ADA, 2002). Zinc is needed for the body's defensive (immune) system to properly work (Wardlaw and Kessel, 2002). It plays a role in cell division, cell growth, wound healing, and the breakdown of carbohydrates. The high mineral composition of the cakes shows that it might help to mitigate some mineral deficiencies.

The evaluated sensory attributes of 100% wheat cake are similar to the plantain base cakes up to 50:50 flour substitution levels. Cakes prepared from 25:75 and 50:50 plantain: wheat flour ratios were rated higher in appearance and overall acceptability than the 75:25 plantain: wheat flour cakes. This is because cakes made from 75% plantain and 25% wheat flour had dull colour, as a result of the activity of phenolase on the plantain during processing (Perez-Sira, 1997). However, colour and oxidative stability of plantain flour could be enhanced by blanching slices in 1.25% $NaHSO_3$ solution (Mepba et al., 2007).

Conclusion

Ripening affects the functional and nutritional properties of plantain flour as well as its products. Acceptable cakes can be produced using plantain: wheat composite flours up to 50:50 substitutions without adversely affecting the sensory quality. Cakes produced from these flour blends can serve as functional foods especially for hypertensive, diabetic and obese patients considering their high protein, magnesium, potassium, and relative high fibre content.

Conflict of Interests

The authors have not declared any conflict of interests.

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