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African Journal of Food Science

Review

A review of main factors affecting palm oil acidity within the smallholder oil palm (*Elaeis guineensis* Jacq.) sector in Cameroon

Likeng-Li-Ngue Benoit Constant[1,2], Ntsomboh-Ntsefong Godswill[1,2], Ngando-Ebongue Georges Frank[2], Ngalle-Bille Hermine[1], Nyouma Achille[1] and Bell Joseph Martin[1]*

[1]Laboratory of Genetics and Plant Improvement, Department of Plant Biology, University of Yaounde 1, Yaounde, Cameroon.
[2]Lipids Analysis Laboratory, IRAD Specialized Centre for Oil Palm Research of La Dibamba, Douala, Cameroon.

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Crude palm oil from the mesocarp of *Elaeis guineensis* Jacq fruits is one of the most consumed vegetable oil in the world. The quality of palm oil assessed mainly by its free fatty acids (FFA) content and impurities, varies between the artisanal and industrial extraction and supply systems. The objective of this paper is to highlight the main parameters that influence the acidity or FFA content of crude palm oil produced by the smallholder artisanal sector. Three parameters examined are: crude palm oil production and extraction methods, microbial activity and oil palm genotype. These three parameters strongly increase lipase activity and hence palm oil acidity. In addition to endogenous lipase in fruit mesocarp, microorganisms found in palm oil are also involved in lipase activity e.g. *Aspergillus* sp, *Mucor* sp, *Penicillium* and *Candida* for fungi; and bacteria such as *Bacillus*, *Pseudomonas*, *Micrococcus, Staphylococcus* and *Enterobacter*. To improve the quality of palm oil, smallholders must first seek oil palm progenies with low acidity oil and respect the standard cultural practices for palm oil production.

Key words: *Elaeis guineensis* Jacq, palm oil acidity, microorganisms, production systems, genotype.

INTRODUCTION

Palm oil from the mesocarp of the oil palm (*Elaeis guineensis* Jacq.) fruit is the most produced vegetable oil in the world. Its consumption in 2015 was estimated at 35% (Soystat, 2016). In Cameroon for example, 70% of crude palm oil (CPO) is produced by the industrial sector constituted of major companies while the informal sector (smallholders) produces 30% CPO. Oil from industrial sector, which is acceptable for its dietary quality, is

*Corresponding author. E-mail: josmarbell@yahoo.fr.

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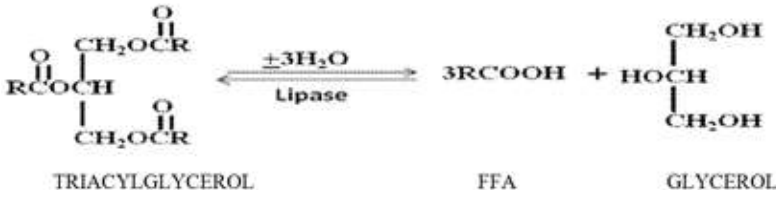

Figure 1. Origin of oil acidity (Patil et al., 2011).

destined for local consumption. Palm oil assures about 90% of locally consumed oil in Cameroon (Hirsch, 1999; Ngando et al., 2013).

Like most vegetable oils, palm oil is mainly composed of triglycerides or triacylglycerols which represent 95% of the total weight constituents. It also contains minor compounds such as diacylglycerol, mono glycerol and free fatty acids (FFA) issued from the biosynthesis and / or hydrolysis of triacylglycerols. Sterol, tocopherol, pigments and metal ions are also represented (Sundram et al., 2003). The majority of fatty acids are palmitic acid followed by oleic acid (Sambanthamurthi et al., 2000; Sundram et al., 2003; Corley and Tinker, 2008; Mancini et al., 2015).

Palm oil quality is usually evaluated on the basis of its acidity (indicator of FFA content) and impurities (Tagoe et al., 2012; De Almeida et al., 2013).

In fact, the FFA content could serve as an indicator for a good harvest and a good method of extraction. Their presence in palm oil indicates the level of oil degradation during the extraction process. If the FFA content is high, this indicates that the fruits were damaged between harvest and extraction or harvested fruits were rotten (De Almeida et al., 2013). High values of acidity due to lipase activity are a reflection of oil quality impairment. Without refining, such oil may be unsuitable for human consumption.

However, refining leads to the loss of palm oil nutritional value. In fact, once released from triglycerides, fatty acids are more susceptible to peroxidation process which breaks the bonds of unsaturated fatty acids and generates aldehydes and ketones responsible for palm oil rancidity. In the presence of water, FFA already present in small amounts act as catalysts in the reaction between the triglyceride and water, generating other FFA. This process occurs in the oil essentially when the water content is greater than 0.1% (Ngando et al., 2013). In oil production process, smallholders do not usually check this aspect.

In addition, oxidation caused by light and temperature is a factor that influences the organoleptic value of the oil by increasing its FFA content. In tropical regions where palm oil is used for domestic purposes, consumers who obtain palm oil from the market are not very concerned about the quality of this oil. Analysis of oil samples from 10 major markets in Douala, Cameroon, showed that oil acidity values of more than 50% of the samples were above 5% (Ngando et al., 2013), which is the maximum limit recommended for dietary CPO. Lipid peroxidation and oil acidity was also reported to increase significantly in CPO samples from none industrial oil mills during the first four weeks of storage making them unfit for consumption (Ngando et al., 2011).

It was also found that CPO contained a wide variation of FFA between 6.49 and 9.44% before storage which increased significantly during the first three months of storage with samples reaching up to 16.50% FFA at 30°C (Goudoum et al., 2015). A study in Nigeria also reported that palm oil acidity varied from 0.97 to 8.43% (Ohimain et al., 2013). The palm oil acidity comes from the hydrolysis of the triglycerides in oil by lipase (Figure 1).

This reaction is enhanced by several factors even though the endogenous lipase activity remains the leading cause of palm oil acidification. Desassis (1957) and De Almeida et al. (2013) showed a significant hydrolytic activity on mesocarp triglycerides of oil palm fruit which are wounded or fallen by abscission during the harvest and fermentation process. In addition, microbial lipase has been identified on palm oil (Morcillo et al., 2013). The FFA content of oil is determined by the analysis of its acidity. Several factors account for the increase of the palm oil acidity and include extraction system especially of the informal sector or smallholder artisanal oil producers (Figure 2); microorganisms present in palm oil (Table 1) and the genotype of oil palm (Table 2). The objective of this review was to highlight the situation of the informal CPO production sector as well as the main factors influencing the acidity of CPO as a contribution towards food safety.

MAJOR FACTORS AFFECTING PALM OIL ACIDITY

Artisanal extraction system

The first main influential factor is the oil extraction system. In this regard, artisanal production of palm oil by smallholders who lack mechanical fruit detaching equipment as in the industrial extraction systems, involves leaving bunches for several days after harvest and before

Figure 2. Some materials used by smallholders for artisanal palm oil production in Cameroon; a: fruits stored for several days; b: boiling of fruits with inappropriate apparatus; c: 'round the world' press and d: motorized press.

oil extraction in order to facilitate the detachment of fruits (Figure 2a). During this process, the lipase activity increases resulting in the hydrolysis of palm oil triglycerides. Before oil extraction, the detached fruits are boiled in drums (inappropriate equipment) using firewood for several hours (Figure 2b). Then the fruits are immediately introduced into the manual continuous screw presses called "round the world" (Figure 2c) or into a motorized press (Figure 2d).

The mixture obtained is boiled in drums containing water. The clarification by heating (using firewood) which removes the last traces of water from the oil is most often incomplete due to energy costs. The residual moisture of artisanal palm oil may reach 0.5% which is the major cause of its rapid acidification during storage (Ngando et al., 2013).

Preliminary studies have shown that palm oil lipase becomes more active in the mature fruits when they are detached or injured; this subsequently increases the acidity value of the palm oil produced (Ngando et al., 2008). By assessing palm oil produced by smallholders, Ngando et al. (2011) found significant differences between the acidity values of oil from smallholders and an industrial company in Cameroon. In addition to that, further studies attribute this significant difference to the long period of fruit storage before the extraction process

Table 1. Some lypolytic microorganisms of palm oil.

Classes	Microorganism	Role	References
Bacteria	*Bacillus* sp. *Pseudomonas* sp. *Staphylococus aureus* *Micrococcus* sp. *Enterobacter* sp.	Production of lipase and amylases Microorganism from contaminate oil	Okechalu et al. (2011), Tagoe et al. (2012), Ohimain et al. (2013)
Fungi	*Mucor* sp. *Aspergillus niger* *Penicillium* sp.	Production of lipolytic enzymes	Khan et al. (2005), Okechalu et al. (2011), Izahet al. (2013), Ohimain et al. (2013), Ezediokpu et al. (2015)
	Candida sp. *Aspergillus fumigatus* *Geotrichum*	Production of lipase	Okechalu et al. (2011), Tagoe et al. (2012), Agu et al. (2013), Izah et al. (2013), Ohimain et al. (2013)

Table 2. FFA contents in the mesocarp of fruits from different oil palm origins and progeny.

Origin	N°	Cross	Acidity (% palmitic acid)
Déli x La Mé	1	LM 2 T x DA 115 D	24.02
	2	LM 2 T x DA 115 D	30.95
	3	PO 3174 D x PO 3349 P	7.3
La Mé	4	PO 3281 T self	27.63
	5	PO 4973 T x PO 4749 P	5.25
	6	PO 4973 T x PO 4749 P	23.29
	7	PO 3281 T	39.6
Déli x YA	8	LM 8102 D x PO 4257 T	24.17
	9	LM 8102 D x PO 4257 T	28.56
Yangambi	10	LM 718 T self	28.67
	11	LM 718 T self	17.36
	12	PO 4257 T x PO 4260T	36.58
	13	PO 4257 T x PO4260 T	46.93

Source: Ngando et al. (2008).

(Tagoe et al., 2012). These authors evaluated the quality of palm oil from the fruits stored at different durations which showed that the acidity value of palm oil increases with the fruit storage time. Moreover, after its production and in order to increase profits, palm oil is often stored to be either consumed or sold during lower production periods. Oil acidity increases during such conservation periods. Gulla and Waghray (2011) showed that, the storage time influences FFA content of oil. Moreover, the duration of heat treatment and screen pore sizes were found to influence palm oil extraction yield and quality (Mulindi et al., 2016).

It can be concluded in line with Noviar et al. (2016) that, all activities conducted by humans in the informal palm oil production sector are liable to increase CPO acidity.

Influence of microorganisms on palm oil quality

The second influential factor is the action of micro-organisms. The microorganisms present in palm oil constitute a major determinant of increased oil acidity. Microorganisms are minute living things classified as: bacteria, fungi, mold and unicellular algae. They play several roles in human diet. In vegetable oils in general and especially in palm oil, these organisms play a fundamental role in the deterioration of dietary oil quality by increasing lipase activity. It has been reported that

45% of existing lipases are produced by bacteria, 21% by fungi, 18% by animals, 11% by plants and 3% by algae (Patil et al., 2011). An examination of the factors that influence palm oil quality revealed 15 fungi and 14 bacteria in palm oil (Tagoe et al., 2012). Okechalu et al. (2011) also found 11 microorganisms on commercialized palm oil.

These microorganisms secrete lipase during their metabolism, which activates the hydrolysis of palm oil triglycerides and increases FFA content. Lipases catalyze various reactions such as hydrolysis of triglycerides, esterification and transesterification of lipids (Demirbas, 2009; Ridha et al., 2015). Lipolytic activity of fungi like *Aspergillus* sp, *Mucor* sp and *Penicillium* sp has been demonstrated on rotten oil palm spikelets (Khan et al., 2005). The *Aspergillus* genus and *Enterobacter* were also identified in palm oil (Izah et al., 2016). Agu et al. (2013) showed a high lipolytic activity of microorganisms in oil containing soil. The microorganisms identified in this case belonged to the genera *Mucor* sp., *Aspergillus flavus* and *Candida* sp. Moreover, microbial lipase was identified on palm oil (Morcillo et al., 2013) in addition to endogenous lipase of the mesocarp of ripe fruit (Ngando et al., 2006).

Thus, palm oil acidity increases as a function of the microbial load. The presence of yeast in the mesocarp of the oil palm fruit was also demonstrated (Tombs and Stubbs, 1982). Yeasts which belong to the group of fungi secrete digestives enzymes including lipases and proteases. Palm oil acidity varies with the degree of fruit infection by microorganisms (Tombs and Stubbs, 1982). Their frequency in the commercialized palm oil was clearly defined in three markets within Jos Metropolis in Nigeria (Okechalu et al., 2011). The divergence between microorganisms and their variability could be explained by the diversity of the mode of production of marketed CPO.

These microorganisms are mostly present in the environment and are found in palm oil due to contamination by poor conditions prior to oil extraction which is common in the case of Cameroonian small-holder sector. The contamination could come from water and soil (Table 1, Figure 2). In general, palm oil producers do not take these parameters into consideration. They mostly use contaminated material (Figure 2). The lipolytic action can also occur when the fruit is bruised, releasing 8 to 10% of FFA within 40 minutes (Ekwenye, 2006).

Influence of palm genotype on oil acidity

Thirdly, the genotype of oil palm also determines the quality of oil it produces with regards to its acidity value. Palm oil acidity comes from the hydrolysis of palm oil triglycerides by active lipase present in the mesocarp of oil palm fruits at maturity (Ngando et al., 2006). This hydrolysis releases FFA in the palm oil. Lipases belong to the proteins group, derived from DNA by transcription and translation mechanisms. Since DNA depends on plant genome, it appears that palm oil acidity depends on the plant's genome. Analysis of palm oil acidity of some 11 oil palm progenies has shown that this trait is transmitted with the dominance of high acidity (Likeng et al., 2016). Other studies showed that palm oil acidity varies with respect to palm genotype or geographic origins (Table 2) and oil palm progenies (Ngando et al., 2008).

All progenies in Table 2 are used for seed production at the oil palm Specialized Research Centre of La Dibamba (Douala-Cameroon), which provides commercial seeds to producers. The study of palm oil acidity of individual palms have shown a great variability between the progenies on the one hand and within each progeny on the other hand. Likeng et al. (2016) working on the genetic determinism of palm oil acidity obtained only 4 out of 11 progenies (analyzing oil derived from between 17 and 32 individuals per progeny) with 100% high acidity. This could be due to the fact that the palm oil acidity (POA) gene being dominant (whatever the type of cross), results either in a high-acid homogeneity or heterogeneous progeny. The work of Likeng et al. (2016) suggested that the gene responsible for the acidity of palm oil is monogenic with strong dominant acidity and that a progeny is homogeneous with high acidity, if at least one of the crossed parents exhibits high acidity. Guedes (2014) reported that there is variability of fruit acidity of *Jabuticaba* (*Myrciaria jabuticaba*, Myrtaceae) progeny grown in a tropical climate.

León et al. (2004) also showed the influence of crossing type on FFA composition. All these observations highlight the possible heritability of fruit acidity in general and that of palm oil in particular, as confirmed by several studies (Iwanami et al., 2012; Morcillo et al., 2013; Likeng et al., 2016).

CONCLUSION

It can be reiterated from this and other studies that the acidity of palm oil is affected by several factors, the major ones being extraction procedures, presence of microorganisms and genotype of the palm tree. Since high acidity oil is unfit for human consumption, the production of hybrid seeds with low acidity remains the ideal approach to enhance this product thanks to the knowledge on heritability of the acidity trait.

To achieve this, a study of the acidity of individual genitors used for commercial seed production is imperative since such palm trees could be used in hybridization towards the production of better quality oil. In this light, a study to identify the low palm oil acidity genitors of La Dibamba germplasm underway is already revealing promising preliminary results.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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Full Length Research Paper

Evaluation of impact of some extrusion process variables on chemical, functional and sensory properties of complimentary food from blends of finger millet, soybean and carrot

Boru Asefa[1*] and Eneyew Tadese Melaku[2]

[1]Department of Food Technology and Process Engineering, College of Engineering and Technology, Wollega University, Ethiopia.
[2]Food Science and Applied Nutrition, School of Biological and Chemical Science and Technology (BCST), Addis Ababa Science and Technology, Addis Ababa, Ethiopia.

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Complimentary food is other food in addition to breast milk. The objective of this work was to evaluate the impact of extrusion cooking screw speed (300, 350 and 400 rpm) and barrel temperature (150, 160, and 170°C) variation on chemical, functional and sensory values of complimentary food made of finger millet in soy bean ratio of 80, 85 and 90% and carrot juice. The incorporation of carrot juice was realized through inbuilt piston type pump to the extruder barrel to maintain the dough moisture at 18% throughout the extrusion process. Proximate compositions were analysed following AOAC procedures. Crude protein was 12.295, 11.623 and 9.984%, oil was 4.927, 3.278 and 3.25%, and carbohydrate was 69.53, 72.14 and 72.98% for the blend ratios of 80, 85 and 90%, respectively, and they were significantly (P<0.01) different with blend ratio variation. Beta-carotene content of the extrudates did not significantly change with extrusion process parameters. The functional properties (water solubility and water absorption indexes) were significantly influenced by barrel temperature and blend ratio (P<0.05). The sensory evaluation of the selected extrudate was performed in seven hedonic scale on quality attributes of aroma, taste, mouth feel, color and overall acceptability. The gruel extruded from 85% finger millet and 15% soybean flour blend, extruded at 150ºC barrel temperature and 350 rpm screw speed was selected with superior organoleptic quality.

Key words: Complimentary food, carrot, finger millet, soybean, extrusion cooking, functional properties.

INTRODUCTION

The level of under-nutrition among children remains unacceptable throughout the world, with large number of children living in developing world with low income (Happiness et al., 2011). The problems of malnutrition, manifested by stunted growth, underweight and waste of infants and children, is related to the demographic, geographic and socio-economic dimensions in which infants and children live. In Ethiopia, for example, over 472,000 children die each year before their fifth birthdays, and the country ranks sixth in the world in terms of the absolute number of children deaths (UNICEF – Ethiopia, 2010). Malnutrition in children results from the interaction

between poor diet and disease and leads to most of anthropometric deficits observed among children in Ethiopia and the level of malnutrition is significantly with nearly one in two (47%) Ethiopian children under five years of age stunted (short for their age), 11% wasted (thin for their height) and 38% underweight (Temesgen, 2013).

The most important nutrition problems documented in Ethiopia are protein energy malnutrition and micro-nutrients deficiency (zinc, iron, vitamin A, and vitamin C deficiencies) (Temesgen, 2013). Consumption of cereal-legumes-vegetable extrudate by infants at complementary feeding age is not common in Ethiopian complementary feeding practices. In addition, the usual practice may result in a complementary food that is not energy dense as the starchy and protein polymers may not be well converted into their breakdown products. The usual homemade complimentary food results in high water uptake and little solid content which reduces the quantity and quality of micro and macro nutrient availability.

Fortified nutritious commercial complementary foods are rarely available especially in the rural areas and where available, they are often too expensive and beyond the reach of most of the families (Happiness et al., 2010).

Abiodun et al. (2012) showed that cereal-legume blends are relatively high in protein (both quality and quantity) and energy because the legumes supply the lysine lacking in cereal and the cereals provide cysteine and methionine which are low in legumes.

In this study, finger millet (cereal), soy bean (legume) and carrot (vegetable) are selected for cooking extrusion process. In cooking, extrusion process polymers like starch, proteins, and dietary fibbers are modified and the functional properties of the product improved because of high temperature and pressure, mixing, shearing, and puffing within short time (Guy and Horne, 1988).

Therefore, in this work, the selected raw materials were locally available and the extrusion cooking process well modifies the macromolecules and improves the functional properties of the complimentary food.

MATERIALS AND METHODS

Sample preparation

Finger millet (black local variety), soy bean and carrot were purchased from Bahir Dar open market. The finger millet was cleaned (THE ALVAN BLACH, 3SW/2M), milled to 700 µm (Fellows, 2000) particle size by hammer mill (THE ALVAN BLACH, 212/10E), packaged in plastic bags and stored for mixing prior to extrusion. The soy bean was decorticated and cleaned (The Alvan Blach, 3SX/3M), and the bran and impurities separated by the grain and pulse sifter blower (THE ALVAN BLACH, 3SW/2M). The cleaned decorticated bean was milled and packaged in plastic bags and stored for mixing similarly. Fresh carrot was purchased, washed, pealed by vegetable peeler (H-BIAUGEAUD, A302) and crushed in cutter-mixer (H.BIAUGEAUD, R23). The crushed carrots were pressed by hydraulic extractor to get clear juice (Cammire, 1991).

Finger millet flour in soy bean flour 80 (80% finger millet flour and 20% soybean flour), 85 (85% finger millet flour and 15% soybean flour) and 90% (90% finger millet flour and 10% soybean flour), were mixed using universal mixer (T1387) before extrusion process. The extrusion process was conducted according to full factorial split plot design with three factors and three levels. The maximum proportion of soy bean selected was 20% and the minimum was 10% according to Aceites (2000).

Extrusion process

The extrusion process was conducted by co-rotating twin screw extruder (Clextral, BC-21 N0 194, Firminy, France). The barrel has 25 mm diameter screws with 300 mm useful length and compression ratio of 1:2.9 driven by screw motor type AC ABB. The mixed flour was alternatively fed into the extruder inlet by volumetric feeder type KMV-KT20. The carrot juice was injected into the extruder by positive displacement pump (type Clextral DKM). At the end of the extruder, a die plate with a circular hole of 9.7 mm diameter was fixed. The temperature of the three zones of the extruder was controlled by Eurotherm controller (Eurotherm Ltd. Worthing, UK) on separate control panel board.

The dough moisture was kept constant at 18% according to Iwe and Ngoddy (1998). The amount of carrot juice required to be pumped was calculated according to Golob et al. (2002). As the dough appeared at the die, the barrel temperature was adjusted to 150, 160, and 170°C and the screw speed was also adjusted to 300, 350 and 400 rpm. The residence time was measured using stopwatch and food colorant (FD&C Red # 40) and recorded to be 34, 30 and 28 s at 300, 350 and 400 rpm, respectively. The extrudate was placed on aluminium foil coved table at room temperature for drying for one hour and milled by the hammer mill. The extrudate flour was vacuum packed (TEPRO, pp5) and stored for further analysis.

Proximate analysis of extrudate

Moisture

Moisture content of samples were determined following AOAC (1990) using the official method 925.09. Cleaned crucible was dried in an oven at 105°C for 1 h and placed in a desiccator to cool.

Crude oil

The oil content of the flours was determined according to AOAC official method 4.5.01 (AOAC, 1990). The extraction was carried out

*Corresponding author. E-mail: boru251@gmail.com.

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by using Soxhlet using N-hexane for about 4 to 6 h (AOAC, 1990).

Crude protein

Total nitrogen of the samples was determined according to AOAC (1990). Micro Kjeldahl method was used to determine crude protein.

Ash

A clean and dry porcelain dish containing 5 g sample was placed in a muffle furnace (thermolyne, 48000 furnaces) set at 800°C for 8 h and then cooled in a desicator and weighed, and the ash content was determined according to AOAC (1990).

Crude fiber

Crude fiber was determined by Walker (1990) method, about 1.5 g sample was place in ash less capsules and treated with 1.25% H_2S0_4 and 1.25% NaOH alternatively under reflux (Fibertec system FOSS-2023) for 30 min. The treated samples were dried and socked in acetone for 3 min, rinsed with distilled water and placed in an air drying oven (STATUIC Scientific, UK) at 105°C for 3 h before incinerating subsequently in a muffle furnace (thermolyne, 48000 furnaces) at 550°C for 2 h.

Carbohydrate

Carbohydrate contents of the flours blend ratio and their extrudates were calculated by Saskia and Martin (2008) method.

Carbohydrates (%) = 100 − (% moisture + % protein + % fat + % ash + % crude fiber)

Calcium, iron and zinc

The measurement of these minerals was conducted according to Olapade and Aworh (2012). Extrudate flour samples (ca. 2 g) were ashed at 800°C for 5 h in a muffle furnace (thermolyne, 48000 furnaces). The ashed samples were dissolved in 2% HCl and diluted to 50 mL with distilled deionized water. The concentrations of zinc, iron and calcium were determined from an aliquot using Inductively Coupled Plasma/Optical Emission Spectrometry (ICP-Spectroscopy: ultima-2).

Beta carotene

The determination of β-carotene was carried out according to AOAC (1995) method. A conical flask containing 50 ml of 95% ethanol,10 g of the extrudate flour sample was placed and maintained at temperature of 70-80°C in a shaking water bath (DKZ-series shaking water bath) for 20 min with periodic stirring. The supernatant was decanted, allowed to cool and its volume was measured by means of a measuring cylinder and recorded as initial volume.

The final extract was transferred to 50 ml beaker for absorbance measurement. The absorbance was measured using spectro-photometer (JENWAY 63000) at wavelength of 436 nm. A glass cuvette containing pet-ether (blank) was used to calibrate the spectrophotometer to zero point. Samples of each extract were placed in cuvettes and readings were taken.

Determination of functional properties of extrudates

Water absorption index

Water absorption index of the flour and extruded products were determined (Anderson, 1982). Sample (about 1.25 g) was placed in about 40 ml centrifuge tube and suspended in 15 ml distilled water. The sample was incubated by using a shaker (DKZ-series shaking water bath) at about 25°C for 30 min and was centrifuged at 3000g for 5 min (L-530 table top low speed centrifuge). Mass of the sample was determined before and after the decantation of the clear supernatant of centrifugation. The WAI was calculated as grams of absorbed water per gram of dry sample mass (1.25 g). The clear supernatant of the centrifugation was transferred into pre-dried (105°C) and weighed glass beaker (about 50 ml) for the estimation of the water solubility index (WSI).

Water solubility index

The supernatant preserved from WAI measurement was evaporated at 105°C in air drying oven (STATUIC Scientific, UK) for overnight. The WSI was calculated as a ratio of dry residue to the original mass (about 1.25 g) used to estimate WAI and the result was expressed as percentage.

Sensory evaluation of the products

For sensory analysis, among all six samples selected based on correlation between the factors and responses (proximate analysis results and functional property), result show significant difference at $p<0.05$ and $p<0.01$ using SPSS-20 output values (Table 2). The sensory evaluation was carried out on quality attributes of aroma, taste, mouth feel, colour and overall acceptability based on a 7 point hedonic scale as described by Iwe and Onuh (1992).

Statistical analysis

The data obtained from proximate compositions and functional properties were statistically analyzed using SPSS version-20. The correlation effect between sample treatments and the indices were done using analysis of variance (ANOVA) with a probability of $p< 0.05$.

RESULTS AND DISCUSSION

The data of the correlations between the independent and dependant variables were analysed based on the ANOVA output data of the SPSS version 20 software conducted. All the mean values of nutritional composition are shown in Table 1.

Effect of process parameters on nutritional quality crude protein and ash

The protein content of the product was highly significant

Table 1. The mean proximate compositions and functional properties.

Parameter	Mean ± SD
Protein (%)	11.3±1.26
Ash (%)	3.572±0.19
Oil (%)	3.819±1.09
Moisture (%)	8.694±0.55
Fiber (%)	1.066±0.48
Viscosity (cp)	65.332±13.12
Ca (mg/100 g)	222.366±105.36
WSI (%	18.277±3.96
WAI	4.849±0.56
β-Carotene (µg/100 g)	0.75±0.30
Carbohydrate (%)	71.55±1.93
Fe (mg/100 g)	2.764±0.75
Zn (mg/100 g)	.793±0.32

SD, Standard deviation.

Table 2. The correlation matrix between the independents (BR, temperature and SS) and the dependants (protein % and ash %) variables.

Variables	Correlation	Protein (%)	Ash (%)
BR	Pearson correlation	-0.751**	-0.116
	Sig. (2-tailed)	0.000	0.304
Temperature	Pearson correlation	-0.060	-0.110
	Sig. (2-tailed)	0.595	0.328
SS	Pearson correlation	0.099	0.075
	Sig. (2-tailed)	0.378	0.506

******Correlation is significant at the 0.01 level (2-tailed); *****correlation is significant at the 0.05 level (2-tailed).

Table 3. The raw materials compositions.

Finger millet in soy bean (%)	Moisture content (%)	Protein (%)	Oil (%)	Ash (%)
100	9.980±0.089	6.315±0.119	1.953±0.112	3.684±0.025
90	8.694±0.272	8.949±0.272	3.363±0.305	3.803±0.020
85	8.460±0.763	11.606±0.168	3.896±0.235	3.768±0.100
80	7.430±0.552	13.386±0.307	4.769±0.111	3.850±0.090
0	5.590±0.038	38.5±0.208	18.23±0.321	3.5±0.021
Carrot juice	92.475±0.024	0.704±0.006	-	0.850±0.012

with blend ratio variation at $p < 0.01$ as indicated in Table 2.

Additionally, Table 3 indicates the manner how the variation is significant as the proportion of the soy bean flour (unextruded) decreased from 20 to 10%, the mean value of the protein changed from 12.2951 to 9.9839%. The enhancement of the crude protein was attained through blending the finger millet flour with soy flour; consequently, the recommended daily allowance of protein can be attained through blending cereal with legume and it is similar to Olapade and Aworh (2012) investigation. The recommended daily allowance (RDA) of protein from FAO/WHO/UNU (2004) table is 1.18 g/kg/day for children from 6 month to 1 year old and the

Table 4. Blend ratio with protein and ash content.

BR		Protein (%)	Ash (%)
80	Mean±SD	12.30±0.7	3.5919±0.166
85	Mean±SD	11.63±0.97	3.5841±0.083
90	Mean±SD	9.984±0.74	3.5394±0.267

SD, Standard deviation.

Table 5. Correlation between the independent (BR, temperature and SS) and the dependant variables (oil and moisture).

Variable		Oil (%)	Moisture (%)
BR	Pearson correlation	-0.633**	0.301**
	Sig. (2-tailed)	0.000	0.006
Temperature	Pearson correlation	-0.252*	0.352**
	Sig. (2-tailed)	0.023	0.001
SS	Pearson correlation	-0.065	-0.110
	Sig. (2-tailed)	0.561	0.327

**Correlation is significant at the 0.01 level (2-tailed) and *correlation is significant at the 0.05 level (2-tailed).

mean value of crude protein% from this study result was 11.3006% from Table 4. The correlation between the blend ratio and total ash content was not significantly different. Olapade and Aworh (2012) confirmed that extrusion of the blends of fanio and cowpea flour had no change with blend ratio.

The temperature and screw speed variation had no significant effect on both the crude protein and total ash. The result agreed with Abiodun et al. (2012) report on acha and cowpea mixture extrusion and observed that temperature and screw speed variation had no impact on protein and mineral content.

Effect of blend ratio on extrudate oil content

The oil content of the extrudate increased as the proportion of the soy bean flour increased which was highly significant at 0.01 levels shown in the following table (Table 5). The incorporation of oil is important as it is one of the essential macro nutrients to increase the energy density of the product. The mean values of oil for extrudate from 80% finger millet oil content was 4.9274%, 85% finger millet the oil content was 3.2784%, and 90% finger millet had 3.2499% oil. The daily intake of fat (FAO/WHO/UNU, 2004) table is 4.0 to 9.0 gm/kg/day and it is to the required standard.

Oil content against temperature was significant at $p<0.05$ and the correlation was negative, that is, as the extrusion temperature increase the oil content of the product decreased. This is because as the product emerges from the die (the tip of extruder) the short chain fatty acids vaporised as volatile components so that reduction of total oil content increased as the cooking extrusion temperature increased from 150, 160 to 170°C. Alvarez et al. (1990) revealed that reduction of lipid oxidation in twin-screw extruder as the temperature measured at the die increased, consequently, the stability of the remaining oil improved.

From Table 5, moisture of the extrudate was significant at $P<0.01$with BR. The reason behind this was the extrudate puffed very well as the carbohydrate content increased consequently releasing much water at the exit following this, when the extrudate dries at room temperature, the porous structure absorbs more moisture than released at the edge of extruder barrel.

The effect of blend ratio variation had significant impact on carbohydrate content as presented in Table 6 at $P<0.01$. As the proportions of soy bean flour increase, the carbohydrate % decreased and directly proportional to the finger millet flour increment. Carbohydrate was not significant against temperature and screw speed variation.

This study result on beta carotene content enhancement shows one step improvement towards raising the pro-vitamin A content of the developed complimentary food by bio-fortification through pumping carrot juice into the barrel instead of water.

Minerals (zinc, iron and calcium)

Iron and calcium contents of the extrudates were not influenced by BR, screw speed and barrel temperature.

Table 6. Raw materials crude fibre and carbohydrate percentage.

Finger millet in soy bean (%)	Fiber (%)	Carbohydrate (%)
100	0.855±0.025	77.213±1.236
90	1.126±0.011	74.065±1.86
85	1.153±0.110	71.117±1.56
80	1.336±0.006	69.229±1.025
Soy bean flour	0.848±0.012	31.600±1.235

Table 7. the correlation between the independents and dependent variables (viscosity, WAI and WSI).

Variables	Correlation	Viscosity (cp)	WAI	WSI (%)
BR	Pearson correlation	0.095	0.443**	-0.280*
	Sig. (2-tailed)	0.401	0.000	0.011
Temperature	Pearson correlation	0.185	-0.144	-0.238*
	Sig. (2-tailed)	0.097	0.199	0.033
SS	Pearson correlation	-0.213	-0.055	0.127
	Sig. (2-tailed)	0.056	0.623	0.260

**Correlation is significant at the 0.01 level (2-tailed) and *correlation is significant at the 0.05 level (2-tailed).

Iron and zinc were among the micro-minerals required in a minute amounts. The recommended daily allowance is 1.1-2 and 2-3 mg/kg/day for zinc and iron, respectively (FAO/WHO/UNU, 2004), for infants.

Zinc content was not significantly affected by temperature in addition to BR variation but significantly affect screw speed variation. The relation between the zinc content and screw speed was inversely proportional. The result disagreed with Muhammad et al. (2012) investigation report which states that extrusion screw speed variation did not have intensive impact on mineral composition.

The calcium content of the extrudate flour was not significant with blend ratio, barrel temperature, and screw speed. Since the dominant proportion of the raw materials was finger millet, the soy bean flour contributes to the composition of calcium, with insignificant degree of variation.

Functional properties of extrudates

The result (Table 7) of this study agrees with Onyango et al. (2004) which stated that the viscosity of 9-10 g/100 g flour suspension was 350 to 400 cp and the energy density was 0.2-0.3 kcal/g and the value was below the required energy density. The viscosity of the extrudate for 85% was 75.0407 cp and its energy density according to Onyango et al. (2004) was 0.85 kcal/g and the minimum energy density required by complimentary food was 0.8 kcal/g (WHO/UNICEF, 1998).

Water solubility index (WSI)

This study indicate (Table 7) that WSI was significant at $P<0.05$ with blend ratio and temperature and not significant with screw speed. Water solubility index (WSI) was a measure of starch degradation; it means that as the WSI increase starch degradation consequently increase soluble molecules in the extrudates. The finger millet was milled whole (with bran); consequently, the WSI decreased and agrees with Badrie and Mellowes (1992) report. Water solubility index was significantly influenced by temperature at 0.05 level; the three temperatures are stated in Table 7.

Water absorption index (WAI)

WAI is an indicator of the ability of flour to absorb water, depends on the availability of hydrophilic groups which bind water molecules and on the gel-forming capacity of macromolecules (Hoseney, et al., 1992). The correlation indicates that WAI was highly significant with blend ratio at $P<0.01$ level as indicated in Table 7. The value of the WAI varies from 4.5954 g of water/gram of sample at80% finger millet, 4.75 g/g at 85% finger millet, to 5.202 g/g at

Table 8. The mean value of sensory characteristics scored by the panellists and assigned ranks

Products	Aroma	Rank	Taste	Rank	Mouth feel	Rank	Color	Rank	Overall acceptability	Rank
80 160 350	5.2±0.45	3	5.4±0.89	3	5.4±1.52	2	5.6±2.19	1	5.8±1.3	2
85 150 300	5.2±0.84	3	4.8±0.84	4	4.4±0.55	5	3.8±0.84	4	5±1.73	4
85 160 300	4.6±1.34	4	4.8±0.84	4	5±1.41	3	3.2±1.3	6	5.4±0.89	3
80 150 350	6±1.22	1	5.6±1.14	2	5±1	3	3.6±0.89	5	4.8±1.64	5
80 160 300	5.8±0.84	2	5.8±0.84	1	4.8±1.1	4	4.4±1.14	3	5±1.87	4
85 150 350	5.8±0.84	2	5.8±1.3	1	5.6±0.55	1	5.2±1.3	2	6.6±0.55	1

90% finger millet these values progressively increased as the proportion of finger millet increased.

Sensory analysis

Sensory evaluation was conducted by panellists who judge the organoleptic characteristics of the extrudate gruels on the quality attributes of aroma, taste, mouth feel, colour and over all acceptability. The average score recorded by judges was considered and presented in Table 8. According to the result, the higher preference score (rank) given to the product produced at 80:150:350 (80% finger and 20% soy bean flour extruded at 150°C barrel temperature and 350 rpm screw speed) on aroma quality attribute. The aroma of gruels produced at 80:160: 300 and 85:150:350 blend ratio-temperature-screw speed both got the second rank, while the panellists provided the least preference score to both product 80:160:350 and 85:150:300 blend ratio-temperature-screw speed. This indicated that aroma was more influenced by screw speed and extrusion temperature variation than blend ratio variation as evident in the second and third rank, was given to the same blend ratio and temperature but different screw speed (85:150:350 and 85:150:300).

Table 8 clearly shows that the highest preference score (1) given by the panellists for taste organoleptic characteristics was for gruels extruded at 80 160 300 and 85 150 300. The least rank (4) was given to 85 150 300 and 85 160 300 products. The rank provided indicated that taste is influenced by blend ratio and temperature. This may be due to sugar content variation between the blends and carmalization of sugar at different temperature within the same blend ratio which affects the taste of the gruel. The panellist's judgment result presented (Table 8) showed for overall acceptability quality attribute, the superior preference score (1) was given to 85 150 350 and the least rank (5) was assigned to gruel produced at 80 150 350.

Among six gruels, the extrudate from 85% finger millet at 150°C and 350 rpm screw speed given the highest preference score (1) for three quality attributes (taste, mouth feel and over all acceptability) and got the second rank (2) for two quality characteristics (aroma and colour). Therefore, the gruel produced from extrudates of 85% finger millet and 15% soy bean at 150°C and 350 rpm screw speed was selected to be the best product and the process parameters (blend ratio, barrel temperature and screw speed) taken as the optimum parameters for commercialization purpose.

Conclusion

In this study, the potential to develop nutritious compli-mentary food from cereal-legume-vegetable combination based and locally available raw materials by cooking extrusion process was observed. The variation of the blend ratios of both the finger millet (80, 85 and 90%) and soy bean (20, 15 and 10%) resulted in improvement of macro (protein, oil and carbohydrate) and micro (calcium, iron, zinc and beta-carotene) nutrients of the extrudates. The addition of soy bean significantly increased the protein and oil content and the incorporation of carrot juice improved the beta-carotene content of the extrudate. Therefore, the developed products become high energy density complimentary food (0.85 kcal/g) to combat the malnutrition problem of infants and children. The cooking extrusion process was performed at three levels of barrel temperatures (150, 160 and 170°C) and three levels of screw speeds (300, 350 and 400rpm). Cooking extrusion process improves the functional properties such as water solubility index, viscosity and water absorption index of the extrudates. The organoleptic evaluation of the product was also influenced by variation of blend ratio and process parameters of cooking extruder machine. In conclusion, the product produced from 85% finger millet and 15% soy bean flour at 150°C and 350 rpm was selected to be the best product.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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Full Length Research Paper

Sensory analysis of extruded corn-based breakfast cereals with whole peach palm fruit (*Bactris gasipaes*, kunth) powder

Ivone Lima Santos[1], Caroline Joy Steel[2], Jaime Paiva Lopes Aguiar[3], Marcio Schmiele[2], José Carlos de Sales Ferreira[1] and Francisca das Chagas do Amaral Souza[3*]

[1]Postgraduate Programme in Food Science, Federal University of Amazonas (Universidade Federal do Amazonas, UFAM), Manaus, Amazonas, Brazil.
[2]Department of Food Technology, School of Food Engineering, University of Campinas (UNICAMP), Cidade Universitaria Zeferino Vaz, CEP 13083-862, Campinas, Sao Paulo, Brazil.
[3]Brazilian National Institute for Research in the Amazon, Coordination Society of Environment and Health (CSAS) and Laboratory of Physical Chemistry of Food (LFQA) Av André Araújo 2936, 69067-375, Manaus, AM, Brazil.

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This research work aimed to study the sensory characteristics of corn-based breakfast cereal with whole peach palm fruit (*Bactris gasipaes*, Kunth) powder. Sensory analysis was performed after approval of the local ethics committee (26884014.9.0000.5020) and written consent of the panelists. The samples were offered to 70 untrained panelists in disposable bowls codified with three random digits. The panelists reported how much they liked the product in terms of taste and crispness, their purchase intention, preference, and attitude or intention to consume. The scores given to the product with 25% whole peach palm fruit powder were significantly higher than the scores given to the other two study products, making it commercially viable.

Key words: Peach palm fruit powder, sensory analysis, breakfast cereal.

INTRODUCTION

In the last few years, consumers have shown higher desire for processed products that promote a balanced diet, aggregating nutritional value and bioactive compounds. Bioactive compounds are important to human health and nutrition, especially to prevent diseases, and it has been the focus of much research (Kay et al., 2009; He and Giusti, 2010).

Extruded foods are popular because they are ready-to-eat, crispy, and colorful, and have pleasant shapes (Hirth et al., 2014). However, they are often considered junk food (unhealthy) because of their composition, mainly of carbohydrates (Bolanho et al., 2015).

The extrusion process allows the development of numerous tastes, shapes, colours, and sizes, making

*Corresponding author. E-mail: francisca.souza@inpa.gov.br. Tel: 55929925921025, 559236431964.

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extruded foods attractive to all kinds of consumers (Takeuchi et al., 2005). The addition of fruit powders in snacks and breakfast cereals may improve their nutritional quality and attractiveness. Fruit powders and extracts contain high levels of bioactive components, such as phenolic compounds and carotenoids, among others, making them a source of antioxidants and increasing the organoleptic quality of the products (Camire et al., 2007; Brennan et al., 2011; Potter et al., 2013).

The combination of tastiness and high nutritional value resulted in numerous snacks and processed cereals that are very successful, providing they contain natural ingredients with nuts and fruits (Payne, 2000). Although these products have been available for some decades, they meet the new dietary trends because of their high-energy and high-protein contents, nutritiousness, practicality, and wholesomeness (Souza, and Menezes, 2006).

Peach palm fruit (*Bactris gasipaes*, Kunth) is a fruit native to the Amazon region. Its powder, including all its residues to increase fiber content, can be added to extruded breakfast cereals to increase their nutritional quality and consumption of the fruit, which is usually eaten cooked in the region.

Clement and Mora Urpí (1987) reported that peach palm fruit powder is very similar to cornmeal and can often replace cornmeal, increasing the nutritional quality of a preparation. The fruit is very high in beta-carotene, a highly bioavailable functional component (Rodrigues-Amaya, 1993; Cozzolino and Cominetti, 2013).

Many studies have reported the beneficial effects of certain dietary components to human health. Such components have become known as functional ingredients, and the foods that contain them, functional foods (Hasler, 1998). Functional foods are defined as foods that not only fulfill their basic nutritional functions, but also benefit the body by improving health and reducing the risk of diseases (Berté et al., 2011). Hence, these foods are being sought by consumers who wish to improve their quality of life through diet. Many functional foods originated by combining pharmacology with food technology (Coelho and Wosiacki, 2010).

β-carotene is the predominant pigment in the human macula, and its increased intake has been associated with a lower incidence of eye diseases, such as age-related macular degeneration (AMD), cataracts, and retinitis pigmentosa (Fullmer and Shao, 2001; Ozawa et al., 2012). Recently, frequent and high dietary lutein intake has also been suggested as a means of preventing mild cognitive impairment and Alzheimer's disease in older people (Johnson, 2012; Kiko et al., 2012).

The interest in ingredients rich in dietary fiber (DF) has increased, and the importance of this food component has led to the development of a large market for fiber-rich products and ingredients (Pszczola, 2008). The intake of foods with high DF content has been related to several physiological and metabolic effects: increase of the fecal bulk, provision of a favorable environment for beneficial intestinal microbiota multiplication, and prevention and control of obesity, atherosclerosis, coronary heart diseases, colorectal cancer, and diabetes (Vergara-Valencia et al., 2007).

The determination of the polysaccharide composition of DF (pectin, cellulose, and hemicellulose) is important to understand their physiological function, structure and organization in food products, allowing its planned use in functional foods (Waldron et al., 2003).

Extrusion cooking has been used by the food industry for many years. Ready-to-eat, grain-based food products, such as snacks, breakfast cereals, and pasta, and products with textured soy protein can be extruded (Suknark et al., 2001; Lin and Hsieh, 2002). Breakfast cereals are the precursors of a wide variety of extruded foods that today occupy numerous supermarket shelves (Sardagna et al., 2002)

Sensory analysis investigates people's responses to sensations caused by physiological reactions. Individuals respond to certain stimuli and the interpretation of such responses generates the intrinsic properties of a product. This requires individuals to interact directly with products. The stimulus is measured by physical and chemical processes, and the sensations, by psychological effects. The sensations provoked by a product vary in intensity, extension, duration, quality, and pleasantness (IAL, 2008).

Sensory analysis focuses on the sensory characteristics of a product and determines which product is preferred by a target population. Affective testing, also called consumer testing, can be classified into two categories: Acceptability and preference. The first aims to assess how much consumers like or dislike a given product, and the second, to assess consumer preference between two or more products (Damásio and Silva, 1996; Silva, 1997).

Consumer testing is mainly used for assessing the quality of a product, optimizing a product and/or process, and developing new products. The hedonic scale measures product appeal and consumer preference (Macfie and Thomson, 1994).

Two ready-to-eat corn-based breakfast cereals were developed with different percentages of peach palm fruit powder. The present study investigated the sensory characteristics of the breakfast cereals with whole peach palm fruit (*Bactris gasipaes*, Kunth) powder.

MATERIALS AND METHODS

Processing of breakfast cereals

The development of extruded corn-based breakfast cereals with whole peach palm fruit powder relied on a central composite design with full factorial of 2^2, resulting in 12 runs that defined the optimized formulation points. The optimization provided optimal

PANELIST Nº_____ Date:____/_____/_____Name:_____

1. You are receiving 03 labeled samples of an extruded breakfast cereal with or without peach palm fruit powder. Please try them and rate your general impression of the product using the scale below:

(9) like extremely
(8) like very much
(7) like moderately _____( ) Comments
(6) like slightly
(5) neither liked nor disliked _____( )
(4) dislike slightly
(3) dislike moderately _____( )
(2) dislike very much
(1) dislike extremely

2. Now using the same scale above, try the samples again and rate their taste.

_____( ) Comments
_____( )
_____( )

3. Again, using the same scale above, try the samples again and rate their crispness.

_____( ) Comments
_____( )
_____( )

4. Using the scale below, tell us what you would do if you saw any of the samples for sale. IfI found this product for sale, I:

5. Definitely would buy
4. Probably would buy _____( ) Comments
3. Might buy _____( )
2. Probably would not buy _____( )
1. Definitely would not buy

Form 1. Sensory analysis of a corn-based breakfast cereal with peach palm fruit powder using.

PANELIST Nº_____ Date:____/_____/_____.Name:_____

Paired preference test

You are receiving three labeled samples. Please tell us which one you prefer.

_____ Comments:

Form 2. Sensory analysis of a corn-based breakfast cereal with peach palm fruit powder using a paired preference test.

processing points, which consisted of substituting 25 and 50% (maximum possible) of the cornmeal by peach palm fruit powder. The control cereal did not contain peach palm fruit powder.

The mixture was processed by the double-screw extruder 20DN-GNF 1014/2 (BRABENDER, Germany) with a circular matrix of 2.8 mm and fixed temperature (70-100-130-150°C).Only moisture and peach palm fruit powder content varied.

The breakfast cereals were then sprayed with glucose syrup, dried in an incubator, and packaged in sterile plastic bags.

Sensory analysis

Sensory analysis was performed at the laboratory of the National Institute for Amazon Research (Instituto Nacional de Pesquisa da Amazônia) – INPA. The laboratory has the right conditions for the procedure, such as proper lighting, individual booths, and absence of distractions, such as odours or noises that may influence the panelists' wellbeing and the study results. The researchers instructed the panelists verbally. The sensory analysis stage of the study was approved by the local Research Ethics Committee under protocol number 26884014.9.0000.5020. The study complied with all the regulations established by the National Council of Health/Brazilian Ministry of Health (Brasil, 1997).

The study recruited 70 male and female panelists aged 18 to 60 years. The samples were served in white, disposable bowls labeled with three random digits.

A hedonic scale investigated consumer acceptability of the breakfast cereal, an attitude or a purchase intention scale investigated purchase intention, and a paired preference test investigated consumer preference, as instructed by Instituto Adolfo Lutz (IAL, 2008).

Hedonic scales allow panelists to express their general impression of a product or its attributes. The study used 5-point, 7-point, and 9-point scales.

The panelists used 9-point scales ranging from "like extremely" to "dislike extremely" to report their general impression of a product and how much they liked or disliked its taste and crispness. Five-point scales ranging from "definitely would buy" to "definitely would not buy" investigated purchase intention (Form 1). The data were analyzed by analysis of variance (ANOVA), and the means of each pair of samples were compared by the Tukey test. The graphs were constructed by the software STATISTICA version 5.5 (STATSOFT, USA).

In the paired preference test (Form 2), the panelists received the three samples and chose their favorite.

The attitude or intention scales (Form 3) allow the panelists to express their desire to consume or purchase a product. The

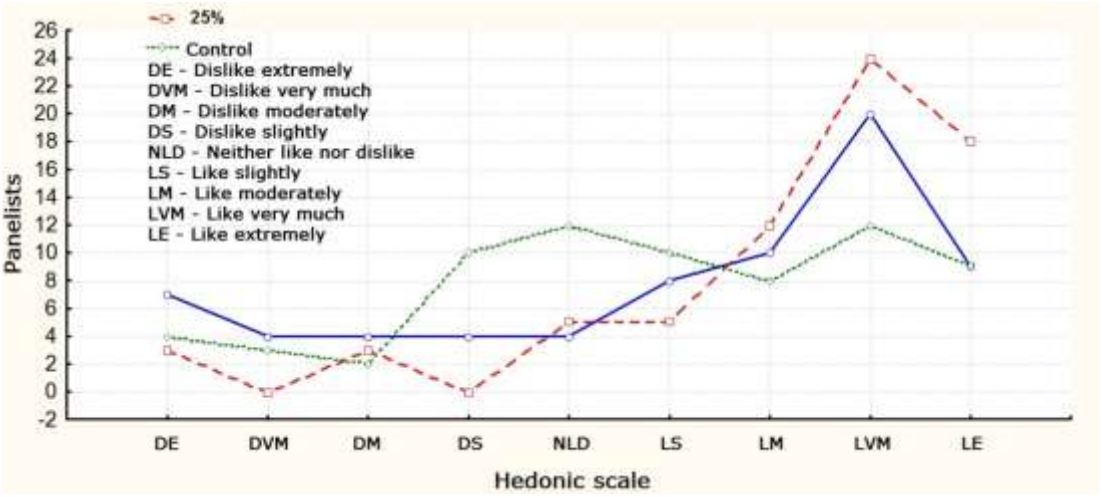
PANELIST Nº_____ Date:____/_____/_____.Name:_____

Consumer testing of intention to consume

You are receiving three labeled samples. Please tell us your intention to consume them using the scale below.

(7) Always consume		
(6) Very frequently consume	_____ ( )	Comments
(5) Frequently consume		
(4) Sometimes consume	_____ ( )	
(3) Rarely consume		
(2) Very rarely consume	_____ ( )	
(1) Never consume		

Form 3. Sensory analysis of a corn-based breakfast cereal with peach palm fruit powder using an intention-to-consume scale.



Graph 1. Distribution of product acceptability.

study used a 7-point scale. The options ranged from “definitely would buy” to “definitely would not buy,” with “might buy” in the middle.

RESULTS AND DISCUSSION

The flours processed from peach palm by-products have high level of non-starch polysaccharides, and consequently, they are important as a source of dietary fiber for inclusion in other foods, such as breakfast cereals or bakery products (Bolanho et al., 2015).

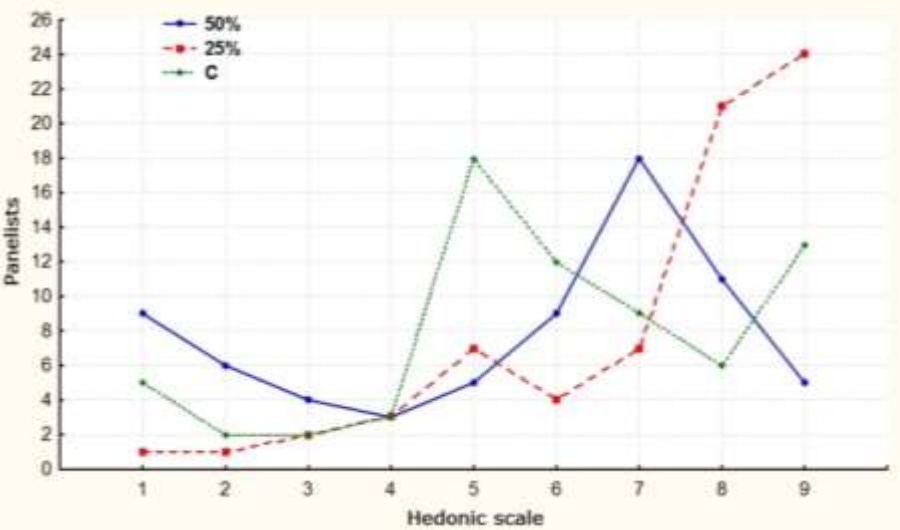
Graphs 1 to 3 show how the panelists’ rated theirgeneral impression, taste, and crispness of three corn-based breakfast cereals, two with added peach palm fruit powder, using a 9-point hedonic scale.

Graph 1 shows that the panelists preferred the sample with 25% peach palm fruit powder, considered the optimal point by the technological analyses. The intervals 8 (like very much) and 9 (like extremely) have the highest frequencies. The sample with 50% peach palm fruit powder was also well accepted, not differing statistically from the sample with 25% peach palm fruit powder.

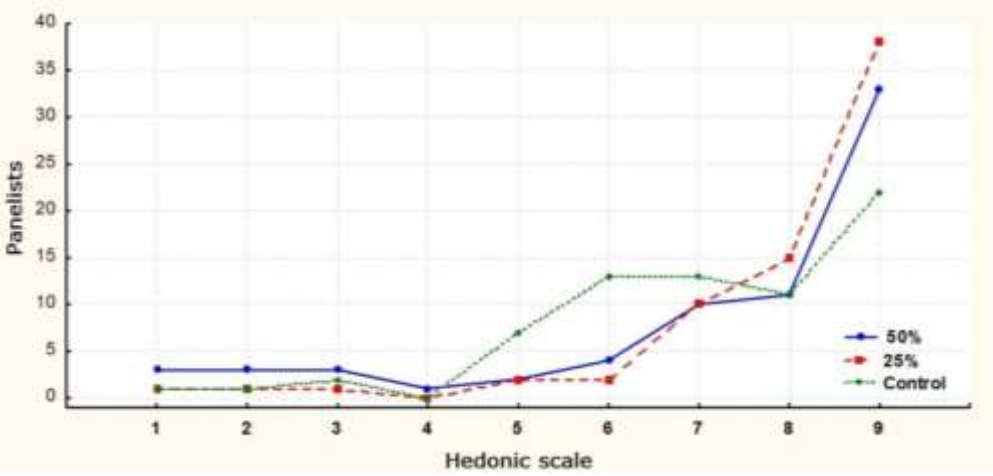
Graph 2 shows that the panelists preferred the taste of the sample with 25% peach palm fruit powder. Again the intervals 8 (like very much) and 9 (like extremely) have the highest frequencies. However, the taste of the sample with 50% peach palm fruit powder was not as appreciated as its general impression, with interval 7 (like moderately) having the highest frequency.

The general impression and taste of the control sample received the lowest scores, with interval 5 (neither like nor dislike) having the highest frequency. According to Food Insight (Food Insight, 2011), taste is the main attribute consumers take into account when purchasing a product.

The crispness of the sample with 25% peach palm fruit powder was also the panelists’ favourite. However, since intervals 1 (dislike extremely) to 5 (neither like nor dislike) of all samples had very low frequencies, the crispness of



Graph 2. Distribution of taste.



Graph 3. Distribution of crispness.

all samples can be considered satisfactory.

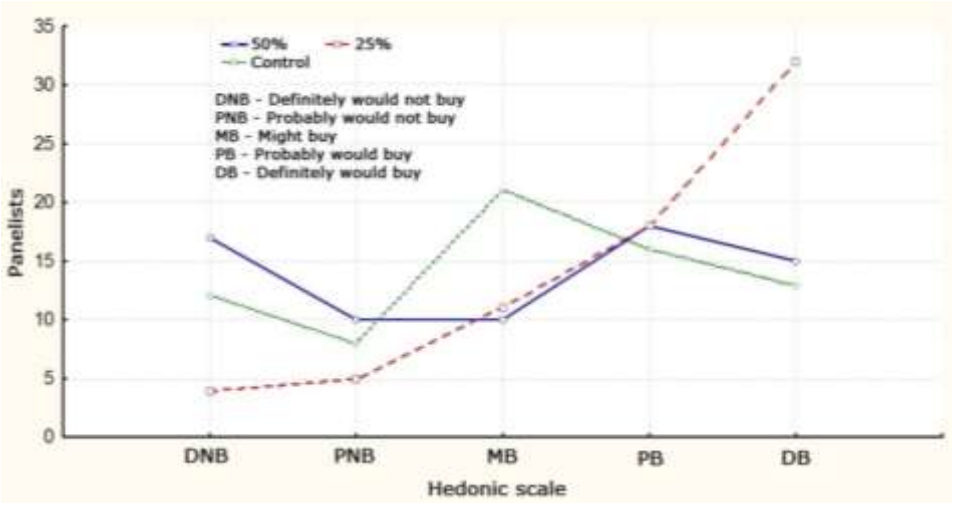
According to Hough et al. (2001), when consumers do not like the texture or crispness of a product, they reject the product, regardless of how much they like other attributes. Even great taste cannot save a soggy product. Most baked or extruded products with low moisture content, such as breakfast cereals, snacks, cookies, and wafers, are crispy. If the moisture content of these products increases due to water absorption from the atmosphere or from different nearby products during transportation, their crispness decreases, making them soggy (Roudaut et al., 1998).

The low acceptability of the control sample is probably due to the higher cornmeal content, which increases expansion. Highly expanded products are more aerated, which decreases their hardness. The sample with 50% whole peach palm fruit powder had the highest fiber content, making it the hardest sample because fiber increases hardness (Gularte et al., 2012). The sample with 25% whole peach palm fruit powder had intermediate fiber content, thus, intermediate hardness and higher crispness.

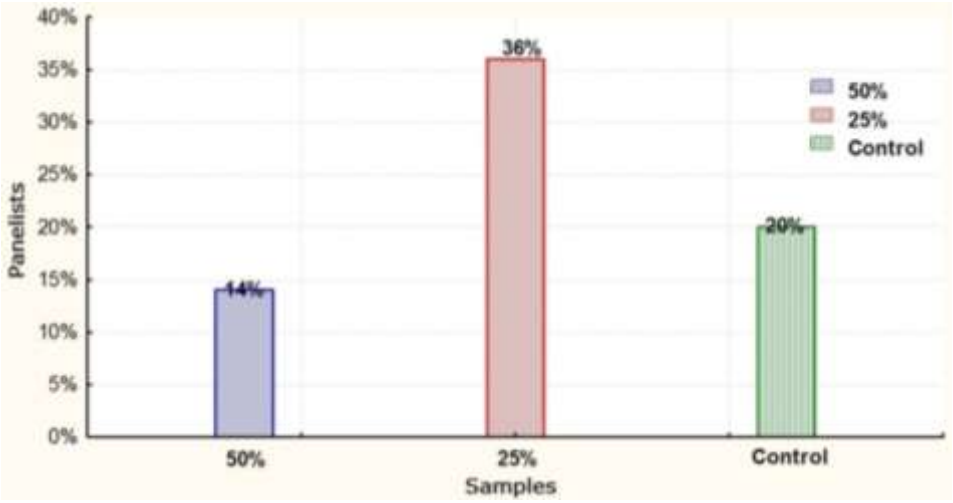
Avoiding the loss of crispness is of great interest to the food industry because crispness is associated with freshness and quality, and consumers reject soggy products (Souza and Menezes, 2006).

Graph 4 shows that the sample with 25% peach palm fruit powder had the highest purchase intention, with interval 5 (definitely would buy) having the highest frequency. This result confirms the other results that indicated the superiority of this sample: best general impression, taste, and crispness.

The control sample had the lowest purchase intention, with interval 3 (might buy) having the highest frequency,



Graph 4. Distribution of purchase intention.



Graph 5. Distribution of consumer preference.

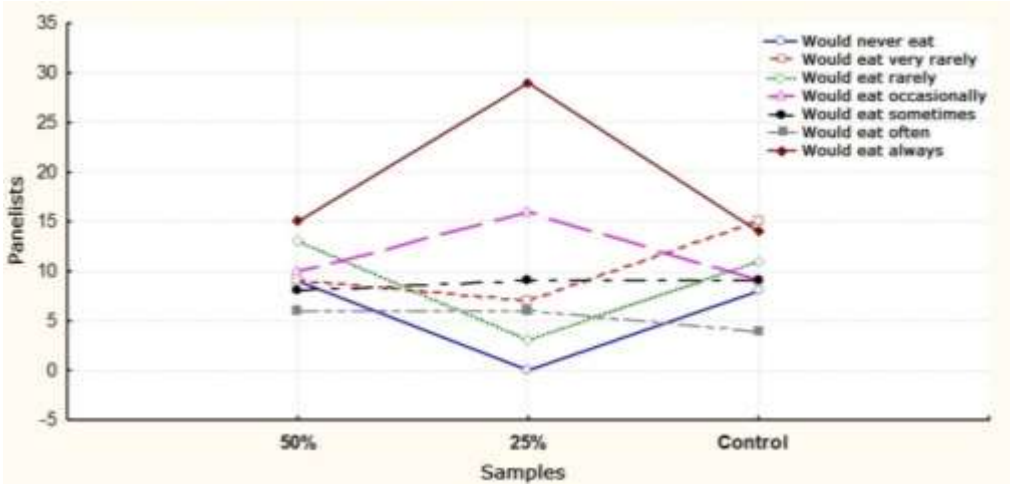
similar to its crispness (neither like nor dislike).

Graph 5 shows consumer preference using the paired preference test. Again the sample with 25% peach palm fruit powder was the favorite, with significantly higher consumer preference. Graph 6 shows that the sample with 25% peach palm fruit powder also had the highest intention to consume since interval 7 (would always eat) obtained the highest frequency.

The control sample had the lowest intention to consume, with interval 2 (would very rarely eat) having the highest frequency. According to Lucia (2008), aroma and taste are very important characteristics that affect the sensory properties of food products with special ingredients. Fiber-rich by-products may be incorporated into food products as inexpensive, non-caloric bulking agents for partial replacement of flour, fat, or sugar, as enhancers of water and oil retention and to improve emulsion or oxidative stability (Elleuch et al., 2011). Furthermore, the market of functional foods is increasing, and there are few types of flours commercially available that can be added to food products to increase their fiber content at low cost. Thus, the flours produced have a promising market, especially for being very light in color, whichfacilitate their incorporation into food products.

Conclusion

Sensory analysis using hedonic scales showed that extruded corn-based breakfast cereal with 25% whole peach palm fruit powder had higher acceptability, taste, crispness, purchase intention, consumer preference, and



Graph 6. Distribution of intention to consume.

intention to consume than the corn-based control sample. Partial substitution of by peach palm fruit (*Bactris gasipaes,* Kunth) powder is a good option for the development of new extruded breakfast cereals, since such product has good sensory characteristics and acceptability higher than 50%, indicating its market potential.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests

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Full Length Research Paper

Development, quality evaluation and estimated contribution of composite flour snack foods to nutrient requirements of young children aged 2 to 6 years

Hannah Oduro-Obeng* and Wisdom Annorsey Plahar

Council of Scientific & Industrial Research (CSIR) Food Research Institute, P. O. Box M.20, Accra, Ghana.

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Snack food consumption is an avenue for the young children of the world to meet their daily nutrient requirements. In recent times, biscuits and cakes prepared from a cocktail of grain and root crops have gained much popularity due to the versatile nature and nutritional quality of their composite flours. Flour samples prepared from broken rice fractions, soybeans, and orange-fleshed sweet potato (OFSP) were used to develop appropriate formulations with wheat flour to obtain a final blend composition of 60% wheat flour, 10% rice flour, 15% OFSP and 15% soybean flour, aimed at achieving fairly high nutrient contributions in the blends with regards to protein, vitamin A, iron and zinc without necessarily sacrificing the potential aesthetic, functional and sensory characteristics of the final products. The final blend obtained was used for the preparation of cake bread and biscuit snack foods for young children aged 2 to 6 years old. The products were evaluated for their physicochemical and sensory properties as well as their possible contribution to Recommended Dietary Allowances (RDAs). Significant improvements in the protein, vitamin A, zinc and iron contents were achieved with the composite blends for both products. Consumer acceptability of the products was also appreciably high. At a moderate daily consumption rate of two 1-cm slices of the cake bread (approximately 54.0 g) or two pieces of biscuit (approximately 44.0 g), children aged 2 to 3 years will satisfy over 30, 110, 20 and 8% of their RDAs for protein, vitamin A, iron and zinc, respectively. Older children who can consume more than the amounts stipulated above could have greater percentages of their RDA satisfied. Effective promotion of the production and consumption of such products is required to help improve micronutrient consumption by young children.

Key words: Biscuit, cake bread, children, complementary snacks, micronutrient, Recommended Dietary Allowances (RDAs).

INTRODUCTION

World-wide, and especially in developing countries like Ghana, malnutrition including micronutrient deficiencies continues to be a major public health issue largely due to insufficient food intake in terms of both quality and quantity (Bhutta and Salam, 2012). Increased urbanization and globalization has also exposed many people, especially children in both urban and rural communities, to quick, convenient, cheaper and ready-to- eat

processed foods and beverages that may be low in essential micronutrients (Adair and Popkin, 2005; Piernas and Popkin, 2010; Duffey et al., 2013). Deficiencies in these micronutrients are usually deleterious and almost irreversible. They include, vitamin A, iron and zinc deficiencies. The use of a variety of local food ingredients which are rich sources of micronutrients in food preparations in comparison to other interventions has proven to be a viable and sustainable approach in tackling all forms of malnutrition in addition to promoting food security in the long term (Pobee et al., 2017). Their diversification beyond the traditional food cuisines and potential uses in alternative product development such as snack food has also attracted much attention.

Recent research suggests that the consumption of snacks foods which includes biscuits, cakes and bread, soft drinks, chips and candies has increased with time as most low- to middle-income countries experience nutrition transition phenomena (Bermudez and Tucker, 2003; Thow and Hawkes, 2009). These snacks foods usually in the forms of convenience baked or fried products are mainly produced from refined wheat flour; they are self-fed and eaten between meals (Hess et al., 2016). Evidence suggests that the topmost consumers of these snack foods are young children and adolescents (Huffman et al., 2014). Wilson (1999) reported that eating between meals can contribute to total nutrient intake and ultimately help meet an individual's RDA in a day. In light of this, the composition of ingredients used in the production of these bakery foods is equally as important as the final product in attaining a nutritious and healthy snack for all age groups. In Ghana, biscuits and bread are common snacks widely consumed. They are both baked foods mainly produced from refined wheat flour and rich in carbohydrates.

Composite flour utilization in recent past from crops such as cassava, cocoyam, sweet potato, sorghum and millet for bakery products has gained prominence in many countries which traditionally import intermediate foods such as wheat flour for this purpose. Flour from these root and tuber crops have been used in the production of bread, cookies, doughnuts and noodles (Tortoe et al., 2017, Akonor et al., 2017). Their uses and benefits in the preparation of products such as biscuits and cakes have been extensively studied (Chauhan et al., 2016; Ho and Abdul Latif, 2016; Kidane et al., 2013). The choice of cereals and legumes in these blends is chiefly attributed to the complementary nature of the proteins in these cereal- legume blends that provide significant levels of essential amino acids (Amagloh et al., 2012; Lartey et al., 2000). However, in Ghana, little research results has been reported on the use of broken rice fractions in addition in some of these composite flour blends in snack food (cake bread and biscuit) preparation.

Losses in rice milling exceed 30% as broken fractions on average in Ghana due to the use of rudimentary tools and machinery in harvesting and post-harvest practices along the rice value chain (Appiah et al., 2011). These fractions are known to be a rich source of carbohydrates, fibre, B-vitamins, essential amino acids, potassium and calcium (Adu-Kwarteng et al., 2003). Broken rice flour is notably low in sodium, has a blunt taste and is gluten free hence its novelty in especially hypoallergenic snack products (Folorunso et al., 2016).

OFSP varieties released in Ghana have increased levels of β-carotene and range from yellow- to orange-coloured flesh. Considered an excellent source of pro-vitamin A carotenoids, these new varieties have the potential to address vitamin A deficiency. There is still a lack of diversity in the utilization of OFSP flour in food preparation as the majority of consumption is still limited to cooked and boiled forms in traditional meals. Successful utilization and acceptability of the orange-fleshed sweet potato by the consumer depends on creating a culturally acceptable sweet potato product, and several reports attest to this issue (Amagloh et al., 2012; Bonsi et al., 2014). Its potential impact on children's vitamin A status as well as significant improvements in vitamin A intake and serum retinol concentrations has also been well-investigated in a South African cohort (van Jaarsveld et al., 2005). OFSP is also a good source of fibre, potassium, phosphorus, vitamins E and C, iron and natural sugars, such as glucose and fructose (Lai et al., 2013), which can provide a sweet taste, colour and flavour to food enhancing its aesthetic value.

Soybeans were considered in the formulation because of their high protein content and quality amino acid profile and their content of minerals, such as calcium and iron (Plahar et al., 2003). It is for these reasons that in the current study, the concept of developing energy-dense, nutrient-rich snacks was explored using composite flour from broken rice fractions (which is an underutilized food by-product from the milling of paddy rice in Ghana), OFSP, local legumes (soybeans) and wheat flour aimed at meeting the macro and micronutrient needs of young children.

This study, therefore, specifically aimed to determine the nutritional value and physical and organoleptic properties of two snack foods (biscuits and cake bread) developed from composite flour made of OFSP, soybeans, broken rice and wheat and compared to control wheat flour. Secondly, the study also sought to

*Corresponding author. E-mail: hanoduro@yahoo.com.

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Table 1. Blend formulations used and the expected nutritional contribution.

Blend	% Flour (w/w)				Expected nutritional contribution per 100 g			
	Wheat	Rice	OFSP	Soybean	Protein (g)	Pro-vitamin A (mg)	Zinc (mg)	Iron (mg)
Control	100	0	0	0	13.7	0.001	1.70	0.60
Composite 1	30	30	20	20	17.27	2.62	1.73	2.24
Composite 2	50	20	15	15	16.54	1.96	1.05	1.24
Composite 3	20	40	20	20	16.62	2.61	1.74	2.22
Composite 4	60	10	15	15	18.57	2.61	1.71	2.28

determine the estimated contribution of these formulated snack foods to the nutrient requirements of young children aged 2 to 6 years old. The results of this study will continue to provide opportunities for the use and support of indigenous and underutilized food crops and by-products which are readily available and culturally acceptable in healthy snack food preparations for young children and adults alike and also help achieve food and nutrition security.

MATERIALS AND METHODS

Unless otherwise stated, all ingredients and raw materials used were sourced from a bakery shop in a local market in Madina, a suburb of Accra, in the Greater Accra Region of Ghana. Orange-fleshed sweet potato (OFSP) roots (var. *Apomden santom*) used in the preparation of the sweet potato flour was supplied by a smallholder farmer in Cape Coast, Ghana. Samples of parboiled broken rice (*Oryza sativa*) fractions (var. Jasmine 85) were supplied by the Ashiaman Irrigation Project, Tema. Soybeans (*Glycine max)* were of the Salintuya variety and were obtained from the CSIR-Savanna Agricultural Research Institute, Nyankpala, Tamale.

Preparation of flours

Orange-fleshed sweet potato (OFSP) flour

The established procedure for the preparation of the orange-fleshed sweet potato (OFSP) flour for use in the formulation of the snack foods is a modification of the method developed by Plahar (2011). Selected matured fresh sweet potato roots were washed, peeled with a knife, and the peeled roots washed again in clean water. The roots were then cut into thin slices of approximately 3.0-mm thickness using a One-Touch automatic deluxe vegetable slicer (Model KC25, Daka Res. Inc., China) and soaked in 1% sodium meta-bisulphate solution for 10 min to prevent bleaching of the orange colour. The conditioned slices were then spread thinly on drying trays and dried in a mechanical dryer maintained at 60°C for ten hours. The dried slices were milled in a disc attrition mill (Hunt No. 2A Premier Mill, Hunt & Co., UK) into smooth flour. The resulting OFSP flour samples were stored sealed in polyethylene bags until use.

Full-fat soybean flour

The final procedure was a modification of the process developed by Plahar et al. (1997). Cleaned soybeans were toasted for 20 min in an electric oven maintained at 140°C. They were then dehulled by breaking in a disc attrition mill (Hunt No. 2A Premier Mill, Hunt & Co., UK) and winnowed. The dehulled grits were then milled into flour using the disc attrition mill. The flour samples were packaged and sealed in polyethylene bags and stored frozen for use.

Rice flour

A simple procedure involving sorting and milling of broken rice samples was used for the preparation of the rice flour. Sorting was performed to remove coloured pieces and chaff from the bulk. The sorted clean rice was milled in a disc attrition mill as described for the soybean samples.

Composite blend formulation

Four composite blends were formulated, and the nutritional quality evaluated theoretically to achieve a desirable nutritional composition with regards to the protein, vitamin A, zinc and iron contents. This procedure was performed using values obtained from Food Composition Tables (FAO, 2012) to obtain a product that could meet the specified RDA guidelines for young children (WHO, 2002). OFSP was chosen to provide the source of pro-vitamin A. Broken rice was used in part as a carbohydrate source and mainly as to promote its utilization in bakery products and soybeans to provide protein. Blend formulations and their expected nutritional contributions are shown in Table 1. The four formulations were screened for two snacks: Biscuits and cake bread.

Preparation of snacks

Two snacks (biscuits and cake bread) were developed from the four composite blends and control wheat flour using standard ingredient formulations as shown in Tables 1 and 2. Choice of these two snacks was influenced by the likelihood of it being adopted as similar snacks are given to pre-schoolers in Ghana. For the preparation of the cake bread, 600 g of the composite flour was sifted, and all dry ingredients including 40 g sugar, 1 g nutmeg flour, 4 g instant yeast, and 6 g table salt were weighed and mixed. Then, 300 ml evaporated milk and 2.5 ml vanilla essence were added to 300 ml warm water, poured into the flour mixture and mixed to form a firm dough. The dough was kneaded on a floured board, cut into 40 g pieces that were rounded into rolls, placed in baking pans and allowed to proof in a fermentation cabin at 35°C for 3.0 h. The rolls were baked in a preheated, locally made oven maintained at 200°C for 15 min. For the preparation of the biscuits, the composite flour was sifted, and all dry ingredients including 150 g sugar, 3.6 g baking powder, 1 g nutmeg powder, and 2.5 g table salt were weighed and mixed. Exactly 5.0 ml vanilla

Table 2. Ingredient composition of biscuits and cake bread

Ingredient	Quantity	
	Cake bread	Biscuits
Composite flour blend	600 g	600 g
Sugar	40 g	150 g
Margarine	100 g	250 g
Evaporated milk	300 ml	-
Eggs	-	164.5 g
Baking powder	-	3.6 g
Nutmeg	1 g	1 g
Yeast (Instant)	4 g	-
Table salt	6 g	2.5 g
Vanilla essence	2.5 ml	5.0 ml
Warm water*	270 - 310 ml	-

*Varied to produce right mixing consistency.

essence was added to 164.5 g eggs and whipped thoroughly. This mixture was then poured into the flour mixture and mixed manually to form a firm dough that was rolled on a floured board to a thickness of 6.0 mm, cut into 5.8 cm diameter round shapes with biscuit cutters and baked in a preheated oven at 140°C for 45 min.

Sensory evaluation

The products were evaluated for their sensorial attributes including appearance, colour, taste, crispness (for biscuits) and texture (for bread), aroma, mouth feel, after-taste and over all acceptability. A nine-point hedonic scale was used to test for the above-mentioned sensory attributes for both cake bread and biscuits. The evaluation was undertaken by a panel of twenty trained staff of the CSIR-Food Research Institute (FRI), Ghana (on two separate occasions for each snack) who had previously participated in the evaluation of snacks. The test was conducted in a facility conforming to ISO 8589. The coded samples were presented separately at room temperature to each panel member for evaluation. Panellists were provided water to refresh their palate before evaluating successive samples. This activity formed a major part of the product development process and was used in the selection of the best formulation for both snacks.

Final blend selection and quality evaluation of snack foods

Based on the above screening exercise, in addition to their expected nutritional contributions, the best blend was then selected and used for the preparation of cake bread and biscuits snack foods by the method described above, along with a wheat flour control. The samples were evaluated for consumer acceptability, nutritional quality, and physical properties and estimated contribution of the snacks to the vitamin A, iron, zinc and protein requirements of children aged 2 to 6 years.

Consumer acceptability

Mothers (66) with pre-school children (2 to 6 years) were recruited for rating the consumer acceptability of the two composite snack foods made of 60% wheat flour, 10% rice flour, 15% OFSP and 15% soybean flour and the corresponding 100% wheat flour control. These mothers were recruited from three private Nursery and Kindergarten schools in Madina, a suburb of Accra in the morning as they dropped off their kids at school. Before then, a list of candidate mothers with children aged 2 to 6 years was obtained from school heads with permission and prior notice provided to the mothers. Subsequently, a letter was written to inform the mothers of the purpose of the study through the heads of these schools. From each school, twenty-two mothers were randomly selected from the list to participate after informed consent was signed. Mothers were used rather than the targeted pre-school children because mothers' and children's food preferences are said to be significantly but moderately related, and their acceptance of food can influence their children's intake (Tomlins et al., 2007). Each mother tasted one piece of biscuit (approximate 22 g) and one slice of cake bread (approximately 27 g) of both composite and control wheat samples presented in random order and coded with three digit random numbers. Mothers assessed the products separately based on colour, taste, appearance, flavour and overall acceptability. Evaluation was performed using a nine-point hedonic scale with 1 representing "dislike very much" and 9 representing "like very much". Mothers were also made to sign a consent form before the study was carried out.

Chemical analysis

Moisture (AOAC 925.10), protein (AOAC 984.13), fat (AOAC 920.39C) and ash (AOAC 923.03) were determined by the AOAC (2005) standard methods while carbohydrates were calculated by difference and energy values were obtained using the Atwater factors 3.47, 8.37 and 4.00 for protein, fat and carbohydrates, respectively (Eyeson and Ankrah, 1975). Iron and zinc were determined by the atomic absorption spectrophotometric methods with a Perkin Elmer atomic absorption spectrophotometer No.3030 (AACC, 2000). The pro-vitamin A content of the products was determined following the HPLC method described by Rodriguez-Amaya and Kimura (2004), and the vitamin A/retinol equivalent was calculated subsequently as described by WHO/FAO Joint Expert Consultation (2002).

Colour measurements

The colour of cake bread and biscuit samples was measured using the L*, a* and b* colour space (CIE LAB space) with Colorimeter

Table 3. Mean sensory scores for cake bread snack foods from composite flours and control[1].

Sensory characteristic	Wheat/rice/soy/OFSP blends				
	Composite 1	Composite 2	Composite 3	Composite 4	Control
Appearance	4.85 ± 2.30^{d}	6.25 ±1.70^{c}	5.30± 2.00^{d}	7.35± 1.30^{b}	8.60 ± 0.60^{a}
Colour	4.55 ± 2.50^{d}	6.40 ±1.90^{c}	5.30 ± 2.20^{d}	7.30 ± 1.50^{b}	8.55 ± 0.60^{a}
Taste	4.90 ±2.40^{b}	5.65 ± 2.00^{b}	5.10 ±2.00^{b}	7.60 ±1.30^{a}	8.05 ± 1.40^{a}
Aroma	5.60 ± 2.00^{b}	6.15 ± 1.80^{b}	5.75 ± 1.90^{b}	7.25 ±1.30^{a}	8.00 ± 1.10^{a}
Texture	5.55 ±2.10^{c}	6.15 ± 2.00^{c}	6.00 ±2.30^{c}	7.10 ± 1.20^{b}	8.40 ± 0.80^{a}
Mouth-feel	5.05 ±2.00^{c}	5.95 ± 1.90^{c}	5.50 ±1.80^{c}	7.00 ±1.60^{b}	8.30 ± 1.20^{a}
After-taste	4.40 ±2.20^{d}	5.75± 2.10^{c}	5.10± 2.00^{c}	6.80 ± 1.60^{b}	8.15 ± 1.20^{a}
Overall acceptability	4.80± 2.10^{b}	5.85± 1.90^{b}	5.15± 2.10^{b}	7.60± 1.40^{a}	8.30 ± 0.90^{a}

Values show the mean ±SD (n=25 adult staff of FRI). Means in a row with different superscript letter are significantly different (P<0.05)
[1]Interpretation of scores: 1 = dislike extremely; 2 = dislike very much; 3 = dislike moderately; 4 = dislike slightly; 5 = indifferent; 6 = like slightly; 7 = like moderately; 8 = like very much; 9 = like extremely.

CR-200 (Minolta, Model CR310, Minolta Camera Company Ltd., Osaka, Japan). The measurements were taken for both the top and bottom of each sample. The measuring head of the meter was carefully placed on three different locations on the sample and the meter reading taken. Measurements were determined in triplicate, and the mean and standard deviations determined. The L* value indicates lightness, where L* = 0 is completely black and L* = 100 is completely white. The a* values represent red to green with positive a* and negative a* depicting red and green, respectively. The b* values on the other hand represent yellow to blue, with positive b* representing yellow and negative b* representing blue. The meter was calibrated with a white tile (L*=97.51, a*= +0.29, and b*=+1.88). ΔE values were calculated to indicate the extent of deviation of colour in the samples from the standard tile colour used. ΔE is calculated as the square root of the sum of the squared deviations of L*, a* and b* values (Oduro-Yeboah et al., 2010):

$$\Delta E = \sqrt{[\Delta L^2 + \Delta a^2 + \Delta b^2]}$$

Water activity measurement

The water activity of ground samples of biscuit and cake bread was measured at 25°C using a hygrometer (Rotonic Hygrolab®, Rotronic AG, Grindelstrasse 6, 8303 Basserrsdorf, Schweiz). All parameters were analysed in triplicate on an as-is basis.

Statistical analysis

Data were analysed using the Statistical Package for Sciences (SPSS, version 21.0) statistical software to generate means and standard deviations of triplicate determinations. Statistical parameters were estimated using analysis of variance (ANOVA). Differences between means were evaluated by the Duncan's new multiple range test, and significance was accepted at P<0.05

RESULTS AND DISCUSSION

Sensory evaluation for selection of final blend

Results of sensory evaluation of cake bread and biscuits samples prepared with the different levels of composite flour as compared to the control are shown in Tables 3 and 4, respectively. Subsequently, selection of the final blend was based on the highest mean sensory scores for the cake bread and biscuit samples produced with the four composite blends. Colour and appearance, like any other sensory attribute, play a major role in determining consumer acceptance of food products. Particularly in bakery goods, colour and appearance constitute one major sensory characteristic that determines consumer choice in Ghana. Colour and appearance therefore are important sensory properties considered in all food product development efforts. For these sensory attributes, there were significant differences (P<0.05) in the composite cake bread samples and the control. The low rating of colour and appearance compared to the control can be attributed to the darker colour and brownish appearance of the cake bread across composite flours as the substitution for wheat flour with soybeans, OFSP and rice flour increased. However Composite 4 was rated "liked moderately" for both attributes with a mean score of 7.35 and 7.30 for appearance and colour respectively, which were significantly higher than the scores for the other composite flours. Browning in bread could be directly related to the increase in fibre content (Ndife et al., 2011) as well as caramelization and maillard reactions as the protein contributed by the soybean flour must have reacted with the added sugars and the natural sugars in the OFSP during the baking process (Dhingra and Jood, 2002). A decrease in colour score of composite flour baked products as substitution increased has been noticed by Sharma and Chauhan (2000).

Aroma and taste are two key sensory attributes which affect the perception of food to be consumed. For aroma and taste, Composite 4 cake bread was rated the same in the degree of likeness as the control ("like very much"). Statistically, there was no significant difference (P>0.05) between Composite 4 sample and the control samples for

Table 4. Mean sensory scores for biscuit snack foods from composite flours and control[1].

Sensory characteristic	Wheat/rice/soy/OFSP blends				
	Composite 1	Composite 2	Composite 3	Composite 4	Control
Appearance	6.75 ± 1.50^{b}	7.25 ± 1.70^{ab}	6.05 ± 2.00^{b}	7.45 ± 1.10^{ab}	7.95 ± 1.10^{a}
Colour	6.45 ± 1.60^{b}	7.05 ± 1.90^{a}	6.00 ± 1.90^{b}	7.58 ± 0.80^{a}	8.25 ± 0.70^{a}
Taste	5.85 ± 1.70^{d}	7.25 ± 1.50^{b}	6.40 ± 1.70^{c}	7.60 ± 0.80^{b}	8.35 ± 0.80^{a}
Aroma	6.50 ± 1.60^{c}	7.40 ± 1.30^{b}	6.50 ± 1.60^{c}	7.45 ± 0.90^{b}	8.20 ± 0.80^{a}
Crispness	5.65 ± 1.80^{d}	6.75 ± 1.50^{c}	5.95 ± 1.80^{d}	7.55 ± 1.30^{b}	8.05 ± 0.10^{a}
Mouth-feel	6.35 ± 1.60^{c}	7.10 ± 1.30^{b}	6.20 ± 1.60^{c}	7.45 ± 0.90^{b}	8.50 ± 0.60^{a}
After-taste	6.45 ± 1.50^{c}	7.00 ± 1.40^{b}	6.10 ± 2.00^{c}	7.45 ± 0.90^{b}	8.45 ± 0.50^{a}
Overall acceptability	6.05 ± 1.70^{c}	7.25 ± 1.40^{b}	6.15 ± 1.70^{c}	7.55 ± 0.90^{b}	8.50± 0.60^{a}

Values show the mean ±SD (n = 25 adult staff of FRI). Means in a row with different superscript letter(s) are significantly different (P<0.05)
[1]Interpretation of scores: 1 = dislike extremely; 2 = dislike very much; 3 = dislike moderately; 4 = dislike slightly; 5 = indifferent; 6 = like slightly; 7 = like moderately; 8 = like very much; 9 = like extremely.

aroma and taste. The other three composite flours produced cake bread samples with similar but significantly reduced aroma and taste scores. The not significant difference (P>0.05) between Composite 4 and the control can be attributed to the relatively lower soy, rice and OFSP flour substitution in Composite 4 blend. The presence of more rice and OFSP as well as soybean flours could have accounted for the lower ratings of Composites 1, 2 and 3. In addition to this some of the panellist expressed a limiting sensory attribute of a beany aroma and "root crop" after-taste in these samples. Several studies have reported that higher substitution of wheat flour with soybeans and OFSP in bread and biscuits making was associated with a beany flavour, "root" aroma and after taste (Sabanis and Tzia, 2009; Tortoe et al., 2017).

The scores for texture and mouth feel which depicts softness and chewiness of the composite cake bread samples decreased with OFSP, soybean and rice flour substitution as shown by the ratings describing them in Table 3 compared to the control. However, Composite 4 produced cake bread with ratings of "like moderately". Cake bread containing rice flour between 30 and 40% and OFSP and soybean flour of 20% each representing Composites 1 and 3 had the lowest sensory rating relative to Composite 4 and the control. The contribution of additional fibre ostensibly from rice, OFSP and soybean in the composite blends might have resulted in the hard texture of the cake bread relative to the control (Sabanis and Tzia, 2009). Substitution of wheat flour with non-wheat flour in bakery products results in the retention of less gas hence producing a dense texture that is undesirable to the consumer.

Over all acceptability scores generally revealed that Composites 2 and 4 which had between 10 to 20% wheat flour substituted for rice flour and 15% wheat flour substituted for OFSP or soybean flours were "liked slightly" and "liked very much" respectively. In totality, Composite 4 produced cake bread samples were rated highest amongst all attributes and was not significantly (P>0.05) different from the control wheat sample.

A similar trend to the cake bread was observed in the sensory ratings of biscuits produced from the four composite flours (Table 4). Sensory attributes for biscuits prepared with Composite 1 were rated between 'like slightly' to 'like moderately', whereas those for Composite 3 were all rated 'like slightly'. Biscuit products from Composite 2 had all the sensory attributes scored 'like moderately' with scores for Composite 4 biscuits indicating between 'like moderately' and 'like very much'. Taste, colour, crispness and overall acceptability for the Composite 4 biscuits had scores indicating 'like very much'.

From the above sensory scores for both the cake bread and biscuits produced from the four composite flours and the control, it was quite apparent that Composite 2 and Composite 4 were the best formulations and would produce acceptable products in addition to their nutritional attributes. From the theoretical values shown in Table 1, however, Composite 4 was expected to have higher content of protein, vitamin A, zinc and iron than Composite 2. In addition to its higher mean scores for the sensory attributes, Composite 4, consisting of 60% wheat flour, 10% rice flour, 15% OFSP and 15% soybean flour, was considered the best blend for use in the production of the snack foods for the desired nutritional and sensory attributes.

Consumer acceptability

The mean scores for consumer acceptability of the snack foods are shown in Table 5. For all the sensory attributes, mean scores for the cake bread ranged between 8.0 and

Table 5. Consumer acceptability of composite snack foods compared with the control.

Component	Cake bread		Biscuit	
	Control wheat flour	Composite flour	Control wheat flour	Composite flour
Appearance	8.20±0.66[a]	7.82±0.63[a]	7.80±0.68[a]	7.50±0.66[a]
Colour	8.41±0.78[a]	7.50±0.64[b]	8.61±0.58[a]	7.91±0.80[a]
Taste (sweetness)	8.59±0.63[a]	7.61±0.60[b]	8.21±0.83[a]	7.61±0.76[b]
Flavour	8.00±0.63[a]	7.85±0.61[a]	8.11±0.59[a]	7.71±0.70[a]
Overall Acceptability	8.41±0.70[a]	7.89±0.59[a]	8.00±0.68[a]	7.89±0.81[a]

Values show the mean ±SD (n = 66 mothers with pre-school children 2 to 6 years). For each snack food, figures in a row with different superscript letter are significantly different (P<0.05). [1]Interpretation of scores: 1 = dislike extremely; 2 = dislike very much; 3 = dislike moderately; 4 = dislike slightly; 5 = indifferent; 6 = like slightly; 7 = like moderately; 8 = like very much; 9 = like extremely.

8.6 for the control (indicating 'like very much' to 'like extremely') and between 7.5 and 7.9 for the composite flour cake bread (indicating 'like moderately' to 'like very much') on the 9-point hedonic scale. Except for colour and taste, all other sensory attributes had the same degree of likeness (P>0.05) for both the composite flour cake bread and the control, and this pattern was also true for the overall acceptability mean scores. The slight but significant differences observed in the colour and taste of the composite flour cake bread and the control could be attributed mainly to the orange colour and sweetness of the OFSP in the composite flour (Lai et al., 2013) and also the browning reaction during baking. This variation, albeit significant, had no effect on the degree of liking, as the mean scores for both products are interpreted as 'like very much' for colour and taste. Consequently, both control and composite cake bread samples showed no significant difference in overall acceptability. Similar results were observed for composite breads prepared with 40% OFSP compared with 100% wheat bread (Rangel et al., 2011).

Acceptability scores for biscuits also ranged from 7.8 to 8.6 for the control wheat biscuits and from 7.5 to 7.9 for biscuits made from the composite flour (Table 5). Here, except for taste, all other sensory attributes of the biscuits made with composite flour were not significantly different (P>0.05) from the control, including the overall acceptability scores. Again, this variation in taste, though significant, did not affect the degree of liking ('like very much') on the 9-point hedonic scale. This finding is an affirmation that snack foods prepared from composite flour blends of 60% wheat flour, 10% rice flour, 15% OFSP and 15% soybean flour are acceptable and can lead to enhanced utilization of local raw materials in composite food preparations. Similar scores of acceptability of biscuits made with approximately 10% OFSP and wheat was observed in other studies (Laelago et al., 2015).

These results are in concordance with the results from the semi-trained panellist sensory scores, which is a good indication that the cake bread and biscuit products are likely to be accepted by the target group leading to enhanced consumption.

Product quality evaluation

Proximate composition and water activity (a_W)

The final blend composition of 60% wheat flour, 10% rice flour, 15% OFSP and 15% soybean flour was used to prepare cake bread and biscuit samples and the quality evaluated.

The results obtained for the chemical and physical properties investigated are shown in Table 6. Generally, the values for ash, fat and protein were lowest in the control wheat flour produced caked bread and biscuits samples and higher in the composite flour produced samples albeit not significant (P>0.05) with fat content of the cake bread. These differences could be attributed to the composite flour blend components. Ash content of the composite blend increased due to the significantly higher mineral content of all the non-wheat flours. The reverse however was recorded for the carbohydrate and energy values for both products. These results are in agreement with those obtained by Ndife et al. (2011). The relatively low energy and carbohydrate values in the composite flour products may be attributed to the lower levels of wheat flour used relative to the control. Also the lower energy values can be attributed to the apparently higher fibre (data not shown) and protein content in the composite flour. Dietary fibre forms a significant fraction of the bran of whole grains and their health promoting benefits have been researched extensively (Malunga et al., 2017). Using composite flour made from grain cereals and root and tubers in bread and biscuit preparation increases the fibre content which lowers the carbohydrate value of the product. This finding was reported by Serrem et al. (2011) who obtained similar results. The energy values obtained from the composite flour products conformed to the FAO/WHO (1994) recommended minimum energy

Table 6. Proximate composition, vitamin A, iron, zinc, and water activity (A_w) of formulated snack foods prepared from wheat, rice, soybean and OFSP composite flours.

Component	Cake bread		Biscuit	
	Control wheat flour	Composite flour	Control wheat flour	Composite flour
Moisture (g/100 g)	29.20±0.04[b]	32.60±0.01[a]	2.80±0.08[d]	3.40±0.07[c]
Protein (g/100 g)	7.89±0.07[c]	8.76±0.07[b]	6.49±0.04[d]	9.48±0.02[a]
Fat (g/100 g)	10.67±0.01[c]	10.69±0.11[c]	24.22±0.16[b]	25.71±0.23[a]
Ash (g/100 g)	1.30±0.01[c]	1.83±0.02[b]	1.11±0.01[d]	2.11±0.01[a]
Carbohydrates (g/100 g)	50.97±0.03[c]	46.10±0.07[d]	65.36±0.13[a]	59.30±0.20[b]
Energy (Kal/100 g)	320.57±0.16[b]	304.35±0.69[c]	486.68±1.12[a]	485.29±1.42[a]
Vitamin A (mg RE/100 g)	0.037±0.003[d]	0.624±0.007[b]	0.127±0.043[c]	0.810±0.013[a]
Iron (mg/100 g)	1.92±0.12[d]	2.86±0.27[b]	2.53±0.16[c]	4.00±0.18[a]
Zinc (mg/100 g)	0.51±0.14[c]	0.69±0.35[a]	0.52±0.01[c]	0.56±0.01[b]
Water activity (A_w)	0.89±0.001[a]	0.89±0.002[a]	0.55±0.020[b]	0.44±0.007[c]

[1]Values are averages of duplicate readings (Mean ± SD). Means with different superscript letter in a row are significantly different (P< 0.05).

content of 400 Kcals/100 g.

The moisture content of the samples ranged between 2.8% for control wheat flour biscuits to 32.6% for the composite flour cake bread (Table 6). Generally, the biscuit samples contained very low moisture (2.8 and 3.4%, respectively, for the control wheat flour and composite flour). The higher moisture content in the composite flour products relative to the control may be attributed to the blend composition of the composite flours. Soluble protein contained in soy flour contributes to a greater moisture holding capacity (Sabanis and Tzia, 2009). In addition, the high fibre content in the composite blend caused retention of moisture. High fibre content in foods is known to be associated with moisture retention (Maneju et al., 2011). Although the moisture content of the composite flour biscuit was greater than for the control, the corresponding water activity values did not follow the same trend. The presence of rice, soy and OFSP flours in the composite flour blend bound some of the available water to reduce the water activity. Water activity values of 0.89 as obtained for the cake bread samples in the present study are likely to encourage proliferation of microorganisms, including many types of yeast, such as Candida*, Torulopsis, and Hansenula* and *Micrococcus* (Fennema, 1985), if the product is kept for a long period of time on the shelf. Fortunately, such products are typically consumed within a few days after baking. The biscuit samples, on the other hand, had such low water activity values that they will not encourage any microbial proliferation.

Vitamin A, iron and zinc content

The composite flour produced cake bread and biscuit samples resulted in significantly higher ($p<0.05$) contents of vitamin A than their corresponding wheat flour control samples (Table 6). Similar results were recorded for iron and zinc contents. According to Nzamwita et al. (2017) wheat flour is a poor source of vitamin A. Several studies involving the use of OFSP flour in product formulations have reported significant pro-vitamin A carotenoid concentrations in the final product as well as higher serum vitamin A status in biological samples after consumption (van Jaarsverd et al., 2005; Low et al., 2007; Bonsi et al., 2014; Pobee et al., 2017). Deficiencies of essential micronutrients especially those of public health concern are deleterious and their cost to productivity is unquestionable. These findings suggest that food ingredients such as OFSP when used as a strategy to combat micronutrient malnutrition will not only be successful but also sustainable. According to the FAO (2009), vitamin A, iron and zinc are responsible for most of the micronutrient deficiency problems in Ghana. In a study conducted in Northern Ghana, Simler et al. (2005) found that 75% of children aged between two and five years suffer from sub-clinical vitamin A deficiency, and 35% suffer from severe vitamin A deficiency. Under the prevailing circumstances, the formulated snack foods from the present study will contribute significantly to the search for a sustainable means to help solve these micronutrient deficiency problems. Vitamin A is essential in the health of the cornea, gastrointestinal tract, skin, urinary tract and lungs. The vitamin A content in the composite flour snack foods meets more than enough for all age groups.

Iron content also increased significantly by 48.96 and 58.0% in the composite flour samples respectively for cake bread and biscuit, while increases of 35.3 and 7.7% were recorded for zinc. Both nutrients are essential and are important in haematopoiesis and the prevention of

Table 7. Colour values of formulated snack foods prepared from wheat, rice, soybean and OFSP composite flours.

Component	Cake bread		Biscuit	
	Control wheat flour	Composite flour	Control wheat flour	Composite flour
Top colour				
L	58.02±0.89[c]	49.94±0.34[d]	67.39±1.65[a]	60.65±1.68[b]
a	+9.36±0.26[a]	+8.91±0.21[a]	+0.53±0.20[c]	+1.62±0.09[b]
b	+20.99±1.09[b]	+11.32±0.38[c]	+23.79±1.44[a]	+24.18±1.25[a]
ΔE	44.80[b]	49.26[a]	37.25[d]	43.10[c]
Bottom colour				
L	75.87±0.61[a]	63.65±0.94[c]	70.58±0.08[b]	53.40±1.53[d]
a	+0.23±0.04[d]	+1.72±0.44[b]	+0.75±0.05[c]	+4.40±0.13[a]
b	+24.77±0.72[b]	+28.27±0.34[a]	+25.35±1.72[b]	+18.65±1.64[c]
ΔE	31.50[d]	42.95[b]	35.73[c]	47.37[a]

[1]Values are averages of duplicate readings (Mean ± SD). Means with different superscript letter in a row are significantly different (P< 0.05).

anaemia especially in children below 5 years and women in general. Zinc is especially important for the prevention of infections and to support the immune system as well as in growth, cognitive and motor development (Busie et al., 2017; Nzamwita et al., 2017).

Colour

Bakery products are supposed to have a peculiar colour gamut for the topside and the bottom side that should meet consumer expectations. In the present study, the colour of the snack foods produced from the composite flour was measured at both the topside and the bottom side and compared with that of the standard control samples to determine the extent to which consumer expectations could be satisfied. The results indicated that control bread and biscuit samples were slightly but significantly lighter in colour at the topside, as indicated by the greater L* values, than the composite flour products (Table 7). The a* values for the topside of the control flour biscuit samples also showed less intense red colour than the composite flour samples. The composite flour cake bread samples, however, recorded slightly but significantly deeper topside red colour than the control. Several studies have reported a lower L value for bread produced with composite flours including soy, cowpea or fenugreek flour (Hooda and Jood, 2005; Sabanis and Tzia, 2009). Positive b* values obtained for the topside of the cake bread and biscuit samples indicated degree of yellowing. Whereas the same intensity of yellow was obtained for control and composite biscuit samples, the cake bread samples showed a deeper yellow in the control samples than the composite flour products. OFSP flour has a distinctive yellow to orange colour and this has an influence on their products determining the degree of consumer acceptance. Apart from being antioxidants, OFSP are rich sources of pro-vitamin A carotenoids, a precursor of vitamin A. This vitamin is essentially important in the prevention of night blindness and certain atherosclerosis conditions. The ΔE values obtained clearly show a wider deviation in colour of the composite flour products from the standard tile colour than the control flour samples.

Similar to the topside colour values, the bottom side colour of the control samples were also lighter in colour (greater L* values) than the composite flour products for both the cake bread and biscuit samples. Additionally, the degree of redness in both products were different for composite and control with the composite giving a more red colour than the control as indicated by the a* values (Table 7). As observed with the topside colour of the products, there were significant differences in the deviations from the standard tile colour between the control and composite flour for both cake bread and biscuits with the composite flour products showing greater deviations from the standard white tile. The differences obtained in the instrumental measurements of L*, a*, and b* values confirmed the slight differences in the sensory scores for colour shown in Tables 3 and 4, where the samples were rated between 'like moderately' and 'like very much' and close to the wheat flour controls.

Estimated contribution of composite flour snack foods to RDA of pre-school children aged 2 to 6 years

The results for the contribution of the two snack foods to the RDA of children aged 2 to 6 years is shown in Table 8. These contributions were based on an assumed minimum daily serving size of two 1-cm slices of the cake

Table 8. Estimated contribution (%) of composite flour snack foods to RDA for protein, vitamin A, iron and zinc for children between two and six years old.

Nutrient		Age group (Years)			
		2 -3		4-6	
RDA per day[1]	Protein (g)	13.0		19.0	
	Vitamin A (µg)	300		400	
	Iron (mg)	7.0		10.0	
	Zinc (mg)	3.0		5.0	
		Bread	**Biscuit**	**Bread**	**Biscuit**
Contribution from snack food per day[2]	Protein (g)	4.73	4.17	7.10	6.26
	Vitamin A (µg RE)	337.42	356.98	506.14	535.48
	Iron (mg)	1.54	1.76	2.32	2.64
	Zinc (mg)	0.37	0.25	0.56	0.37
% of RDA	Protein	36.4	32.1	37.4	32.9
	Vitamin A	112.5	119.0	126.5	133.9
	Iron	22.0	25.1	23.2	26.4
	Zinc	12.3	8.3	11.2	7.4

RDA, Recommended Dietary Allowance; [1]Source: Food and Nutrition Board (2003). [2]Based on an assumed serving size of two 1-cm slices cake bread (approximately 54.0 g wb) or two pieces of biscuit (approximately 44.0 g wb) for two- to three-year-olds, and three 1-cm slices cake bread (approx. 81.0 g wb) or 3 pieces of biscuit (approximately 66.0 g wb) for four- to six-year-olds.

bread (approximately 54.0 g) or two pieces of the biscuit (approximately 44.0 g) for the two- to three-year-old age group, and three 1-cm slices of bread (approximately 81.0 g) or 3 pieces of biscuit (approximately 66.0 g) for the four- to six-year-old age group. This assumed quantity of consumption is justified from informal information obtained from interactions with mothers used in the consumer acceptability studies because there was no publication on quantity of consumption for these age brackets. At this rate of consumption, children aged 2 to 3 years old will satisfy approximately 36, 112, 22 and 12% of their RDA for protein, vitamin A, iron and zinc, respectively, from the cake bread and 32, 119, 25 and 8% of their RDA for protein, vitamin A, iron and zinc, respectively, from the biscuits (Table 8). Children above this age group (that is, 4 to 6 years old) will satisfy more than the amounts stipulated above. From the values obtained, the products could satisfy more than the RDA for vitamin A as well as significant proportions of protein and iron requirements at the assumed consumption levels.

Conclusions

It is economic and nutritionally satisfactory for the consumer to have alternative products on the market that best suits their needs. From this study, the use of 60% wheat flour, 10% rice flour, 15% OFSP and 15% soybean flour in composite flour for cake bread and biscuits was found to be nutritionally superior to refined wheat flour cake bread and biscuits using the same quantity of bakery ingredients. Substitution of wheat flour with broken rice fractions, OFSP and soybean flours resulted in significant increases in pro-vitamin A carotenoid, protein and zinc contents and met the recommended minimum energy requirements of about 400 Kcal/100 g of food. Consumer acceptability of the products was also quite high. Consumption of the baked products will also contribute significantly to the RDA of young children especially for vitamin A, iron and zinc on a daily basis. Composite blends as was used in the present study could serve as an alternative source of less expensive yet nutritious flours for the preparation of cake breads and biscuits. There is however the need to ascertain the bioavailability of these nutrients in the products taken into consideration the phytate content of whole grain cereals and root and tuber crops.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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