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Physicochemical and Sensory Properties of Cookies produced from Composite Flour of Wheat, *Acha* and Whole Orange Fleshed Sweet Potato

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Abstract

In Nigeria, reliance on wheat flour in the bakery industries has over the years restricted the use of other cereals and tuber crops available to domestic use. Recently government has collaborated with the research institutes to encourage the use of composite flours in the production of food products such as bread, cookies etc. *Acha* has been a potential crop which contributes significantly to people's diet and play a vital role in food security especially in developing countries like Nigeria. This study investigated the physicochemical properties and acceptability of cookies produced from wheat, *acha* and whole orange fleshed sweet potato (OFSP) flour blends. Cookies were produced by substituting wheat flour with *acha* and OFSP flours. The wheat:*acha*:whole OFSP were formulated into six different ratios (90:0:10, 80:10:10, 70:20:10, 60:30:10, 50:40:10 and 50:50:0), using 100% wheat flour as the control. The functional properties of the composite flours, proximate, carotenoid content, physical and sensory properties of cookies produced from each formulation were determined using standard procedures. The result of the functional properties revealed that the composite flours had higher gelatinization temperatures (56.50– 75.00°C), emulsion stability (47.16 - 52.34%), emulsion capacity (45.61-50.44%), wettability(0.97-1.27%) and water absorption capacity (1.52 - 1.79g/ml) than the control. The result of the proximate analysis showed that the cookies from the flour composites compared favourably with the control samples, thus the crude protein, fat and carbohydrate ranged from 9.67 - 11.98%, 7.87 - 12.58% and 59.32 - 67.62% respectively, hence, recorded high energy values (379.97-398.49Kcal/100g). The carotenoid contents (1.94 - 4.95µg/100g) of the cookies increased with increase in the proportion of (OFSP) fleshed sweet potato flour. The physical properties of the cookies produced from the composite flours compared favourably with the control. The general acceptability of the cookies ranged from 7 7.68-8.52 (Liked moderately to Liked very much), which shows that all the cookies samples were generally accepted. The general acceptability of the cookies from wheat:*acha*:whole OFSP (50:50:0) substitution had the highest value(8.52) which denotes Liked very much and was mostly preferred. However, cookies samples from wheat:*acha*:whole OFSP (70:20:10) competed favourably with the control sample (100% wheat) with the values of 8.08 and 8.36 respectively for overall acceptability. This indicates that *acha* and OFSP flours could be used in the production of acceptable and quality cookies and could also be used for substituting wheat flour up to 70% level in cookies production without adversely affecting the sensory properties of the cookies.

Keywords: Composite flours, wheat, acha, Orange fleshed sweet potato, cookies

Introduction

Cookies are nutritious ready-to-eat baked snacks available in different shapes and sizes. They are one of the most popular bakery items consumed among all age groups in many countries due to their creamy taste and low water activity which defines their long shelf life (Chauhan *et al*., 2015; Usman *et al*., 2015). Conventionally, cookies are produced from wheat flour due to its gluten content which improves its texture (Oluwafemi and Seidu, 2017). The consumption of cookies in Nigeria spreads across all class and age of people (Nwanekezi, 2013). Wheat (*Triticum spp*) is a temperate crop that does not thrive well under tropical conditions (Adbelghafor *et al*., 2010). The dependence of wheat flour in the baking industries is a major constraint in biscuit, bread production. Huge sum of money are involved in wheat importation; in 2010 alone, Nigeria spent N 635 billion ($4.2 billion) on the importation of wheat (Momoh, 2011).

Acha (*Digitaria exilis*) also known as "hungry rice" is a cereal crop of West African origin belonging to the family *Graminaea* (Aviara *et al*., 2017). The white *acha* (*Digitaria exillis*) and brown *acha* (*Digitaria iburua*) are the two most prominent varieties (Aviara *et al*., 2017). In West Africa, *acha* is mainly grown and cooked by women, as a special food for treats at weddings, and other ceremonies (Chinwe *et al*., 2015). However, despite its nutritional value and potential food applications, it is still underutilized (Glew *et al*., 2013). According to Chinwe *et al*. (2015), *Acha* is a food security crop due to its composition which has potentials to serve as a food fortificant. They are gluten-free and are often consumed whole, therefore, are considered as health grains (Jideani, 2012). According to Ayo *et al*. (2018), *Acha* does not only have potentials to contribute significantly to whole grain diets, wellness, economic status improvement, and food security in developing economies, but also, contain significant amounts of micronutrients.

Sweet potato (*Ipomoea batatas*) is a starch-rich tuber crop that is consumed across Nigeria (Okorie and Onyeneke, 2012). It is a vital staple crop that serves as an important food crop of major economic importance in the tropical regions where it is grown (Vimala, 2011). It is ranked among the world's most important, versatile and underutilized food crops (Ezeano, 2010). Majority of sweet potato varieties are less nutritive when compared to the OFSP variety whose rich beta-carotene content is considered as a very cheap source of vitamin A especially for young children (Effiong *et al*., 2018).

One of the problems that militate against food security in developing countries such as Nigeria is postharvest loss and underutilization of locally cultivated food crops. OFSP has a short post-harvest shelf-life due to the rapid physiological deterioration of the root. *Acha* on the other hand, has been reported by Sani and Silas (2012) to be underutilized as a cereal food and underexplored in terms of research when compared to other commonly consumed cereals such as rice and wheat. All these efforts were aimed at reducing dependence of bakeries on wheat flour, improving the nutritional values of cookies and finally, to add value to indigenous crops. In this study, an attempt to increase the utilization of composite flours in cookie production was investigated by the substitution of wheat flours in varying amounts with *Acha* and OFSP flours. Thus, this study aimed at (1) producing cookies from composite flours of wheat, *acha* and whole OFSP. (2) Determining the physicochemical and sensory properties of the cookies produced.

Materials and Methods

Source of raw materials

Acha and wheat grains were purchased from Ubani Main Market, Umuahia. OFSP (UMUSPO4) were procured from National Root Crops Research Institute (NRCRI), Umudike, all in Abia State, Nigeria.

Sample preparation

Production of wheat flour

Wheat grains (plate 1) were processed into flour (plate 4) by using the method described by Peter *et al.* (2017). The wheat grains were sorted manually by removing, stone debris, extraneous materials, washed with clean tap water, drained using a plastic perforated screen, and oven dried (Gallenkemp, 300 Plus, England), at 60°C for 8h. The dried wheat grains were milled using a hammer mill (HMC-HM6630, China), sieved through 0.2mm screen to obtain resultant flour and packaged in a transparent polyethylene bag for further use.

Production of acha flour

The method described by Mbaeyi-Nwaoha and Uchendu (2016) was adopted in the production of *acha* flour. *Acha* grains were sorted, washed (in clean water) and drained of water with a perforated plastic bowl. The clean *acha* grains were oven dried (Gallenkemp, 300 Plus, England) at 50ºC for 6h, milled using hammer mill (HMC-HM6630, China) and sieved (0.2 mm mesh size) to obtain *acha* flour which was packaged in a polyethylene bag until needed.

Production of whole orange fleshed sweet potato flour

Whole OFSP (Plate 3: UMUSPO4) was processed into flour (Plate 6) according to the method described by Adeleke and Odedeji (2010). Sound orange fleshed sweet potato tubers were sorted and washed with clean water and scrapped manually with sharp stainless steel kitchen knife, rewashed and sliced into 2cm thickness and blanched in steam for 2 min. The blanched potato slices were cooled rapidly and oven dried at 60°C for 24 h. Afterwards, the dried potato slices were milled using attrition mill, sieved through 0.2mm screen into resultant flour and packaged in transparent polyethylene bag till further needed.

Composite flour formulations

Composite flours from *acha*, wheat, and whole OFSP flours (plates 4-6) were formulated as shown in Table 1.

Production of cookies from composite flours of wheat, acha and whole OFSP

Cookies were produced according to the method described by Peter-Ikechukwu *et al*. (2017). The ingredients used include: margarine (200g), sugar (120g), egg (125ml), water (75ml), salt (5g), milk flavour (5ml), baking powder (5g). Using an electric mixer (Model 28a-Bl England), margarine and sugar was creamed until fluffy. Exactly 500g flour was added to the mixture and mixed continuously for 60 seconds to form dough. A mixture of egg, milk flavour was added to the dough and thoroughly mixed until stiff dough was formed. The dough was rolled out, cut into circular shapes (5cm diameter) of uniform thickness and baked in a pre-heated oven at 212°C for 15min in the oven. After baking, the cookies were cooled to room temperature, packed in low density polyethylene bags and sealed in an airtight transparent plastic container.

Determination of functional properties of flour samples

Water absorption capacity, oil absorption capacity, wettability, emulsion capacity and emulsion stability, foam capacity, foam stability, Gelatinization temperature were determined according to the method described by Onwuka (2018).

Determination of proximate composition of cookies

The moisture, ash, fat, crude fibre, crude protein contents of the cookies were determined according to the method described by Onwuka (2018) while carbohydrate was calculated by difference. The energy value was estimated using Atwater factors as described by Onwuka (2018).

Determination of carotenoid content of cookies

The spectrophotometric method described by Onwuka (2018) was employed in the determination of carotenoid contents of the cookie samples.

Determination of physical properties of cookies

Determination of height

The height of the cookies samples were determined by measuring them with a calibrated ruler (Ayo *et al*., 2007).

Determination of weight, breaking strength, diameter, spread ratio and thickness

The weight, breaking strength, diameter and spread ratio and thickness of the cookies was determined using the methods described by Bala *et al*. (2015). Thickness of cookies was determined by measuring the diameter of four cookie samples placed edge to edge with a digital Vernier caliper. An average of six values was taken for each set of samples. Average value for thickness was reported in millimeter.

Determination of sensory properties of the cookies

The sensory properties of the cookies samples were evaluated by 25 panelists using a 9-point Hedonic scale as described by Iwe (2014).

Statistical analysis

One Way Analysis of Variance was carried out using the Statistical Product of Service Solution (SPSS) version 23.0. Treatment means were separated using Duncan multiple range test at 95% confidence level ($p<0.05$).

Results and Discussion

Functional properties of the wheat, acha and whole OFSP composite flours

Functional properties of wheat, *acha* and whole OFSP flour blends are presented in Table 2. The water absorption capacity of the composite flours ranged from 1.42-1.79g/ml. The water absorption capacity of the flour composites gradually increased with increase in the proportion of *acha* flour. It was observed that flour blends with OFSP had higher water absorption capacity. The result showed that the control sample (100% wheat) had the least water absorption capacity (1.42g/ml) compared to all the flour composites. Composite flour from wheat:*acha*:whole OFSP (50:40:10) had the highest value for water absorption capacity (1.79g/ml) and this may be due to an alteration in the starch crystalline structure(Twinomuhwezi *et al*., 2020). Water absorption capacity is the capacity of flour to absorb water and swell for enhanced consistency in food (Offia-Olua, 2014). The values obtained in this study for water absorption capacity was higher than the range of values (1.26 - 1.64g/ml) reported for composite flours from water yam and soybean (Olapade and Akinyanju, 2014) and values (1.00 - 1.05g/ml) reported for *Acha*-based flour supplemented with tiger nut flour (Ayo *et al*., 2018). The oil absorption capacity of the flour composites ranged from 1.46-1.74g/ml. The oil absorption capacity of the flour composites followed the same trend as observed in water absorption capacity. Composite flour samples with Wheat:*Acha*:Whole OFSP (50:40:10) had the highest value (1.74g/ml), while the control (100% wheat flour) sample recorded the least (1.46g/ml). There was gradual increase in the values of the oil absorption capacity as the proportion of *acha* flour increased. It was also observed that the flour composite without OFSP flour was significantly lower than other flour composites (Table 2). This indicates that OFSP also has high oil absorption capacity. The oil absorption capacity as a functional attribute contributes to flavour retention and enhanced mouth feel (Iwe *et al.,* 2016). The highest oil absorption capacity (1.74g/ml) recorded for Wheat:*Acha*:Whole OFSP (50:40:10) composite flour could be attributed to lipid binding capacity of the hydrophobic proteins present in the flour (Shrestha and Srivastava, 2017). The flour samples with high oil absorption capacity can therefore, be used in bakery products where fat absorption is desirable (Suresh *et al*., 2015). Composite flour produced from wheat:*acha*:whole OFSP (50:40:10) had the highest value for wettability (1.27 sec.), while the control had the least(0.92 sec.) This is an indication that flour composites with high value of wettability would have slow rate of dispersion in water than that of composite flours with lower wettability values (Ubbor and Akobundu, 2009), such as the control and flour composite from wheat:*acha* (50:50). The variations in wettability values could be attributed to the polarity of the flour molecules, their contact surfaces and their porosity (Mohebby *et al*., 2011).

The foam capacity progressively increased from 9.78 for flour composite from wheat:acha (50:50) to 12.75 % for the control (100% wheat flour) sample. The significant variation in foam capacity of the flour blends implies that their solubilized protein and polar and non-polar lipids which affects foam capacity differed (Zhou *et al*., 2011). The values obtained for foam capacity in this study was higher than 6.67 to 10.33 % reported for wheat and cocoyam flour blends (Anon *et al*., 2021), and 8.20 - 11.28 % reported for finger millet, wheat, soybean and peanut flour blends (Okache *et al*., 2020). This could be attributed to differences in the flour samples. The foam stability of the flour blends ranged from 4.39 to 4.83 %. Composite flours from 100% wheat (control) and wheat: OFSP (90:10) had the highest value (4.83%

respectively) and was not significantly different ($p>0.05$) from each other. Sample with 50:40:10(wheat:acha:OFSP) had the least. According to Acuña *et al*. (2012), flours with high foam stability has more protein-protein interactions at the air-water interface which promotes the formation of a multilayer film which results in viscoelastic resistance. The high foam stability observed in the 100% wheat and wheat: OFSP (90:10) flour samples could be due to the high proportion of wheat in flour samples which contains the highest protein. The significantly lower foam stability values obtained for flours in this study can be attributed to the low protein contents of the raw materials. According to Iwe *et al*. (2016) the foam stability of flours increases with increased protein content. The emulsion capacity of the flour composites ranged from 44.40-50.44%. Composite flour from wheat:*acha* (50:50) had the highest value while the control(100% wheat) had the least. There were significant differences ($p<0.05$) in the emulsion capacity among the flour composites. It was observed that emulsion capacity increased as the proportion of *acha* increases. The range of values obtained for emulsion capacity in this study was higher than 18.57 - 46.36% reported as emulsion capacity of high quality cassava, toasted bambara groundnut and roasted cashew kernel flour blends (Elochukwu *et al*., 2019), and values (16.14 to 22.14 %) reported for wheat, watermelon seeds and cassava composite flour (Ubbor and Akobundu, 2009). Emulsifiers are incorporated into cookie formula to improve dough handling and the product's overall quality (Hoque *et al*., 2009). This shows that Composite flour produced from wheat:*acha*:whole OFSP (50:50:0) will make good emulsifiers compared to other flour samples in this study. Emulsion stability of the flour composites ranged 46.32-52.34%. The composite flour with wheat:*acha*(50:50)*,* had the highest value for emulsion stability. There was significant difference ($p<0.05$) among the composite flours. The result followed the same trend as observed in emulsion capacity. Increased in the proportion of *acha* flour progressively increased the emulsion stability. The significant variation in emulsion stability of the flour samples could be attributed to differences in their pH and solubility (Adebowale *et al*., 2005). The range of emulsion stability obtained in this study was higher than the values (38.38 to 48.65 %) reported as emulsion stability for wheat, rice and potato composite flour (Suresh *et al*., 2015) and values (8.86 to 17.19 %) reported for wheat, watermelon seeds and cassava composite flour (Ubbor and Akobundu, 2009). The gelatinization temperature of the flour blends ranged from 56.50 to 75.00°C. Gelatinization temperature is the temperature at which the gelatinization of starch takes place (Iwe *et al*., 2016). The result of the gelatinization temperature followed the same trend with that of emulsion stability. The gelatinization temperature increased with increase in the proportion of *acha* flour (Table 2). The highest gelatinization temperature (75.00°C) obtained in composite flour with wheat:*acha*:whole OFSP (50:50:0) could probably be as a result of its high carbohydrate content (Table 3). It could also be attributed to the fact that its starch granules were more damaged thus facilitating swelling (Awuchi *et al*., 2019). The lowest value of gelatinization temperature obtained in flour produced from the control (100% wheat) could probably be due to its protein and fat content (Table 3).

Proximate composition of cookies from wheat, acha and whole OFSP composite flours

The proximate composition of cookies (Plates 7-13) produced from the composite flours are presented in Table 3. The moisture content ranged from 10.98% for cookies sample wheat:*acha* (50:50) to 12.53% for the control (100% wheat) sample. It was observed that there was progressive reduction in moisture content as the proportion of *acha* flour increased. This is evidence that cookies sample with high level of *acha* with low moisture content will have a longer shelf life than the cookies produced from the control sample (100% wheat). There was significant difference ($p<0.05$) among the samples in terms of moisture content. According to Ndulaka and Obasi (2018), cookies are generally low moisture foods. Baked products with moisture content less than 13% are stable from moisture-dependent deterioration (Ayo-Omogie and Odekunle, 2015). The moisture content of all the cookies produced was below this specified moisture content indicating that they can be stored at room temperature and be less prone to fungal and microorganism infections (Awuchi, 2019). The crude protein ranged from 9.67-12.23%. The cookies produced from 100% wheat had the highest protein value while the wheat:*acha* (50:50) had the least. This could be attributed to the fact that both *acha* and OFSP are not good sources of protein. Wheat flour has higher protein content (14.70%) than OFSP (Kumar *et al*. (2011) and Ukim *et al*. (2013) and this explains why cookies produced from 100% wheat flour had the highest protein content. The range of crude protein value obtained in cookies produced in this study was higher than values (5.39 - 6.32%) reported for wheat based cookies substituted with OFSP flour (Temesgen *et al*., 2015), but lower than values (12.61 - 15.03%) obtained in cookies from wheat, *Acha* and pigeon pea flour blends (Adeyanju *et al*., 2018). The fat content of the cookies ranged from 7.87% for wheat:*acha* (50:50) to 13.65% for the control (100% wheat). There were significant differences ($p>0.05$) among the fat content of the cookies. Cookies produced from the control sample (100% wheat) had the highest value for fat (13.65 %). Similar finding was reported by Adeyeye (2016) when cookies produced from 100% wheat flour had the highest fat content (9.93%) compared to 6.91 - 8.71 % obtained in cookies supplemented with sorghum flour. More so, the range of fat obtained in this study was lower than 23.09 to 27.33 % reported for cookies produced from wheat and wheat-pumpkin seed flour (Ifesan *et al*., 2020). This could be due to the high fat content of pumpkin seed compared to acha and sweet potato. The crude fibre ranged from 1.54 for cookies produced from 50:50:0(wheat:acha:OFSP) to 2.01 for 90:0:10(wheat:*acha*:OFSP). The result showed gradual reduction of crude fibre of the cookies samples as the proportion of *acha* increased. This suggests that *acha* flour used in this study possess lower crude fibre than wheat flour. The range of crude fibre obtained in this study was lower than 2.56 to 2.98 % reported as the crude fibre content of cookies from wheat, *acha* and pigeon pea flour blends (Adeyanju *et al*., 2018), but higher than 0.82 to 1.64 % reported as for cookies produced from wheat and OFSP (Temesgen *et al*., 2015). Fibre enhances gastro intestinal tract, cardiovascular health, and as well reduce intercolonic pressure thereby reducing the risk of colon cancer (Awuchi, 2019). The ash content of the cookies samples ranged from 2.08% for wheat:*acha*:OFSP (90:0:10) to 2.33%. It was observed that whereas ash content increased with increase in proportions of *Acha*, thus indicating that *Acha* used in this study possess higher mineral content than the wheat and OFSP. Iwe *et al*. (2016) affirmed that the ash content of food gives an idea of the total quantity of the mineral elements in the food. The range of ash obtained in this study was higher than 0.82 to 1.64 % obtained in wheat based cookies supplemented with OFSP flour (Temesgen *et al*., 2015), and values (1.35 to 2.10%) reported as ash content of cookies produced from wheat/cooking banana flour blends (China *et al*., 2020). The carbohydrate content of the cookies ranged from 57.45 to 67.62%. The carbohydrate content of the cookies increased as the proportion of *acha* increases. Cookies produced from wheat:*acha*:whole OFSP flour (50:50:0) had the highest carbohydrate content value (67.62%) and this could probably be due to the significant amount of *acha* flour which Istifanus and Agbo (2016) has reported to be a rich source of carbohydrate. Similar finding was reported by Ufot *et al.* (2018) where whole wheat based biscuit supplemented with 25% *acha* flour had the highest carbohydrate content (68.70%) compared to 67.90% obtained in the control (biscuit processed from 100% wheat flour). The control (100%) cookies samples had the least carbohydrate content. The energy value increased from 379.97 kcal/100g for wheat:*acha*:whole OFSP (50:50:0) to 401.46 for the control(cookies produced from 100% wheat).There were significant differences ($p<0.05$) in the energy value of the cookies (Table 3). Besides carbohydrate content of food products like cookies, protein and fat contents also contribute to their energy value (Ikuomola *et al*. (2017). This explains the high energy value recorded for cookies produced from wheat:*acha*:whole OFSP flour (100:0:0). The range of energy value obtained for cookies in this study was higher than 356.21 - 375.25Kcal/100g reported for cookies produced from wheat, cocoyam and African yam bean flour blends (Igbabul *et al*., 2015).

Carotenoid content of the cookies from wheat, acha and whole OFSP composite flours

The carotenoid contents of the cookies ranged from 1.73kcal/100g for the control sample (100% wheat) and 4.15 kcal/100g for wheat: *acha*:whole OFSP flour (50:40:10). There were significant differences ($p<0.05$) among the carotenoid content of the cookies. It was observed that all cookies containing OFSP flour recorded higher carotenoid content compared to cookies produced from flours without OFSP. Previous study reported that OFSP contain enough carotenoid to meet over 90% of vitamin A needs (Mohanray and Sivasankar, 2014). Similar finding was reported by Temesgen *et al.* (2015) where cookies produced with lesser quantity of OFSP had the least carotenoid content value (0.55 to 10.31µg/100g) while cookies samples containing the highest proportion of OFSP had the highest carotenoid content value (13.11µg/100g).

Physical properties of the cookies from wheat, acha and whole OFSP composite flours

The physical properties of cookies produced are presented in Table 5. The weight of the cookies ranged from 2.67 g to 3.41g. Cookies produced from all the composite flours had higher weights than the control (2.67g). This could be attributed to the high carbohydrate content of the cookies samples compared to the control sample. Although the range of weight for cookies recorded in this study was lower than 18.20 - 19.75g reported for cookies produced from wheat and fermented *Afzelia africana* composite flour (Igbabul *et al*., 2018). The cookies diameter ranged from 4.49 to 5.23. It was observed that all cookies samples with composite flour of OFSP had higher values than the control (100% wheat). Moreover, the diameter was found to increase as the proportion of *acha* flour increased. Diameter determines the quality of flour used (Bala *et al*., 2015). According to Adejuyitan *et al.* (2009), wheat flour has a higher gluten content than its composite counterparts which forms an elastic network and results in the cookies structure contraction during baking. This explains the low diameter value recorded for cookies produced from wheat:*acha*:whole OFSP flour (100:0:0). The thickness of the cookies ranged from 0.83 mm for the control(100% wheat) to 1.92mm for cookies produced from wheat:whole OFSP flour(90:0:10). The higher value for thickness obtained in cookies made with composite flours could be due to the higher adsorption of moisture of the dough owing to the presence of water binding component (Ikuomola *et al*., 2017). Interestingly, Peter-Ikechukwu *et al*. (2017) reported that the higher the thickness of cookies the higher its ability to withstand stress. This implies that cookies from the composite flours have the ability to withstand stress more than the control (100% wheat). The range of thickness obtained in cookies produced in this study was lower than 12.50 - 13.50mm reported for cookies produced from wheat flour and fermented *Afzelia africana* flour (Igbabul *et al*., 2018) and values (9.49 - 10.13mm) of thickness obtained in wheat based cookies supplemented with OFSP flour (Temesgen *et al*., 2015). The differences in the various cookies could be attributed to the thickness of the dough rolled out during processing. The breaking strength ranged from 4.14-4.93kg. Cookies produced from the control sample (100% wheat) had the highest value for breaking strength while cookies produced from wheat:*acha*:whole OFSP (50:50:0) had the least. It was observed that the value of the breaking strength reduces as the proportion of *acha* increased. The reduction could be attributed to the carbohydrate/starch content of composite flours from *acha* and whole OFSP which may not be as hard/strong like that of wheat. Hardness of cookies is caused by the interaction of proteins and starch by hydrogen bonding. A previous study, confirmed that composite flours are utilized in achieving reduced breaking strength during cookies production (Ayo *et al*. (2007). The breaking strength refers to the force required to break cookies and is dependent on the interaction between the proteins and starch hydrogen bonds (Ikuomola *et al*., 2017). The spread ratio of the cookies samples ranged from 3.74-5.09 for cookies samples wheat;*acha*:whole OFSP (50:40:10) and wheat:acha:whole OFSP (90:0:10), respectively. Spread ratio of the cookies reduces with increased in substitution of *acha*. Spread ratio is used to determine flour quality and the rising capacity of the produced cookie (Bala *et al*., 2015). According to Kiin-Kabari *et al*. (2021), low spread ratio values can be attributed to tightly bound starch polymer molecules which results in a less viscous dough of non-wheat flours. The values of spread ratio obtained in cookies produced in this study was lower than 5.20 - 5.93 reported for cookies produced from *acha* and tiger nut (Ayo *et al*., 2018). Cookies thickness can impact spread, increased cookies thickness leads to increased spread (Panghal *et al*., 2018). This is an evident that cookies with the highest value for spread ratio possess high value for thickness. The height of the cookies ranged from 5.71 to 6.00cm for cookies produced from wheat:acha (50:50) and wheat:*acha*:whole OFSP flour (50:40:10) respectively. Height of the cookies increases with increased in substitution of *acha*. The result of the height of the cookies followed the same trend as observed in the spread ratio. According to a previous study, this can be attributed to the proportion of the raw materials in the formulation (Davidson *et al*., 2017). Interestingly, Kolawole *et al*. (2018) opined that consumers may prefer cookies that possess higher height than shorter ones at the same price. The range of height obtained in cookies produced in this study was higher than values (0.42 to 0.52 cm) reported for cookies with added cashew apple fibre (Ebere *et al*., 2015), but lower than values (6.00 to 7.70 cm) reported as height of cookies from wheat and cricket flour blends (Egwujeh *et al*., 2018).

Sensory properties of the cookies from wheat, acha and whole OFSP composite flours

Table 6 shows the sensory properties of cookies. The appearance of cookies produced from wheat:*acha*:whole OFSP flour (50:50:0) was most accepted. This acceptance rate could be a resultant effect of maillard reaction which imparted a brown colour of the cookies during heating (Okwunodulu *et al*., 2019). The value for appearance obtained in this study was higher than the range of values (6.40 to 8.00) reported by Adeyanju *et al*. (2021) for cookies produced from wheat, *acha*, and African yam bean composite flour. In terms of taste, the result ranged from 7.44 for cookies samples produced from wheat:*acha*:whole oramge fleshed sweet potato(90:0:10) to 8.36 for cookies produced from wheat:*acha*:whole OFSP flour (50:50:0). It was observed that cookies samples with equal amount of wheat and acha was most preferred in terms of taste. However, the values for taste obtained in this study were higher than values obtained in wheat based cookies (6.57 - 7.80) substituted with OFSP flour (Temesgen *et al.*, 2015). The result of the texture ranged from 7.40 for cookies sample with wheat:*acha*:whole OFSP (50:40:10) to 8.24 for sample with wheat:*acha*:whole OFSP (50:50:0) obtained in this study was higher than the values (5.90 to 8.00) obtained in cookies produced from germinated pigeon pea, fermented sorghum, and blanched cocoyam flour blends (Okpala *et al*., 2013), and the range of values (6.17 to 8.00) obtained by Temesgen *et al.*(2015) for cookies produced from wheat- OFSP cookies.In terms of aroma, cookies samples produced from the control sample (100% wheat) had the highest value of aroma (8.12), while the least value (7.20) was recorded for cookies sample produced from wheat:*acha*:whole OFSP (90:0:10). However, the result of the aroma obtained in this study connotes 'like moderately' to 'like very much' in the 9 point Hedonic scale (Iwe, 2014) for all the cookies samples. Cookies produced from wheat:*acha*:whole OFSP flour (50:50:0) were mostly preferred in terms of general acceptability and this can be because it was most preferred in terms of appearance, taste and texture which have distinct and influential effects on food acceptability (Piqueras-Fiszman, and Spence, 2015).

Conclusion

This study revealed that incorporation of *acha* and whole OFSP flours in wheat flour enhanced some functional properties of the flours which translated to the production of quality cookies that gained general acceptability. In terms of nutrient contents, cookies produced from the composite flour blends recorded significant amounts of protein, fats, carbohydrates and carotenoids. The result obtained showed that cookies produced from the flour composites had better qualities in terms of physical properties such as weight, diameter, thickness spread ratio and height. These properties could attract consumer preference over the control cookies sample. The result of this study also revealed that, cookies produced from wheat:*acha*:whole OFSP flour (50:50:0) had the highest value(8.52) which denotes Liked very much and was mostly preferred in terms of appearance, taste, texture and general acceptability. However, cookies samples from wheat:*acha*:whole OFSP (70:20:10) competed favourably with the control sample (100% wheat) with the values of 8.08 and 8.36 respectively for overall acceptability. This indicates that *acha* and OFSP flours could be used in the production of acceptable and quality cookies and could also be successfully used for substituting wheat flour up to 70% level in cookies production without adversely affecting the sensory properties of the cookies. Therefore, it is recommended that substitution with up to 70% *acha* flour and 10% of OFSP flour could be used in the production of acceptable cookies with high nutrient value and quality physical attributes compared to the control sample (100% wheat).

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Table 1: Formulation of Composite Flour (%)

Wheat Flour	*Acha* Flour	Whole OFSP Flour
100	0	0
90	0	10
80	10	10
70	20	10
60	30	10
50	40	10
50	50	0

Table 2: Functional properties of wheat, *acha*, whole OFSP composite flours

Sample Wheat:*Acha*: OFSP flour	Water absorption capacity (g/ml)	Oil absorption capacity (g/ml)	Wettability (sec.)	Foam capacity (%)	Foam stability (%)	Emulsion capacity (%)	Emulsion stability (%)	Gelatinization temperature (^{O}C)
100:0:0	$1.42^{d}\pm0.03$	$1.49^{d}\pm0.02$	$0.92^{e}\pm0.03$	$12.75^{a}\pm0.03$	$4.83^{a}\pm0.04$	$44.40^{g}\pm0.02$	$46.32^{g}\pm0.00$	$56.50^{e}\pm2.12$
90:0:10	$1.52^{c}\pm0.01$	$1.54^{c}\pm0.02$	$0.97^{e}\pm0.03$	$12.18^{b}\pm0.03$	$4.83^{a}\pm0.02$	$45.61^{f}\pm0.03$	$47.16^{f}\pm0.02$	$59.00^{de}\pm0.00$
80:10:10	$1.61^{b}\pm0.01$	$1.58^{c}\pm0.02$	$1.06^{d}\pm0.02$	$11.58^{c}\pm0.02$	$4.73^{b}\pm0.02$	$47.34^{e}\pm0.03$	$48.97^{e}\pm0.04$	$60.97^{d}\pm0.04$
70:20:10	$1.74^{a}\pm0.05$	$1.65^{b}\pm0.01$	$1.15^{c}\pm0.02$	$10.95^{d}\pm0.01$	$4.64^{c}\pm0.01$	$48.07^{d}\pm0.04$	$49.56^{d}\pm0.04$	$64.00^{c}\pm1.41$
60:30:10	$1.74^{a}\pm0.01$	$1.70^{a}\pm0.01$	$1.21^{b}\pm0.02$	$10.56^{e}\pm0.03$	$4.48^{d}\pm0.03$	$48.53^{c}\pm0.01$	$50.09^{c}\pm0.02$	$68.50^{b}\pm0.02$
50:40:10	$1.79^{a}\pm0.01$	$1.74^{a}\pm0.02$	$1.27^{a}\pm0.01$	$10.15^{f}\pm0.03$	$4.39^{e}\pm0.02$	$48.99^{b}\pm0.01$	$50.29^{b}\pm0.03$	$73.00^{a}\pm0.02$
50:50:0	$1.73^{a}\pm0.01$	$1.46^{d}\pm0.01$	$0.95^{e}\pm0.03$	$9.78^{g}\pm0.02$	$4.81^{a}\pm0.02$	$50.44^{a}\pm0.02$	$52.34^{a}\pm0.02$	$75.00^{a}\pm0.00$

[a-g] ***Means ± standard deviation of duplicate determination. Means bearing the same superscripts within the same column are not significantly different (p>0.05)***

Table 3: Proximate composition and energy value of cookies from wheat, *acha* and whole OFSP composite flours

Sample. Wheat: *Acha*: OFSP	Moisture content (%)	Crude protein (%)	Fat content (%)	Crude fibre(%)	Ash content (%)	Carbohydrate content (%)	Energy value (Kcal/100g)
100:0:0	$12.53^{a}\pm0.04$	$12.23^{a}\pm0.02$	$13.65^{a}\pm0.01$	$1.99^{a}\pm0.03$	$2.16^{c}\pm0.03$	$57.45^{g}\pm0.04$	$401.46^{a}\pm0.00$
90:0:10	$12.05^{b}\pm0.04$	$11.98^{b}\pm0.02$	$12.58^{b}\pm0.01$	$2.01^{a}\pm0.01$	$2.08^{d}\pm0.02$	$59.32^{f}\pm0.01$	$398.49^{b}\pm0.08$
80:10:10	$11.74^{c}\pm0.03$	$11.46^{c}\pm0.01$	$11.43^{c}\pm0.02$	$1.92^{b}\pm0.03$	$2.23^{b}\pm0.02$	$61.23^{e}\pm0.03$	$393.59^{c}\pm0.02$
70:20:10	$11.47^{d}\pm0.04$	$10.93^{d}\pm0.02$	$10.28^{d}\pm0.02$	$1.81^{c}\pm0.01$	$2.27^{ab}\pm0.03$	$63.31^{d}\pm0.03$	$389.20^{d}\pm0.09$
60:30:10	$11.16^{e}\pm0.02$	$10.37^{e}\pm0.02$	$9.14^{e}\pm0.01$	$1.73^{d}\pm0.02$	$2.29^{a}\pm0.03$	$65.33^{c}\pm0.02$	$385.08^{e}\pm0.04$
50:40:10	$10.85^{g}\pm0.04$	$9.83^{f}\pm0.03$	$7.99^{f}\pm0.02$	$1.62^{e}\pm0.01$	$2.31^{a}\pm0.01$	$67.41^{b}\pm0.03$	$380.83^{f}\pm0.04$
50:50:0	$10.98^{f}\pm0.02$	$9.67^{g}\pm0.02$	$7.87^{g}\pm0.01$	$1.54^{f}\pm0.03$	$2.33^{a}\pm0.03$	$67.62^{a}\pm0.04$	$379.97^{g}\pm0.02$

[a-g] ***Means ± standard deviation of duplicate determination. Means bearing the same superscripts within the same column are not significantly different (p>0.05)***

Table 4: Carotenoid content of cookies from wheat, *acha* and whole OFSP composite flours

Samples. Wheat: *Acha*:Whole OFSP flour	Carotenoid (µg/100g)
100:0:0	1.73^{g}±0.05
90:0:10	2.08^{e}±0.04
80:10:10	3.27^{d}±0.02
70:20:10	3.51^{c}±0.04
60:30:10	3.85^{b}±0.02
50:40:10	4.15^{a}±0.04
50:50:0	1.94^{f}±0.03

$^{a-g:}$ ***Means ± standard deviation of duplicate determination. Means bearing the same superscripts within the same column are not significantly different (p>0.05)***

Table 5: Physical properties of cookies produced from the composite flours

Samples. Wheat: *Acha*: Whole OFSP flour	Weight(g)	Diameter(cm)	Thickness(mm)	Breaking strength(Kg)	Spread Ratio	Height(cm)
100:0:0	2.67^{f}±0.04	4.49^{g}±0.02	0.83^{g}±0.01	4.93^{a}±0.03	4.83^{b}±0.09	5.76^{e}±0.03
90:0:10	2.84^{e}±0.03	4.66^{f}±0.02	1.92^{a}±0.02	4.82^{b}±0.02	5.09^{a}±0.10	5.63^{g}±0.01
80:10:10	3.03^{c}±0.03	4.84^{d}±0.01	1.14^{e}±0.02	4.55^{c}±0.01	4.27^{c}±0.09	5.81^{d}±0.01
70:20:10	3.26^{b}±0.02	4.97^{c}±0.03	1.23^{d}±0.02	4.40^{d}±0.02	4.06^{d}±0.05	5.89^{c}±0.02
60:30:10	3.36^{a}±0.04	5.14^{b}±0.02	1.31^{c}±0.01	4.29^{e}±0.02	3.93^{d}±0.07	5.95^{b}±0.02
50:40:10	3.41^{a}±0.01	5.23^{a}±0.02	1.40^{b}±0.01	4.20^{f}±0.02	3.74^{e}±0.00	6.00^{a}±0.01
50:50:0	2.92^{d}±0.03	4.67^{e}±0.02	1.09^{f}±0.01	4.14^{g}±0.02	4.38^{c}±0.08	5.71^{f}±0.01

$^{a-g:}$ ***Means ± standard deviation of duplicate determination. Means bearing the same superscripts within the same column are not significantly different (p>0.05)***

Table 6: Sensory properties of cookies from wheat, *acha* and whole OFSP composite flours

Samples Wheat: *Acha*: Whole OFSP flour	Appearance	Taste	Texture	Aroma	General acceptability
100:0:0	8.24^{ab}±0.93	8.00^{ab}±1.00	7.72^{ab}±1.28	8.12^{a}±1.28	8.36^{ab}±0.86
90:0:10	7.48^{c}±1.19	7.44^{b}±0.82	7.52^{b}±1.00	7.20^{b}±1.22	7.76^{bc}±1.13
80:10:10	7.76^{bc}±1.09	7.64^{b}±0.81	7.68^{ab}±0.95	7.40^{b}±0.96	7.68^{c}±0.90
70:20:10	7.84^{bc}±1.11	7.72^{b}±1.02	7.96^{ab}±0.89	7.84^{ab}±0.90	8.08^{abc}±0.70
60:30:10	7.68^{bc}±1.11	7.64^{b}±0.91	7.64^{ab}±1.08	7.72^{ab}±1.02	7.96^{abc}±0.98
50:40:10	7.64^{bc}±1.35	7.64^{b}±1.35	7.40^{b}±1.15	7.32^{b}±1.25	7.80^{bc}±1.22
50:50:0	8.72^{a}±0.54	8.36^{a}±0.76	8.24^{a}±0.93	7.72^{ab}±1.09	8.52^{a}±0.96

$^{a-g:}$ ***Means ± standard deviation of duplicate determination. Means bearing the same superscripts within the same column are not significantly different (p>0.05)***

***Plates 1-3**: Unprocessed raw materials (wheat grains, acha grains, OFSP tubers) used for the study*

Plate 1: Wheat grains (Triticum aestivum)

Plate 2: Acha grains

Plate 3: OFSP roots (UMUSPO4)

Plates 4-6: Flour Samples

Plate 4: Wheat flour

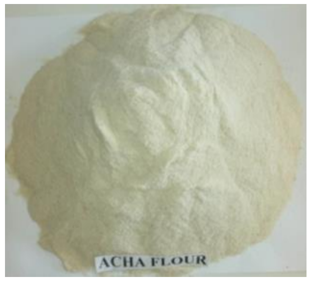

Plate 5: Acha flour

Plate 6: Whole orange fleshed sweet potato flour

Plates 7-13: Cookies samples from wheat, acha and whole OFSP composite flours

Plate 7: Cookies made from 100% wheat flour

Plate 8: Cookies made from 90% wheat flour and 10% whole orange fleshed sweet potato flour

Plate 9: Cookies made from 80% wheat flour, 10% acha flour and 10% whole orange fleshed sweet potato flour

Plate 10: Cookies made from 70% wheat flour, 20% acha flour and 10% whole orange fleshed sweet potato flour

Plate 11: Cookies made from 60% whe flour, 30% acha flour and 10% whol orange fleshed sweet potato flour

Plate 12: Cookies made from 50% wheat flour, 40% acha flour and 10% whole orange fleshed sweet potato flour

Plate 13: Cookies made from 50% wheat flour and 50% acha flour