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Quality Evaluation of Flour and Crackers Made from Acha and Orange-Fleshed Sweet Potato Composite Flour Supplemented with Fermented Cowpea Flour

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Abstract

The present study aimed at evaluating the effects of supplementing 60% acha and 40% orange-fleshed sweet potato (OFSP) composite flour with 0, 10, 20, 30, 40 and 50% fermented cowpea flour on the functional properties of the flour blends and on the proximate composition, mineral content, antinutrients, and sensory characteristics of the crackers made from the blends. The 100% composite of acha and orange-fleshed sweet potato flours served as the control sample. The results obtained showed that all the parameters evaluated varied with the proportion of fermented cowpea flour supplementation. The bulk density increased significantly while the water absorption capacity, oil absorption capacity, pH, wettability, and gelatinization temperature decreased significantly with the increase in fermented cowpea flour supplementation. The moisture and carbohydrate content of the crackers progressively decreased from 8.83% - 8.08% and from 68.34% - 54.33% respectively with increase in cowpea flour supplementation. The ash, fibre, fat and protein contents of the crackers progressively increased from 1.90 - 2.43%, 0.40 – 0.70%, 14.46 – 18.45% and 6.07 – 16.01% respectively with increase in fermented cowpea flour supplementation. The potassium content of the crackers decreased from 87.51 – 68.66 mg/100g while the calcium, magnesium, iron and zinc contents of the crackers increased progressively from 59.16 - 96.61 mg/100g, 12.60 – 36.69 mg/100g, 0.62 – 0.78 mg/100g and 0.78 – 1.08 mg/100g respectively with increase in fermented cowpea flour supplementation. The oxalate and phytate contents of the crackers decreased progressively, while the tannin content increased with increasing fermentation of cowpea flour supplementation. It is evident from the study that acceptable crackers of high nutritional value could be produced from a composite of 60% acha and 40% orange-fleshed sweet potato flour supplemented with 30% fermented cowpea flour. This would increase the utilization of these locally grown crops and reduce wheat importation into the country.

Keywords: Acha, Orange-Fleshed Sweet Potatoes, Cowpea Flour Supplementation, Functional Properties, Crackers, Nutrients, Antinutrients, Sensory Attributes.

Introduction

Crackers are thin and crisp bakery products commonly made of wheat flour, fat, salt and leavening agents (Batista *et al*., 2019). Crackers are popular as snacks and consumed by people of all gender and ages due to their convenience, long shelf-life, low cost, pleasant and varied taste and availability in varied sizes (Ahmed and Abozed, 2015). Based on ingredients used and production method employed, crackers are divided soda crackers or saltines, chemically leavened crackers and savory (flavored) crackers (Maisont *et al*., 2021). Saltine and savory crackers involve a sponge dough fermentation while chemically leavened crackers do not require this step, thereby making their processing easier to manage (Kweon *et al*., 2014). Crackers are considered as a healthy snack option because they contain little sugar, moderate amount of fat and relatively low level of salt (Han *et al*., 2010).

Like other baked products, crackers are traditionally prepared from refined wheat flour. However, a country like Nigeria with unfavourable climatic conditions for commercial wheat production depends on wheat importation to augment local production in order to meet the demands of the users. This wheat importation has negative effects on the economy of the country. Also, products made from refined wheat flour are high in carbohydrate content but low in protein, minerals, vitamins, dietary fibre and other health-protecting constituents. Regular consumption of such unhealthy products could result in protein-energy malnutrition and other diet-related ailments. Furthermore, the consumption of products made from wheat flour or other gluten-containing flours may trigger a problem of gluten intolerance in genetically predisposed individuals, resulting in a condition known as celiac disease. According to Wronkowska *et al*. (2008), the only effective treatment for celiac disease is keeping a strict gluten-free diet throughout the patient's lifetime. The use of composite flours of cereals, legumes, fruits and vegetables from locally grown crops is one of the strategies available for the production of healthy crackers to meet the needs of today's consumers.

Acha (*Digitaria exilis*) commonly referred to as "hungry rice" or "fonio" is an underutilized cereal crop grown in the northern states of Nigeria including Plateau, Bauchi and Kaduna states (Jideani and Jideani, 2011). Acha is a rich source of carbohydrate, fibre, vitamins, minerals, and sulfur-containing amino acids. (Deriu *et al*., 2022). Acha is also a rich source of nutraceuticals such as antioxidants (that contain phenols and waxes) which are known to lower cholesterol (Sadiq *et al*., 2015). Acha is usually consumed as whole grain because of its tiny nature. Consumption of the grain as a whole grain makes it an excellent source of dietary fibre which is associated with a number of health benefits. Kranz *et al*. (2014) reported that increase in dietary fibre consumption could lead to significant lower risks for obesity, type 2 diabetes, constipation, coronary heart diseases and some cancers. Its protein is rich in methionine, an essential amino acid, vital to humans and deficient in major cereals (Olu-owalabi *et al*., 2014). Its utilization in composite flour formulation can add value to the crop and can also lead to its increased utilization. Despite its valuable characteristics and widespread cultivation, acha has generally received limited attention, research and development, which is also why the species is sometimes referred to as an underutilized crop (Rose, 2017).

Orange-fleshed sweet potato (*Ipomoea batatas L*) is a variety of sweet potato developed through conventional breeding in 1995 (Owade *et al.*, 2018). Orange-fleshed sweet potato (OFSP) is a rich source of carotenoids, β-carotene and polyphenols and is gaining importance as the least expensive source of antioxidants which provide several essential health benefits, one of which is the prevention of vitamin A deficiency (Alam *et al.*, 2016). Sweet potatoes have been promoted for their calorie-rich value, but the OFSP variety has been greatly recommended for the reduction of vitamin A deficiency (VAD) in developing countries (Mahmoud and Anany, 2014). OFSP is rich in beta-carotene, a precursor of vitamin A which helps to prevent vitamin A deficiency symptoms like night blindness. Therefore, consumption of OFSP roots can also provide sustainable vitamin A, which plays a major role in preventing and treating night blindness. The total carotene content of OFSP ranges between 19.31- 61.94 microgram/gfw (Islam *et al.*, 2016). According to Mohammad *et al.* (2016), the phenolic acid content of OFSP ranges between 0.130-136.05 mg/100g. The moisture, ash, protein, fat, starch and crude fibre contents of OFSP are 69.42%, 2.04%, 3.69%, 0.42%, 65.41% and 3.68% respectively (Rodrigues *et al.*, 2016). OFSP is also a good source of very important minerals like calcium, iron, potassium, magnesium, zinc and manganese (Sanoussi, 2016). OFSP can be processed into flour for use in the production of bakery products.

Both acha and orange-fleshed sweet potatoes are carbohydrate-based crops that require enrichment with products with high protein content in order to improve the nutritional value of the final product. Flour from legume crops such as cowpea could be incorporated into bakery products to reduce the incidence of protein-energy malnutrition among the consumers.

Cowpea (*Vigna unguiculata L. Walp*) is a multi-purpose, underutilized legume crop mostly grown in dry tropical areas (Boukar *et al.*, 2019). The bulk of cowpea production and consumption is in sub-Saharan Africa where its nutritional value and drought tolerance places it in a unique position in nutrition-sensitive food systems to fight malnutrition, particularly among the most vulnerable— pregnant, lactating women and children under five years (Gomes *et al.*, 2019). Thus, cowpea has been promoted as a high-quality protein constituent of the daily diet among economically depressed communities in developing countries, with the aim of reducing the high prevalence of protein-energy malnutrition (Animasaun *et al.*, 2015). Cowpea is a high-quality plant protein source with a protein content ranging from 23.19-23.60% depending in the genotype (Fabiola *et al.*, 2020). Cowpea is a rich source of iron (61.50mg/kg), zinc (52.75 mg/kg), manganese (12mg/kg) and Cu (5.0mg/kg) (Fabiola *et al.*, 2020). Cowpea is also an important source of antinutrients like phytate, oxalates and tannins (Fabiola *et al.*, 2020).

Statement of Research Problem

The main ingredient in crackers production is wheat flour. Since Nigeria cannot produce sufficient quantity of wheat grains to meet local demands due to unfavourable climatic conditions, wheat is annually imported into the country to augment local production. This

importation has placed a considerable burden on Nigeria's foreign exchange reserves and has negative impact on the economy of Nigeria (Haruna *et al*., 2017).
Secondly, the use of gluten-based flour such as wheat flour for the production of bakery products causes a problem of gluten intolerance in genetically predisposed individuals, resulting in a condition known as celiac disease (Venkatachalam and Nagarajan, 2017).
Thirdly, the use of refined flour from cereal grains without supplementation with legume flours of high protein content to produce crackers or other baked products would give products of low quantity and quality of proteins and would contribute to protein-energy malnutrition that is already prevalent in most communities. It would also give products of low dietary fibre content (Peter-Ikechukwu *et al*., 2018).
Also, despite the nutritional and health promoting constituents in acha, orange-fleshed sweet potato and cowpea, they are underutilized in Nigeria for food product development.

Objectives of the Study

The objectives of the study were to:

- produce flour blends from composites of 60% acha and 40% orange fleshed sweet potato supplemented with fermented cowpea flour and to assess the effect of the supplementation on the functional properties of the flour blends
- assess the effect of the supplementation on the proximate composition, mineral content, antinutrients and sensory properties of crackers made from the blends.

Materials and Methods

Source of Materials

Orange-fleshed sweet potatoes were purchased from a vendor in Oyo state. Acha was purchased from a vendor in Abaji, Abuja, Nigeria. Cowpea, sugar, salt, baking powder and margarine were purchased from Itam market in Itu Local Government Area of Akwa Ibom State.

Samples Preparation

Preparation of acha flour

Acha flour was produced following the method described by Ayo *et al*. (2014). Acha grains were cleaned and destoned using water sedimentation method. Afterwards, they were dried in a hot air oven (model NAAFCO BS Oven: OVH-102, Nigeria) at 55°C for 6 hours. The dried grains were milled using attrition mill, packaged in airtight containers, labelled and kept for subsequent use.

Preparation of orange-fleshed sweet potato flour

OFSP flour was produced according to the method described by Korese *et al*. (2021) with slight modifications. The potato tubers were sorted to remove the damaged ones and washed in potable water to remove the impurities. The tubers were peeled using a stainless kitchen knife and sliced to a thickness of 3 mm. The slices were blanched in hot water at 100°C for 5 minutes. Excess water was drained off and the slices were dried in a hot air oven (model NAAFCO BS Oven: OVH-102, Nigeria) at 60°C till a constant weight was achieved. The dried potatoes were milled using hammer mill and sieved to pass through 250 µm mesh screen. The flour was packaged in an airtight container, labelled and kept for subsequent use.

Preparation of cowpea flour

Cowpea flour was prepared following the method described by Hallen *et al*. (2004). Unfermented, washed and dried cowpeas were milled using attrition mill. The flour was then mixed with potable water (1:4, w/v) to form a slurry followed by the addition of 5% sugar by weight of flour. The slurry was left to ferment in trays at room temperature for 3 days until the pH of the slurry reached 5.50. The fermented slurry was dried in a hot air oven (model NAAFCO BS Oven: OVH-102, Nigeria) at 50°C for 24 hours. The flour was subsequently sieved through 1 mm mesh screen to produce fermented cowpea flour. The fermented cowpea flour was packaged in airtight containers, labelled and refrigerated, prior to use in the production of crackers.

Formulation of composite flour

Composite flour of 60% acha and 40% OFSP was supplemented with 0, 10, 20, 30, 40 and 50% fermented cowpea flour and used for the 60% acha and 40% OFSP experiment. The 100% acha-OFSP composite flour served as control sample. The formulated composite flour blends were analyzed for functional properties while the remaining portions were used for the production of crackers.

Ingredient Formulation and Crackers Production

The ingredients formulation reported by Inyang and Elijah (2020) was used for the preparation of the crackers. The ingredients comprised of flour (400 g), sugar (20.8 g), fat (33.8 g), baking powder (6.52 g), salt (2.08 g) and water (77 ml).

Crackers were produced using the method as described by Inyang and Elijah (2020). Butter, sugar, salt and water were mixed for 1 minute in a dough mixer using the flat beater. The mixture was scraped down and mixed again at high speed for 3 minutes. Flour and baking powder were gradually added to the mixture and mixed at low speed for 3 minutes. The resulted dough was left to rest for 5 minutes and then sheeted to a thickness of 3mm, cut with a square-shaped cutter and baked in an electric oven (model NAAFCO BS Oven: OVH-102, Nigeria) at 170°C for 15 minutes. After baking, the crackers were allowed to cool at room temperature (27°C) for 1 hour. Afterwards, they were packaged in high density polyethylene bags, labeled and used for various determinations.

Methods of Analysis

Determination of pH and functional properties of the composite flour

The bulk density, water/oil absorption capacities, pH, wettability and gelatinization temperature of the composite flour were determined using the method of Onwuka (2018).

Determination of proximate composition of the crackers

The moisture, protein, fat, ash and fibre contents of the crackers were determined using the method described by AOAC (2012). The carbohydrate content was calculated by difference (Onwuka, 2018). The caloric value was calculated using Atwater factor formula as described by Osborne and Voogt (1979).

Determination of mineral content of the crackers

Mineral content (calcium, iron, magnesium, potassium and zinc) was determined using atomic absorption spectrophotometer (UNICAM model 939, UK) as described by AOAC (2012).

Determination of anti-nutrient content of the crackers

The oxalate, tannin and phytate contents of the crackers were determined using the method described by Onwuka (2018).

Sensory evaluation of the crackers

The organoleptic properties (appearance, texture, aroma, taste, after-taste and overall acceptability) of the crackers were assessed by a semi-trained twenty member panelist from the Department of Food Science and Technology, Faculty of Agriculture, University of Uyo, Uyo using a nine-point Hedonic scale as described by Ihekoronye and Ngoddy (1985), where 1 = dislike extremely and 9 = like extremely. The samples served were coded with three-digit random numbers and presented in identical containers. The panelists were asked to rinse their mouth with water provided between the samples to avoid carry over effect. Questionnaire for entering scores were provided to the panel members.

Statistical Analysis

The data obtained were subjected to a one-way analysis of variance (ANOVA) using the Statistical Package for Social Statistics (SPSS Version 21). The means were separated using Duncan's New Multiple Range Test (DMRT).

Results and Discussion

Functional Properties and pH of Acha-OFSP Composite Flour Supplemented with Fermented Cowpea Flour

The functional properties of the composite flour blends are shown on Table 1. The result showed that supplementation of acha-OFSP composite flour with fermented cowpea flour affected the functional properties of the flour blends. The pH of the composite flour supplemented with fermented cowpea flour decreased significantly (P< 0.05) with increase in supplementation with fermented cowpea flour. This could be due to higher acid content in the fermented cowpea flour than in the acha-OFSP composite flour. Fermentation is usually associated with increase in acidity of the product and reduction in pH.

The bulk density increased with increase in cowpea flour supplementation ranging from 0.86 g/cm^3 for the control sample to 0.95 g/cm^3 for the 50% cowpea supplemented flour. Similar observations were reported by Adegunle *et al*. (2014) and Yilma and Admassu (2019) for maize flour supplemented with cowpea flour and wheat flour supplemented with cowpea flour respectively. Bulk density is a measure of the heaviness of solid samples, which is important for determining packaging requirements, material handling and application in the food industry (Oladele and Aina, 2007). The higher the bulk density of the sample, the greater the quantity of material that can be packaged within a specific packaging space. High values of bulk density of flours suggest their suitability for use in food preparations (Hasmadi *et al*., 2010). The increasing bulk density values with increase in cowpea flour supplementation suggest that the fortified composite flours would be suitable for use in different food preparations such as liquids, semisolids or solid foods that require higher values of bulk density.

The water absorption capacity of acha-OFSP composite flour supplemented with fermented cowpea flour decreased significantly (P<0.05) with increase in fermented cowpea flour supplementation. This might be due to the low water absorption capacity of cowpea flour as reported by Obinna-Echem *et al*. (2020). Water absorption capacity is a description of flour to water association ability with limited water supply (Oladele and Aina, 2007). High water absorption capacity indicates that such flour will be useful in the formulation of some foods such as sausage, dough, processed cheese and bakery products (Chandra *et al*., 2019). Therefore, the high water absorption capacity of the composite flours shows that the flours may be useful if applied in production of bakery products.

The oil absorption capacity of the flour blends decreased significantly (P<0.05) with increase in fermented cowpea flour supplementation. The flour's oil absorption ability is essential as it enhances mouth sensation and retains flavor (Bello and Ekeh, 2014). The unfortified flour samples with higher OAC can be useful in bakery products where fat absorption is desirable.

The wettability of the flour blends decreased significantly with increase in cowpea flour substitution. Wettability is a function of the ease of dispersing flour samples in water (Orisa and Udofia, 2020). Composite flours with high value of wettability would have slow rate of dispersion in water than those with lower wettability values Ubbor *et al*. (2022). The decreasing wettability with increase in cowpea flour substitution is an indication that the flours fortified with fermented cowpea flour would have a faster rate of dispersion in water than the unfortified flours.

Gelatinization temperature is the temperature at which the gelatinization of starch takes place (Awuchi *et al*., 2019). The gelatinization temperature of acha-OFSP composite flour supplemented with fermented cowpea flour decreased significantly (P<0.05) with increase in cowpea flour supplementation. This property of starch granules to form a gel when subjected to heat is important in the formulation of baked goods (Iwe *et al.*, 2016). Reduction in gelatinization temperature with increase in cowpea flour supplementation would be of advantage as it would require less energy to cook the product.

Table 1: Functional Properties and pH of Acha-OFSP Composite Flour Supplemented with Fermented Cowpea Flour

Parameters	Blending Ratios (Acha and OFSP Composite flour: Cowpea Flour)					
	100:00	90:10	80:20	70:30	60:40	50:50
pH	5.27^a±0.00	5.11^b±0.00	4.88^c±0.00	4.76^d±0.00	4.65^e±0.00	4.55^f±0.00
B.D (g/cm^3)	0.86^c±0.01	0.87^c±0.01	0.89^b±0.01	0.90^b±0.01	0.95^a±0.00	0.95^a±0.01
WAC (%)	283.33^a±5.77	255.00^b±0.00	240.00^c±0.00	230.00^d±0.00	224.00^e±1.00	220.33^e±0.57
OAC (%)	91.00^a±0.00	86.45^b±0.00	81.56^c±5.77	72.53^d±0.46	57.63^e±2.62	45.33^f±0.28
Wet. (s)	137.00^a±0.00	90.00^b±0.00	78.00^c±0.00	59.00^d±0.00	54.00^e±0.00	51.00^f±0.57
G.T (°C)	78.00^a±0.00	68.00^b±0.00	67.00^c±0.00	66.00^d±0.01	65.00^e±0.00	60.00^f±0.02

Values are means ± standard deviation of triplicate determinations. Means with different superscripts within the same row are significantly different (P<0.05). B.D: Bulk density; WAC: Water absorption capacity; OAC: Oil absorption capacity; Wet: Wettability; G.T: Gelatinization temperature.

Proximate Composition of Crackers made from Acha-OFSP Composite Flour Supplemented with Fermented Cowpea Flour

The proximate composition of crackers made from acha-OFSP composite flour supplemented with fermented cowpea flour is presented in Table 2. The result showed that the moisture content of the crackers decreased significantly (P<0.05) with increase in fermented cowpea flour substitution ranging from 8.83% in the control crackers to 8.08% in the 50% cowpea flour supplemented crackers. This could be due to the lower moisture content of the cowpea flour compared with the acha-OFSP composite flour. Similar observation was reported by Dovi (2013) for biscuits produced from whole sorghum grain flour supplemented with cowpea flour. Moisture content is an indicator of shelf stability (Sanni *et al.*, 2008). High moisture content in foods enhances microbial proliferation (Quinones *et al.*, 2015). The low moisture content of the crackers shows that the crackers can remain shelf-stable for a relatively long period of time without microbial proliferation and subsequent spoilage.

The protein content of the crackers, as expected, increased significantly (P<0.05) with increase in fermented cowpea flour substitution from 6.07% in the control crackers to 16.01% for the 50% cowpea flour supplemented crackers. This could be attributed to the higher protein content of cowpea flour compared to acha and OFSP composite flour. Similar observation was reported by Inyang and Nwabueze (2020) for biscuits produced from acha-green banana flours fortified with cowpea flour Adegunle *et al*. (2014) and Yilma and Admassu (2019) also made similar reports in product supplemented with cowpea flour. Proteins are important components of the human diet and play essential roles as structural and functional components of living systems. Proteins in food provide the body with amino acids which serve as the building blocks of all vital organs, muscles, hormone and biological fluids. Protein deficiency results in health conditions such as kwashiorkor, marasmus and marasmic-kwashiorkor (Chan *et al*., 2017). Due to the high protein content of the composite crackers, consumption of the composite crackers can help alleviate the problem of protein-energy malnutrition prevalent in rural communities within developing countries.

The fat content of the crackers increased significantly ($P<0.05$) with increase in fermented cowpea flour supplementation, ranging from 14.46% for the control crackers to 18.45% for the 50% cowpea flour supplemented crackers. This could be due to the higher fat content in cowpea flour than in acha-OFSP composite flour. Similar observations were reported by Durojaiye *et al*. (2018) for biscuits produced from wheat flour supplemented with Bambara nut and cowpea composite flour. Fat in foods is a high source of energy; serves as a lubricating agent that improves the mouthfeel, flavour and palatability of foods and also serves as a carrier of fat-soluble vitamins (Ikuomola *et al*., 2017).

The ash content of the crackers increased from 1.90% in the control sample to 2.43% in the 50% cowpea flour supplemented crackers. This could be due to higher mineral content of cowpea flour than in acha-OFSP composite flour. Similar observations were reported by Ahmed and Campbell (2012) and Adegunle *et al*. (2014) for bakery products fortified with cowpea flour. Ash content of a food is an indication of the mineral content of that food (Ukpong *et al*., 2020). The higher ash content in the cowpea flour supplemented crackers relative to the control crackers indicates that the cowpea flour supplemented crackers would contain more minerals than the control crackers.

The crude fibre content of the crackers increased from 0.40% in the control sample to 0.70% in the 50% cowpea flour supplemented crackers. This could be due to higher crude fibre content in cowpea flour than in acha-OFSP composite flour. Ahmed and Campbell (2012) similarly reported increase in the fibre content of wheat bread with increase in cowpea flour addition. Fibre increases stool bulk and decreases the time the waste material spends in the gastrointestinal tract (Odom *et al*., 2013). The increasing level of fibre in the crackers indicates that consumption of the crackers produced from acha-OFSP composite flours supplemented with fermented cowpea flour could help abate constipation by increasing stool bulk and reducing the time stool spends in the gastrointestinal tract.

The carbohydrate content of the cowpea flour fortified crackers decreased significantly ($P<0.05$) from 68.34% in the control crackers to 54.33% in the 50% cowpea supplemented crackers. This could be due to the lower carbohydrate content in cowpea flour than in acha-OFSP composite flour. Similar decrease in carbohydrate content of bakery products supplemented with cowpea flour had been reported by other researchers (Ahmed and

Campbell, 2012; Adegunle *et al*., 2014; Inyang and Nwabueze, 2020). The primary role of carbohydrate is to provide energy to cells in the body, particularly the brain, which is the only carbohydrate-dependent organ in the body (Institute of Medicine, 2005).

The energy value of the crackers increased significantly ($P<0.05$) with increase in fermented cowpea flour supplementation ranging from 427.78 kcal/100 g for the control crackers to 447.41 kcal/100 g for the 50% cowpea flour supplemented crackers. The constituents that contributed to the calculated energy value were protein, fat and carbohydrate with fat as the major contributor (9 kcal/g) while protein and carbohydrate contributed 4 kcal/g. This explains why the control cracker with the least fat content recorded the least energy value and 50% cowpea flour supplemented cracker with the highest fat content recorded the highest energy value.

Table 2: Proximate Composition and Energy Value of Crackers made from Acha-OFSP Composite Flour Supplemented with Fermented Cowpea Flour

Parameters	Blending Ratios (Acha and OFSP Composite flour: Cowpea Flour)					
	100:00	90:10	80:20	70:30	60:40	50:50
Moisture (%)	$8.83^{a}\pm0.00$	$8.62^{ab}\pm0.04$	$8.55^{b}\pm1.90$	$8.28^{c}\pm0.04$	$8.12^{c}\pm0.84$	$8.08^{c}\pm0.77$
Protein (%)	$6.07^{f}\pm0.19$	$8.85^{e}\pm0.40$	$11.11^{d}\pm0.40$	$12.71^{c}\pm0.15$	$14.63^{b}\pm0.38$	$16.01^{a}\pm0.40$
Fat (%)	$14.46^{d}\pm0.28$	$15.59^{c}\pm0.51$	$15.83^{c}\pm0.15$	$16.79^{b}\pm0.06$	$17.52^{b}\pm0.47$	$18.45^{a}\pm0.25$
Ash (%)	$1.90^{b}\pm0.11$	$2.27^{a}\pm0.01$	$2.29^{a}\pm0.05$	$2.30^{a}\pm0.02$	$2.36^{a}\pm0.01$	$2.43^{a}\pm0.12$
Fibre (%)	$0.40^{e}\pm0.01$	$0.50^{d}\pm0.00$	$0.56^{c}\pm0.01$	$0.57^{c}\pm0.02$	$0.62^{b}\pm0.02$	$0.70^{a}\pm0.01$
CHO (%)	$68.34^{a}\pm0.18$	$64.17^{b}\pm0.88$	$61.66^{c}\pm0.70$	$59.35^{d}\pm0.21$	$56.75^{e}\pm0.95$	$54.33^{f}\pm0.61$
Energy value (kcal/100 g)	$427.78^{e}\pm1.08$	$432.39^{d}\pm2.65$	$433.55^{d}\pm0.12$	$439.35^{c}\pm0.42$	$443.20^{b}\pm1.93$	$447.41^{a}\pm1.37$

Values are means ± standard deviation of duplicate determinations. Means with different superscripts within the same row are significantly different ($P<0.05$). CHO: Carbohydrate.

Mineral Content of the Crackers Made from Acha-OFSP Composite Flour Supplemented with Fermented Cowpea Flour

The mineral content of the crackers is shown on Table 3. Minerals are important components of the diet which perform various physiological and metabolic functions in the body. They are usually needed in small amount (Soetan *et al*., 2010). The result showed that the calcium content of the crackers increased significantly ($P<0.05$) with increase in fermented cowpea flour supplementation. This could be due to higher calcium content in cowpea flour than in acha-OFSP composite flour. Similar observations were reported by Durojaiye *et al*. (2018) for biscuits produced from wheat flour supplemented with Bambara nut and cowpea composite flour. Calcium is important for developing and maintaining bones and teeth and for supporting the healthy functioning of muscles, nerves and heart (Liliy *et al*., 2017). The calcium content of the crackers can contribute to the recommended daily allowance of calcium of 1000 mg – 1300 mg (FDA, 2016).

The magnesium content of the crackers increased significantly ($P<0.05$) with increase in fermented cowpea flour supplementation ranging from 12.60 mg/100 g in the control cracker to 36.69 mg/100 g in the 50% cowpea flour supplemented cracker. This could be due to higher magnesium content in the cowpea flour than in the acha-OFSP composite flour. Similar observation was reported by Yilma and Admassu (2019) for biscuits produced from wheat flour supplemented with cowpea flour. Magnesium is important for bone health, is needed as a cofactor for numerous reactions in the body and is also essential for nerve and muscle conductivity. According to the United States Department of Agriculture (2018), children require a daily magnesium intake of 80 mg/day. The magnesium content of the crackers can contribute to this required daily intake.

The potassium content of the crackers decreased significantly ($P<0.05$) with increase in substitution with fermented cowpea flour. Inyang and Nwabueze (2020) similarly reported a significant decrease in the potassium content of crackers produced from acha-green banana flour blends fortified with cowpea flour. Potassium has a beneficial effect on sodium balance, and a high dietary intake has been shown to protect human from conditions affecting cardiovascular function (Olagunju *et al*., 2018).

The iron content in the crackers increased significantly with increase in fermented cowpea flour supplementation. This could be due to higher iron content in fermented cowpea flour than in acha-OFSP composite flour. Pereira *et al*. (2014) reported that cowpea is an excellent source of iron and zinc and could be used for the low-income population who suffer from a deficiency of these micronutrients. Iron is needed for the formation of hemoglobin, the component of blood cell that carries oxygen in the blood stream throughout the body. Adequate iron in the diet is essential to minimize the incidence of iron deficiency anemia, which is considered as the most common nutritional disorder worldwide (Short *et al*., 2013). The iron content of the composite crackers can contribute to the required daily intake (RDI) of 7 mg/day for children as recommended by the United States Department for Agriculture (2018).

The zinc content of the composite crackers also increased significantly ($P<0.05$) with increase in fermented cowpea flour supplementation. Similar observation was reported by Hama-Ba *et al*. (2019) for biscuits made from millet supplemented with cowpea and Bambara groundnut composite flour. Zinc in the diet is essential for the synthesis of DNA and RNA, protein, insulin and for proper functioning of immune system (Lilly *et al*., 2017). Its deficiency can affect normal growth and development of children.

Table 3: Mineral Content of Crackers made from Acha-OFSP Composite Flour Supplemented with Fermented Cowpea Flour (mg/100 g)

	Blending Ratios (Acha and OFSP Composite Flour: Cowpea Flour)					
Para-meters	100:0	90:10	80: 20	70:30	60:40	50:50
Ca	59.16^{c} ± 0.68	80.00^{b} ± 0.00	80.30^{b} ± 1.40	80.62^{b} ± 0.00	98.87^{a} ± 0.01	96.61^{a} ± 0.01
Mg	12.60^{c} ± 0.84	24.02^{b} ± 0.01	24.03^{b} ± 0.00	24.13^{b} ± 0.01	35.57^{a} ± 0.85	36.69^{a} ± 0.85
K	87.51^{a} ± 0.15	85.44^{b} ± 0.05	78.36^{c} ± 0.05	76.36^{d} ± 0.05	69.46^{e} ± 0.05	68.66^{f} ± 0.05
Fe	0.62^{d} ± 0.00	0.65^{c} ± 0.00	0.73^{b} ± 0.01	0.74^{b} ± 0.00	0.77^{a} ± 0.01	0.78^{a} ± 0.01
Zn	0.78^{f} ± 0.00	0.81^{e} ± 0.01	0.86^{d} ± 0.00	0.94^{c} ± 0.00	1.02^{b} ± 0.01	1.08^{a} ± 0.01

Values are means ± standard deviation of duplicate determinations. Means with different superscripts within the same row are significantly different (P<0.05).

Antinutrient Content of Crackers made from Acha-OFSP Composite Flour Supplemented with Fermented Cowpea Flour

The antinutrient content of the crackers is shown on Table 4. Antinutrients are substances that reduce the nutritional values of food by reducing the bioavailability, digestibility and utilization of some nutrients (Adeola and Ohizua, 2018). The result showed that the oxalate content of the composite crackers decreased significantly (P<0.05) with increase in fermented cowpea flour substitution, ranging from 0.12 mg/100 g for the control crackers to 0.08 mg/100 g for the 50% cowpea flour supplemented crackers. This could be due to the lower oxalate content of cowpea flour than in acha-OFSP composite flour. Oxalates bind calcium and magnesium and interfere with their absorption and metabolism (Abong *et al*., 2020). Consumption of high levels of oxalate causes corrosive gastroenteritis, shock, low plasma calcium, high plasma oxalates and renal damage (Ariyo *et al*., 2022). The levels of oxalate in the composite crackers were generally low and within the permissible levels of 3-5 mg/kg (Schiavone *et al*., 2007).

The tannin content of the composite crackers increased significantly (P<0.05) with increase in fermented cowpea flour supplementation, ranging from 0.76% in the control cracker to 1.69% in the 50% cowpea flour substituted cracker. This could be due to the higher tannin content in the cowpea flour than in the acha-OFSP composite flour. The findings of this study negate that of Yilma and Admassu (2019) who reported a decrease in the tannin content of biscuits produced from wheat flour supplemented with cowpea flour. Tannins form complexes with minor elements such as phosphorus, calcium, magnesium, etc, as well as with major elements such as carbohydrate and proteins, rendering them unavailable for utilization by the body (Sharma *et al*., 2019). The tannin content of the crackers was within the safe limit of 1.5 g - 2.5g (Sharma *et al*., 2019).

The acha-OFSP composite cracker (control sample) had higher phytate content than all the crackers with fermented cowpea flour supplementation. This might be due to higher phytate content in the acha-OFSP composite flour than in the fermented cowpea flour. The findings of this study disagree with that of Yilma and Admassu (2019) who reported an increase in the phytate content of biscuits produced from wheat flour supplemented with cowpea flour. Phytates have been reported to be widespread in plant grains, including cereals, roots and tubers (Onwuka, 2014). Phytates normally form complexes with protein (protein-phytate complex), chelate dietary minerals like calcium, magnesium, iron and zinc and lower their bioavailability (Grosvenor and Smolin, 2002). Methods such as cooking, soaking in an acid solution, lactic acid fermentation and sprouting can reduce phytates (Onwuka, 2014). The low phytate content of the crackers is an indication that the composite crackers are safe for human consumption.

Table 4: Antinutrient Content of the Crackers made from Acha-OFSP Composite Flour Supplemented with Fermented Cowpea Flour

Parameters	Blending Ratios (Acha and OFSP Composite Flour: Cowpea Flour)					
	100:0	90:10	80: 20	70:30	60:40	50:50
Oxalate (mg/100g)	$0.12^{a} \pm 0.01$	$0.10^{b} \pm 0.00$	$0.10^{b} \pm 0.01$	$0.09^{bc} \pm 0.00$	$0.09^{bc} \pm 0.01$	$0.08^{c} \pm 0.00$
Tannin (%)	$0.76^{e} \pm 0.01$	$0.78^{e} \pm 0.02$	$0.86^{d} \pm 0.01$	$0.89^{c} \pm 0.01$	$1.16^{b} \pm 0.01$	$1.69^{a} \pm 0.01$
Phytate (%)	$0.16^{a} \pm 0.01$	$0.14^{b} \pm 0.00$	$0.13^{b} \pm 0.01$	$0.10^{c} \pm 0.01$	$0.13^{b} \pm 0.00$	$0.13^{b} \pm 0.01$

Values are means ± standard deviation of duplicate determinations. Means with different superscripts within the same row are significantly different (P<0.05).

Effect of Supplementing Acha-OFSP Composite Flour with Fermented Cowpea Flour on Sensory Attributes of Crackers made from the Blends

Sensory evaluation of food is important because it helps to assess the level of acceptability of the product by the consumers. Mean sensory scores for the produced crackers (Table 5) showed that supplementation of acha-OFSP composite flour with fermented cowpea flour affected the sensory attributes of the crackers evaluated. The mean score values for appearance and taste of the crackers substituted with up to 30% fermented cowpea flour did not differ significantly (P>0.05) from the values for the control crackers but at the 40-50% substitution levels, the mean score values were significantly (P<0.05) lower than those of the control crackers. Appearance is an important sensory attribute that induces the first response for the product by the consumers. Both appearance and taste of a food are sensory attributes that ultimately determine its acceptance or rejection by the consumers. The sensory mean score values for the aroma of the crackers showed that supplementation of acha-OFSP composite flour with fermented cowpea flour did not have significant effect (P>0.05) on the aroma of the crackers.

For the crispiness of the crackers, the 30% fermented cowpea flour supplemented cracker had the highest mean score value (6.45) which was significantly (P<0.05) higher than the mean score values for the control sample (4.85) and the 50% cowpea flour supplemented cracker with a value of 4.35. There were however insignificant differences (P>0.05) between the mean score values for the crispiness of the control cracker and the 10, 20, 40 and 50% cowpea flour supplemented crackers.

For the after-taste, the sensory mean scores showed that the 10% and 50% cowpea flour supplemented crackers were not significantly different from the control crackers. However, the sensory score for the 40% cowpea flour supplemented crackers was significantly (P<0.05) lower than the 20% and 30% cowpea flour supplemented crackers. The 30% cowpea flour substituted cracker had the highest mean score for after-taste. Aftertaste is defined as the lingering sensation, flavour or taste in the mouth after the food item has been swallowed (Amyoony *et al.*, 2023).

For the overall acceptability of the crackers, the mean scores by the panelists ranged from 6.00 for the 50% cowpea flour supplemented crackers to 7.85 for the 20% cowpea supplemented crackers. The mean score value for the control crackers (7.50) did not differ significantly from the values for the crackers supplemented with up to 30% fermented cowpea flour. The mean score values for the overall acceptability therefore revealed that acceptable crackers were made from the control crackers and crackers supplemented with up to 30% fermented cowpea flour.

Table 5: Effect of Supplementing Acha-OFSP Composite Flour with Fermented Cowpea Flour on Sensory Attributes of Crackers made from the Blends

Parameters	Blending Ratios (Acha and OFSP Composite Flour: Cowpea Flour)					
	100:0	90:10	80: 20	70:30	60:40	50:50
Appearance	$7.40^{a} \pm 1.50$	$7.20^{ab} \pm 0.89$	$6.85^{abc} \pm 1.63$	$6.90^{abc} \pm 1.48$	$5.75^{c} \pm 2.34$	$6.05^{bc} \pm 2.28$
Taste	$6.15^{a} \pm 1.89$	$6.10^{a} \pm 1.91$	$5.50^{ab} \pm 1.93$	$6.55^{a} \pm 1.76$	$4.50^{b} \pm 2.23$	$4.60^{b} \pm 2.50$
Aroma	$6.45^{a} \pm 2.16$	$6.25^{a} \pm 1.61$	$5.75^{a} \pm 2.09$	$6.25^{a} \pm 1.83$	$5.25^{a} \pm 2.75$	$4.95^{a} \pm 2.68$
Crispiness	$4.85^{b} \pm 2.30$	$5.65^{ab} \pm 1.81$	$5.90^{ab} \pm 1.97$	$6.45^{a} \pm 2.32$	$5.20^{ab} \pm 2.44$	$4.35^{b} \pm 2.47$
After-taste	$5.45^{ab} \pm 1.82$	$5.75^{ab} \pm 1.77$	$5.90^{a} \pm 2.07$	$6.10^{a} \pm 1.91$	$4.40^{b} \pm 2.30$	$5.10^{ab} \pm 2.61$
Overall acceptability	$7.50^{ab} \pm 2.23$	$7.35^{ab} \pm 1.84$	$7.85^{a} \pm 2.15$	$7.65^{a} \pm 1.89$	$6.80^{ab} \pm 2.52$	$6.00^{b} \pm 2.91$

Values are means ± standard deviation of triplicate determinations. Means with different superscripts within the same row are significantly different (P<0.05).

Conclusion

The study has shown that acceptable crackers of high nutritional value could be produced from composite flours of 60% acha and 40% orange fleshed sweet potato supplemented with up to 30% fermented cowpea flour. Supplementation of acha-OFSP composite flour with fermented cowpea flour in the production of crackers resulted in increase in the nutrient composition of the crackers. The use of these locally grown underutilized crops to produce gluten-free crackers would help to reduce the nation's reliance on wheat importation, conserve her foreign exchange earnings, increase the utilization of these crops and increase the farmer's income. The high protein content in the crackers would contribute to addressing the problem of protein energy malnutrition that is still prevalent in most communities.

Recommendations

Based on the findings of this research work, it is recommended that:

- acceptable crackers of high nutritional should be produced from 70% acha-OFSP and 30% fermented cowpea flour blends;
- further research should be carried out to determine the amino acid profile as well as the bioavailability of nutrients in the crackers.

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