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Chemical Composition and Storage Stability of Crunchy Snacks Produced from Corn, Red Kidney Beans and Onion Flour

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Abstract

Corn flour is a very important ingredients in producing crunchy snacks. However, the use of other plant sources to supplement corn flour in producing crunchy snacks is not uncommon. This study thus investigated the chemical composition and storage stability of crunchy snack produced from corn, red kidney beans and onion flour. Three samples **EOD**: Corn: Red Kidney Bean: Onion (70:25:5%); **XYZ**: Corn: Red Kidney Bean: Onion (70:20:10%); **FAV**: Corn: Red Kidney Bean: Onion (70:15:15%) and a control **ABC**: Oyato crunchy snack, were analysed for proximate, mineral, free fatty acid (FFA), thiobarbituric acid (TBA), saponification value (SV), peroxide value (PV), Microbial population and Sensory properties. Proximate Composition; moisture content ranged from 4.03 - 15.33% and crude protein content ranged from 3.33 – 9.52% among the samples. Mineral Composition; P, Ca, Na and Cd ranged between, 31.52 – 51.63 mg/100g, 3.57-4.53 mg/100g, 181.80-314.40 mg/100g, and not detected respectively for the samples. FFA had first month 2.45 – 5.33% and second month 3.14 – 5.33%. Storage stability; TBA first month had 0.18 to 0.51 mgMDA/Kg and second month 1.67 – 2.36 mgMDA/Kg; SV first month had 7.04 - 68.85 mgKOH/g and second month 7.65 to 103.70 mgKOH/g; PV first month had 3.50 to 20.00 meq/Kg and second month 8.50 to 21.50 meq/Kg. The microbial population was relatively low and within safe limits, total viable and fungi count 1.5-7.0×10^2 Cfu/g and 2.5-9×10^2 cfu/g after the first month respectively; total viable and fungi count 9.0-45×10^2 cfu/g and 5.0-25×10^2 cfu/g after second month respectively. There were no significant differences ($p< 0.05$) in the crunchiness, mouthfeel and overall acceptability of formulated crunchy snack samples and the commercial crunchy snack. The crunchy snacks investigated in this study has a good sensory evaluation and storage stability.

Keywords: *Corn, Onions, Red kidney beans, Crunchy Snacks, Flour, Storage*

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1. Introduction

Corn (*Zea mays* L.) is an important annual cereal crop of the world belonging to family Poaceae. The word "maize" is best described using Spanish connotation "maiz" (Shah *et al*., 2016). Corn is one of the major food sources in the world (Adiaha, 2018). Compared to wheat and rice, corn is a more versatile multi-purpose crop (Erenstein *et al*., 2022) which contains significant amounts of bioactive compounds with desirable health benefits beyond its role as a staple food (Sheng *et al*., 2018). Corn flour is very important in producing crunchy snacks.

Most snacks such as cookies are low in protein and if present it's often of poor nutritional quality (Adegbanke *et al*., 2019). In sub-Saharan Africa, the use of other plant sources to supplement corn flour in producing crunchy snacks is not uncommon due to lack of protein and essential nutrients in diet of many households especially among the rural poor (Ojuederie *et al*., 2020). Examples of these plant based supplements are red kidney beans and onion flours. Also, the low purchasing power in getting animal source protein has promoted the use of plant protein sources to supplement crunchy snacks.

Red kidney beans (*Phaseolus vulgaris L.*) are a variety of the common bean (*P. vulgaris*), so named because of its kidney-like shape and its colour. It is a major legume cultivated in parts of East Asia including Indonesia and consumed for its edible seeds and pods over the world (Sutedja *et al*., 2020). According to Rawal and Navarro (2019) about 12 million tonnes of Red Kidney Beans are produced globally per annum which contains numerous bioactive compounds and some nutritional components, such as proteins, resistant starch, dietary fibre, and fat (Ibeabuchi *et al*., 2017). The seed coat of red kidney beans is red, which indicates that it may be a good source of polyphenols as coloured beans are often found to contain polyphenols (Sutedja *et al*., 2020). It is an important tropical legumes used to enhance the protein content in diet of low and medium income earners who cannot afford protein from conventional animal source because of their high prices in Nigeria (Inyang *et al*., 2018). Red kidney beans have extraordinary health benefits due to high quantities of folic acid, calcium, carbohydrates, fibre and proteins amongst the proper functioning of the body (Noah and Banjo, 2020).

Onion (*Allium cepa*), also called a bulb onion, common onion and garden onion is the most widely cultivated species of the genus Allium globally (Mehta, 2017). It is cultivated prominently in the northern part of Nigeria. Onion has been evaluated as an excellent source of flavonoids polyphenols and sulphur containing compounds and dietary fibre (Ren and Zhou, 2021). They among the initially cultivated crops of the world probably due to its greater shelf life and portability (Masood *et al*., 2020) and revered through the ages not only for its culinary uses but also for its therapeutic properties (Bala *et al*., 2021).

Considering the nutritional and confectionery characteristics of corn flour, together with the nutritional profile of red kidney beans, the incorporation of these two with onion flour - a rich source of bioactive substances promises to be a nutritional combination with great prospects.

2. Materials and Methods

2.1 Source of Materials

Corn flour, red kidney beans and onion bulbs were purchased from “Erekesan” market in Akure, Ondo State. All reagents used were of analytical grade.

2.2 Sample Preparation

2.2.1 Preparation of red kidney bean flour

The red kidney beans flour was produced with slight modifications according to the method of Bedier *et al.* (2021). The seeds were thoroughly cleaned, soaked for 24 hours at room temperature (27±2 °C), and the soaked water was drained off. The beans were blanched in hot water (1:5 w/v) at 100 °C for 30 min, drained, washed with fresh water then manually dehulled by hand, drained, oven dried and milled. After milling, it was then sieved through a 425 µm mesh screen, packaged in an air tight container, labelled and stored at 4 °C for subsequent use.

2.2.2 Preparation of onion powder

The onion powder was produced with modifications following the method of Watson *et al.* (2000) and Abiola *et al*. (2017). The peels were peeled off manually using a sterile knife and the bulbs were chopped further and sun-dried over a period of 60-70 hrs at 40 °C. The dried onions were then grinded into fine powder and kept in an airtight jar till when needed analysis.

2.2.3 Formulation of corn flour with red kidney bean and onion flours

The blending ratios used for the present study are as shown in Table 1. The Oyato crunchy snack served as the control sample (ABC**)**.

Table 1: Blending Ratio (%) of Corn Flour with Red Kidney Bean and Onion flours.

Samples	EOD	XYZ	FAV
Corn flour	70	70	70
Red Kidney Bean flour	25	20	15
Onion flour	5	10	15

2.3 Methods

2.3.1 Proximate composition

The proximate composition (moisture content, crude fibre, fat, total ash, and crude protein contents) of the dough meal samples were determined as described by AOAC (2012).

2.3.2 Determination of mineral composition

Mineral composition (Phosphorus, Calcium, Potassium, Lead, Sodium, Cadmium, Manganese, Copper, Iron, and Zinc) were evaluated as described by AOAC (2012). Five grammes (5 g) of each crunchy snack samples were digested with a mixture of nitric and hydrochloric acids (1:1 v/v) and filtered respectively. The filtrate was made up to 5 mL mark in a volumetric flask. Filtered solution was loaded to Atomic Absorption Spectrophotometer, (Buck Scientific Model 210 VGP). The standard curve for each mineral was prepared from known standards and the mineral value of samples estimated against that of the standard curve. Phosphorus was determined using vanado-molybdate method.

2.4 Storage Stability

2.4.1 Determination of Thiobarbituric Acid (TBA)

Thiobarbituric acid of the samples were determined according to Zeb and Ullah (2016). Sample 5 g was dispersed into 50 mL of distilled water in a distillation flask. 25ml of 4MHcl is added to bring the pH to 1.5 followed by an anti-foam preparation and a few glass beads. The flask was heated by means of an electric mantle and so the 50ml distillate was collected after 10min. 5ml of the distillate was pipetted into a conical flask, and 5ml of TBA reagent was added and heated in a boiling water bath for 35min, and the results were obtained.

2.4.2 Determination of Free Fatty Acid (FFA)

The acid value of the oil was determined using titrimetric method according to Di Pietro *et al*., (2020). About 5g of oil was taken in 250ml conical flask, and then 25ml of neutral ethyl alcohol was added to it and then boiled in a water bath. About 1- 2 drops of Phenolphthalein indicator solution was added to the mixture and it was titrated against standard potassium hydroxide solution until a pink end point was reached. Acid value was calculated using equation 1;

$$\text{Acid value} = \frac{V \times N \times 56.16}{W} \qquad \text{Eqn 1}$$

Where, V = Volume of standard KOH solution in ml
N = Normality of standard KOH solution
W = Weight of oil sample in grammes

2.4.3 Determination of saponification value

The saponification value was determined according to AOAC (2012). One gramme (1 g) of the sample was taken and put in a conical flask to which 25ml of O.5 N alcoholic KOH was added and heated under a reserved condenser for 30-40 min to ensure that the sample was fully dissolved. After the sample was cooled, phenolphthalein was added and titrated against 0.2 N HCl until a pink end point was reached. A blank was also determined with the same conditions. The saponification value was calculated using equation 2;

$$\text{Saponification value} = \frac{(B \times T) \times N \times 56.1}{W} \qquad \text{Eqn 2}$$

Where, B = ml of HCl required by blank
T = ml of HCl required by oil sample
N = Normality of HCl
W = Weight of oil in gram

2.4.4 Determination of peroxide value

The Peroxide value (PV) is a measure of the concentration of substances that oxidize potassium iodide to iodine and was carried out according to the method of CTOFs. About 5g of oil samples was dissolved in Acetic acid and chloroform, then saturated Potassium Iodide mixture was added to the sample and the amount of iodine liberated from Potassium Iodide by the oxidative action of peroxides present in the oil was determined by titration with 0.1 N sodium thiosulphate using starch solution as an indicator. Titration was also performed for blanks. The Peroxide Value was calculated using equation 3;

$$\text{Peroxide Value} = (S - B)\, x\, W\, x\, N \qquad \text{Eqn 3}$$

Where, S = Volume of sodium thiosulphate consumed by the sample oil
B = Volume of sodium thiosulphate used for blank
W = Weight of oil sample
N = the normality of sodium thiosulphate

2.4.5 Determination of microbial population

The pour plate method of Sanders (2012) was used to determine microbial count of crunchy samples. The pour plate method was used for culture. About 1ml of the sample was taken aseptically with a sterile pipette and transformed carefully into each of the test tubes containing 9ml of cooled sterilized diluent, each samples in different test tubes were mixed thoroughly to ensure dislodgement and even distribution of microorganisms into the suspended sterile water. A two-fold serial dilution of each 1ml homogenate was prepared. Exactly 1.0 ml of dilution factor 10^{-2} were inoculated into the sterile petri dishes for culturing. Incubation was carried out at 37 °C for 24 h for bacteria growth. Colonies were counted in order to obtain the total viable count using colony counter. Colony counting was carried out visually by counting the number of visible colonies that appeared on the plates.

2.5 Sensory Evaluation

The sensory evaluation was carried out on crunchy snack samples following the method of Adegbanke *et al*., (2019). The sensory quality attributes were appearance, aroma, texture, taste, and overall acceptability of the four (4) crunchy snack samples were evaluated by a total of twenty (20) untrained panellists from the Federal University of Technology, Akure. The panellists were instructed to score the coded samples based on a 9-point hedonic scale with 1 as disliked extremely and 9 as liked extremely.

2.6 Statistical Analysis

Analyses were carried out in triplicates and data generated were subjected to One-Way Analysis of Variance (ANOVA) using Statistical Package for Social Sciences (SPSS) version 23.0. The means were separated using New Duncan Multiple Range Test (NDMRT) at 95% confidence level ($p \leq 0.05$).

3. Results and Discussion

3.1 Proximate Composition of Crunchy Snacks

The proximate composition of crunchy snacks formulated from corn, red kidney beans and onion flour plus a control crunchy snack sample Table 2. The proximate composition shows the amount and distribution of the various major nutrients present in these crunchy snack samples. The ash content which is an indication of the mineral contents ranged from 6.74 to 10.67 g/100g with ABC as the highest and XYZ as the lowest. Thus, the high ash contents in the samples in this present study is an indication of high content of micronutrient which is needed in the body. These values were slightly higher than those reported by Omoba and Alokun-Adesanya (2013) on a ginger spiced maize snack “kokoro”. Crude fat content ranged from 1.91 to 5.06 g/100g with EOD as the lowest and FAV as the highest against the control – ABC at 2.41 g/100g. The fats content reported herein were quite different from the values reported by Omoba and Alokun-Adesanya (2013) on a ginger spiced maize snack “kokoro” with soy powder. This is due to the low fat content of red kidney beans and onions used in this study compared to soy flour. The low fats content observed in these samples may reduce the possibility of deterioration due to rancidity. The moisture content (MC) ranged from 5.92 to 15.33 g/100g across formulated snacks groups, all of which were higher than the control – ABC (4.03 g/100g). EOD had the lowest MC (5.92 g/100g) while FAV had the highest (15.33 g/100g). The increase in MC observed across the group is due to the 5% increase in Onion flour, as it hydroscopic in nature. Samples with lower moisture will have a longer shelf life as higher moisture content promotes deterioration reactions. Likewise, Crude fibre across formulated group was higher than the control group – ABC (14.92 g/100g), ranging from 15.42 to 18.45 g/100g. EOD had the lowest crude fibre (15.42 g/100g) followed by XYZ and FAV in an increasing order. The reduction in crude fibre is due to the reduction in red kidney beans across the group. Hence, an increase or incorporation of red kidney beans into a snack formulation is an increase in expected crude fibre. The crude protein content of the formulated snacks ranged from 5.39 to 9.52 g/100g. The observed increase across FAV to EOD is due to the increase in red kidney beans, as it is a good source of protein. Accordingly, protein content across group was more than that of ABC (3.33 g/100g). The carbohydrate content across formulated snack groups ranged from 46.16 to 57.73 g/100g. The carbohydrate content across formulated snack groups were all lower than that of the control group – ABC (64.64 g/100g).

Table 2: Proximate Composition (%) of Crunchy Snacks

Sample	Moisture Content	Crude Fibre	Crude Protein	Ash	Crude Fat	Carbohydrate
EOD	5.92^{c}	15.42^{c}	9.52^{a}	9.50^{bc}	1.91^{d}	57.73^{b}
XYZ	10.81^{b}	17.71^{b}	7.42^{b}	6.74^{d}	2.98^{b}	54.36^{c}
FAV	15.33^{a}	18.45^{a}	5.39^{c}	9.60^{bc}	5.06^{a}	46.16^{d}
ABC	4.03^{d}	14.92^{d}	3.33^{d}	10.67^{a}	2.41^{c}	64.64^{a}

Mean value with the same superscript across the same column are not significantly different ($p<0.05$). **Keys: EOD**: Corn: Red Kidney Bean: Onion (70:25:5%); **XYZ**: Corn: Red Kidney Bean: Onion (70:20:10%); **FAV**: Corn: Red Kidney Bean: Onion (70:15:15%); **ABC**: Oyato crunchy snack

3.2 Mineral Composition of Crunchy Snacks

The mineral composition in mg/100g of crunchy snack samples is presented in Table 3. The mineral content of a snacks indicates the amount and type of minerals present. It also checks the presence of toxic elements which may cause the food to be unsafe for consumption. The Phosphorus, Calcium, Potassium, Lead, Sodium, Cadmium, Manganese, Copper, Iron, and Zinc content were examined and the abundant minerals in the crunchy snacks were phosphorus, potassium and sodium. The results showed that the crunchy snack will enhance the release of phosphorus which is a good source of bone forming elements. The phosphorus content ranged from 31.52 – 51.63 mg/100g with ABC as the lowest and FAV as the highest. Calcium ranged from 3.57-4.53 mg/100g. Accordingly, EOD had the lowest calcium content while FAV had the highest content. The potassium content ranged from 78.60 – 118.50 mg/100g. ABC the control sample had the lowest potassium content while EOD had the highest potassium content. Potassium is a major nutrient present which has a good significance because an average human diet is deficient in it (Rouf *et al*., 2016). The sodium content was rather highest across the analysed mineral elements. The Sodium ranged from 181.80-314.40 mg/100g. The high sodium and potassium content observed may be unfavourable as high sodium is implicated in coronary diseases like high blood pressure. Fortunately, these also acts as electrolytes and are important and useful in maintaining fluid and blood volume.

Cadmium and lead was not detected in all the samples, indicating the absence of this heavy metal in the crunchy snack. The manganese which is an element needed is small quantity ranged from 0.06 – 0.11 mg/100g. FAV had the highest Manganese with 0.16 mg/100g and closely followed by EOD and XYZ at 0.11 mg/100g while the control sample (ABC) had the lowest value with 0.06 mg/100g.

Table 3: Mineral Composition (mg/100g/%) of Crunchy Snacks

Sample	P	Ca	K	Pb	Na	Cd	Mn	Cu	Fe	Zn
EOD	49.40 ± 0.05^{bc}	3.57 ± 0.03^{cd}	118.50 ± 0.28^{a}	ND	314.40 ± 0.57^{a}	ND	0.11 ± 0.00^{bc}	0.08 ± 0.00^{bc}	2.39 ± 0.01^{b}	0.18 ± 0.00^{a}
XYZ	48.92 ± 0.02^{bc}	3.41 ± 0.03^{cd}	93.30 ± 0.28^{c}	ND	214.20 ± 0.99^{b}	ND	0.11 ± 0.00^{bc}	0.06 ± 0.00^{d}	1.01 ± 0.01^{c}	0.15 ± 0.00^{c}
FAV	51.63 ± 0.01^{a}	4.53 ± 0.03^{ab}	102.60 ± 0.28^{b}	ND	189.90 ± 0.49^{c}	ND	0.16 ± 0.00^{a}	0.08 ± 0.00^{bc}	2.82 ± 0.01^{a}	0.16 ± 0.00^{b}
ABC	31.52 ± 0.01^{d}	4.11 ± 0.06^{ab}	78.60 ± 0.14^{d}	ND	181.80 ± 1.20^{d}	ND	0.06 ± 0.00^{d}	0.29 ± 0.00^{a}	0.59 ± 0.00^{d}	0.06 ± 0.00^{d}

Values are means ± Standard deviation. Means with different alphabetical superscripts in the same column are significantly different ($p \leq 0.05$).

Keys: **EOD**: Corn: Red Kidney Bean: Onion (70:25:5%); **XYZ**: Corn: Red Kidney Bean: Onion (70:20:10%); **FAV**: Corn: Red Kidney Bean: Onion (70:15:15%); **ABC**: Oyato crunchy snack, ND: Not detected

Similarly, copper content ranged from 0.06 – 0.29 mg/100g. EOD and FAV had the same content of copper with 0.08 mg/100g, while XYZ had the lowest copper content and ABC had the highest content. The iron content which is an indication of the blood forming element, is observed to be found in considerably quantity and ranged from 0.59 (ABC) – 2.39 mg/100g (EOD). Thus, the formulated samples had more iron content than observed in the control samples – ABC. The zinc content which is needed in small quantity ranged from 0.06 – 0.18 mg/100g. ABC the control had the lowest zinc content (0.06 mg/100mg) while EOD had the highest zinc content (0.18 mg/100g). All mineral elements analysed in this study differed significantly ($p \leq 0.05$) across samples. The mineral ratio for calcium to phosphorus and sodium to potassium is presented in Table 4.

The Ca/P (0.07 to 0.13) ratio in the present study which is lower than 0.5 is an indication that the formulated samples evaluated are not potential minerals sources for bone formation (Nieman *et al*., 1992). These Ca/P ratios were lower than those reported by Omoba and Alokun-Adesanya (2013) on a ginger spiced maize snack "kokoro". The Na/K ratio ranged from 1.85 – 2.65 and was generally higher than 1.0 recommended WHO standard, thus may be implicated in the incidence of cardiovascular diseases. Furthermore, low potassium intake has been associated with an increased risk of high blood pressure and stroke (Khalil *et al*., 2017).

Table 4: Mineral Ratio of Crunchy Snacks

Sample	Ca/P	Na/K
EOD	0.07	2.65
XYZ	0.07	2.30
FAV	0.09	1.85
ABC	0.13	2.31

Keys: **EOD**: Corn: Red Kidney Bean: Onion (70:25:5%); **XYZ**: Corn: Red Kidney Bean: Onion (70:20:10%); **FAV**: Corn: Red Kidney Bean: Onion (70:15:15%); **ABC**: Oyato crunchy snack.

3.3 Storage Stability of Crunchy Snacks

The storage stability of crunchy snacks produced from corn, red kidney beans and onion flours was determined using the oil quality deterioration tests as shown in the thiobarbituric acid, free fatty acid value, saponification value and peroxide value of the samples.

3.3.1 Thiobarbituric acid value of crunchy snacks

Thiobarbituric Acid (TBA) Value of Crunchy Snacks after storage for one and two months respectively is presented in Table 5. The TBA value, which is an index of lipid oxidation and is a measure of malondialdehyde (MDA), a minor component of fatty acids formed upon degradation of the polyunsaturated acids content of oils (Djikeng *et al*., 2022). It measures hydroperoxides and aldehydic secondary oxidation products of the oils. Oil in good condition has TBA value of 0.02–0.08 MDA/kg (Kirk and Sawyer, 1991; Zeb and Ullah, 2016). It was observed that during storage for the first month TBA ranged from 0.18 to 0.51 mgMDA/Kg. The control (ABC) which is a commercial crunchy snack had the highest TBA number while FAV had the lowest and closely followed by XYZ (0.19 mgMDA/Kg), both of which were not significantly ($p<0.05$) different. After the second month of storage, all samples recorded an increase in TBA value. This spike was averagely over 5 times of its value after the first month of storage, with EOD having the lowest TBA value (1.67 mgMDA/Kg) and FAV with the highest TBA value (2.36 mgMDA/Kg). Thus, denoting that lipid oxidation in the crunchy snacks had progressed after the second month of storage. TBA values were significantly different ($p<0.05$) across samples after the second month of storage.

3.3.2 Free fatty acid value of crunchy snacks

The free fatty acid (FFA) value of crunchy snacks after storage for one and two months respectively are presented in Table 6. The FFA value ranged from 2.45 to 5.33% after the first month and 3.65 to 5.33% after the second month. Acid value indicates the amount of free fatty acids (FFA) present in oil (Yuliana *et al*., 2008). It is a good indicator of oil degradation caused by hydrolysis (Ufuan *et al*., 2021).

There was not much change in FFA from first to the second month of storage, except in XYZ where a drop was recorded from 4.77% after the first month to 3.65% after the second month. EOD, XYZ and FAV were not significantly different after the first month of storage, however, after the second month all samples were significantly different with FAV as the highest. The values herein were above those reported by Idowu and Akinoso (2016) for kokoro (fried corn snack) and Nkubana and Dusabumuremyi (2019) for extruded snacks. This may be due to the higher fats content in the crunchy snacks formulated from the supplementary ingredients. ABC had the lowest FFA value after the first and second months of storage (2.45% and 3.14%) while FAV had the highest FFA values in both months with 5.33% twice.

Table 5: Thiobarbituric Acid (TBA) number of Crunchy Snacks

Sample	First Month (mgMDA/Kg)	Second Month (mgMDA/Kg)
EOD	0.35 ± 0.02^{b}	1.67 ± 0.01^{d}
XYZ	0.19 ± 0.02^{cd}	2.06 ± 0.02^{c}
FAV	0.18 ± 0.07^{cd}	2.36 ± 0.02^{ab}
ABC	0.51 ± 0.04^{a}	$2.30 \pm 0.01a^{b}$

Mean value with the same superscript across the same column are not significantly different ($p<0.05$). **Keys: EOD**: Corn: Red Kidney Bean: Onion (70:25:5%); **XYZ**: Corn: Red Kidney Bean: Onion (70:20:10%); **FAV**: Corn: Red Kidney Bean: Onion (70:15:15%); **ABC**: Oyato crunchy snack.

Table 6: Free Fatty Acid (FFA) of Crunchy Snacks

Sample	First Month (%)	Second Month (%)
EOD	4.49 ± 0.00^{bc}	4.49 ± 0.00^{b}
XYZ	4.77 ± 0.40^{bc}	3.65 ± 0.40^{c}
FAV	5.33 ± 0.40^{a}	5.33 ± 0.40^{a}
ABC	2.45 ± 0.40^{d}	3.14 ± 0.01^{d}

Mean value with the same superscript across the same column are not significantly different ($p<0.05$). **Keys: EOD**: Corn: Red Kidney Bean: Onion (70:25:5%); **XYZ**: Corn: Red Kidney Bean: Onion (70:20:10%); **FAV**: Corn: Red Kidney Bean: Onion (70:15:15%); **ABC**: Oyato crunchy snack

3.3.3 Saponification acid value of crunchy snacks

The saponification values (SV) of the crunchy snacks produced from corn, red kidney beans and onion flour after storage for one and two months are presented in Table 7. Saponification value indicates the average molecular weight of triglycerides in oil (Djikeng *et al*., 2022). It is inversely related to the average molecular weight of fatty acids in oil (Djikeng *et al*., 2022). Accordingly, the saponification values ranged from 7.04 to 68.85 mgKOH/g after the first month of storage. However, after the second month of storage, the range spiked from 7.65 to 103.70 mgKOH/g. There was a small increase for ABC unlike the spiked observed in FAV (103.74 mgKOH/g) after the second month. It was observed that the commercial crunchy snack (ABC) had the lowest saponification value both after the first and second month of storage. The formulated snacks were over seven (7) times of the saponification value of the commercial crunchy snack (ABC). This indicates that the formulated snacks have weightier triacylglycerol than those in the control sample (ABC). Notwithstanding, the SV in this study were below the threshold of 250-260 mg KOH/g according to Codex Alimentarius (2005) for saponification values of oil.

Table 7: Saponification Value of Crunchy Snacks

Sample	First Month (mgKOH/g)	Second Month (mgKOH/g)
EOD	56.95 ± 1.20^{c}	57.80 ± 2.40^{c}
XYZ	61.20 ± 2.40^{b}	68.00 ± 2.40^{b}
FAV	68.85 ± 3.61^{a}	103.70 ± 4.81^{a}
ABC	7.04 ± 6.88^{d}	7.65 ± 1.20^{d}

Mean value with the same superscript across the same row are not significantly different (p<0.05). **Keys: EOD**: Corn: Red Kidney Bean: Onion (70:25:5%); **XYZ**: Corn: Red Kidney Bean: Onion (70:20:10%); **FAV**: Corn: Red Kidney Bean: Onion (70:15:15%); **ABC**: Oyato crunchy snack

3.3.4 Peroxide Value of Crunchy Snacks

The peroxide value (PV) of crunchy snacks after storage for two months is presented in Table 8. The peroxide value after the first month of storage ranged from 3.50 to 20.00 meq/Kg. The peroxide value was lowest in the commercial crunchy snack and highest in FAV. The peroxide value is used as an indicator of deterioration of oils. Generally, the PV in the formulated snacks were about four times higher than in the control sample. Peroxide value is used as an indicator for oil rancidity or freshness (Djikeng *et al*., 2022). It is a measure of concentration of peroxides and hydro-peroxides formed in the initial stages of lipid oxidation (Patel *et al*., 2016). After the second month of storage, the peroxide value was between 8.50 to 21.50 meq/Kg. There was an observed spike in the peroxide value of FAV after the second month of storage. The higher the peroxide value, the more rancid the oil is. Peroxide formation is an indication that lipid oxidation is on-going, these compounds react with low molecular weight metals to produce free radicals that are capable of further lipid oxidation (Kilic and Richard, 2003). These findings in this study shows that FAV will produce more peroxides during long time storage compared to other formulated samples in this study, which is an indication of faster spoilage.

3.4 Microbial Population of Crunchy Snacks

The microbial population of the crunchy snack samples in colony forming unit per gramme (Cfu/g) after storage for two months is presented in Table 9.

3.4.1 Total viable count

The bacteria count ranged from 1.5-7.0 × 10^2 Cfu/g among the formulated samples while the commercial crunchy snack had no bacteria growth after the first month of storage. After the second month of storage, there was an increase in microbial population with bacteria growth ranging from 9.0 – 45.0 × 10^2 cfu/g. The bacterial growth after the first and second month were still within the stipulated ranged of 2 x 10^4 – 6 × 10^6 cfu/g according to Stolz (1999).

Table 8: Peroxide Value of Crunchy Snacks

Sample	First Month (meq/Kg)	Second Month (meq/Kg)
EOD	18.00 ± 0.00^{b}	18.50 ± 0.71^{c}
XYZ	17.50 ± 0.71^{c}	21.50 ± 0.71^{b}
FAV	20.00 ± 1.41^{a}	46.50 ± 2.12^{a}
ABC	3.50 ± 0.71^{d}	8.50 ± 0.71^{d}

Mean value with the same superscript across the same row are not significantly different (p<0.05)
Keys: **EOD**: Corn: Red Kidney Bean: Onion (70:25:5%); **XYZ**: Corn: Red Kidney Bean: Onion (70:20:10%); **FAV**: Corn: Red Kidney Bean: Onion (70:15:15%); **ABC**: Oyato crunchy snack

Table 9: Microbial Population (Cfu/g) of Crunchy Snacks

Samples	First Month		Second Month	
	Total viable count (cfu/g)	Fungi Count (cfu/g)	Total viable count (cfu/g)	Fungi count (cfu/g)
EOD	1.5 × 10^2	2.5 × 10^2	21.0 × 10^2	12.0 × 10^2
XYZ	7.0 × 10^2	9.0 × 10^2	45.0 × 10^2	25.0 × 10^2
FAV	3.5 × 10^2	5.0 × 10^2	31.0 × 10^2	17.0 × 10^2
ABC	Nil	Nil	9.0 × 10^2	5.0 × 10^2

Keys: **EOD**: Corn: Red Kidney Bean: Onion (70:25:5%); **XYZ**: Corn: Red Kidney Bean: Onion (70:20:10%); **FAV**: Corn: Red Kidney Bean: Onion (70:15:15%); **ABC**: Oyato crunchy snack; Cfu/g: Colony forming unit/gramme

The observed spike in the bacteria population is due to the high reproduction nature of bacteria compared to fungi. Also, the higher microbial population observed in the formulated samples may be due to the nutrient-rich nature of the samples, thus becoming a good substrate for microbial growth. In addition, the increase in microbial population may be due to storage condition that promotes microbial growth.

3.4.2 Fungi count

The fungi count ranged from 2.5 – 9.0 × 10^2 cfu/g among samples, however, ABC did not record any fungi growth after the first month of storage. The presence of fungi population in the snack samples can be attributed to the low moisture content (4.03 – 15.33%) as fungi thrive in low moisture products. However, ABC had no fungi growth. This may be due to the hermetic sealing and method of producing the commercial crunchy snack. The microflora population of cereals flours ranged from 2 x 10^4 – 6 × 10^6 cfu/g (Stolz, 1999). However, the values reported in this study are lower than those reported in Stolz (1999). This may be due to fact that the inclusion of red kidney beans and onion flours subsequently reduced the carbohydrate substrate for fungi. After the second month of storage, there was an increase in microbial population with fungi ranging from 5.0 – 25.0 × 10^2 cfu/g. The increase in microbial population may be due to storage condition that promotes microbial growth. The higher microbial population observed in the formulated samples may be due to the nutrient-rich nature of the samples, thus becoming a good substrate for microbial growth.

3.5 Sensory Evaluation of Crunchy Snacks

The result of the sensory evaluation of the crunchy snacks is shown in Table 10. There were significant differences ($p< 0.05$) in the appearance, taste, aroma, shape, crunchiness, mouthfeel and overall acceptability of the formulated crunchy snack samples and the Oyato crunchy snack. ABC – the commercial crunchy snack (control sample) had the highest significant rating ($p< 0.05$) in appearance, shape, and crunchiness. However, XYZ had the highest rating significantly ($p< 0.05$) in taste, aroma, mouth feel and overall acceptability in this study. The values derived in this study were relatively similar to those reported by Idowu and Akinoso (2016) for fried maize snack (Kokoro). The formulated crunchy snacks were significantly higher or at par with the control commercial crunchy snack sample in terms of taste (except FAV), mouth feel (except EOD) and aroma. Thus, showed that these formulated samples generally have a good commercial prospect. The sensory result indicate that the formulated samples were acceptable by the consumers because each sensory attribute had over 50% acceptance.

Table 10: Sensory Evaluation of Crunchy Snacks Produced from Corn, Red Kidney Beans and Onion Flour

Samples	EOD	XYZ	FAV	ABC
Appearance	6.60 ± 1.48^c	7.00 ± 1.05^b	6.03 ± 1.73^d	7.53 ± 1.52^a
Taste	6.63 ± 1.59^b	7.47 ± 1.07^a	6.08 ± 1.19^d	6.57 ± 1.65^c
Aroma	6.30 ± 1.51^c	6.57 ± 1.45^{ab}	6.50 ± 1.46^b	6.27 ± 1.55^d
Shape	6.30 ± 1.42^d	6.73 ± 1.26^{bc}	6.73 ± 1.33^{bc}	7.37 ± 1.43^a
Crunchiness	7.07 ± 1.39^d	7.43 ± 1.22^{bc}	7.43 ± 1.00^{bc}	7.60 ± 1.25^a
Mouth Feel	6.87 ± 1.28^d	7.57 ± 1.04^a	7.13 ± 1.10^c	7.20 ± 1.37^b
Overall Acceptability	7.00 ± 1.22^d	7.60 ± 1.12^a	7.07 ± 1.04^c	7.33 ± 1.63^b

Mean value ± Standard deviation with the same superscript across the same row are not significantly different ($p<0.05$)
Keys: **EOD**: Corn: Red Kidney Bean: Onion (70:25:5%); **XYZ**: Corn: Red Kidney Bean: Onion (70:20:10%); **FAV**: Corn: Red Kidney Bean: Onion (70:15:15%); **ABC**: Oyato crunchy snack

4. Conclusion

This study revealed the proximate composition and storage stability of crunchy snacks produced from corn, red kidney beans and onion flours. The formulated snacks were generally rich in carbohydrate, protein and crude fibre. Furthermore, formulated snacks had moisture content lower than 15% indicating a long shelf life. Accordingly, the findings in this study indicates that the crunchy snacks possess a good storage stability, however, FAV (Corn: Red Kidney Bean: Onion - 70:15:15%) has the potential to deteriorate faster than other formulated samples due to higher values in terms of thiobarbituric acid, free fatty acid, saponification and peroxide values respectively. The microbial population showed the presence of bacteria and fungi, with fungi in higher number. The higher fungi population in the snack samples can be attributed to the low moisture content (4.03 – 15.33%) as fungi thrive in low moisture products. The formulated samples were higher or at par significantly ($p<0.05$) with the control sample in sensory evaluation parameters, while XYZ (Corn: Red Kidney Bean: Onion - 70:20:10%) had the best rating in terms of taste, aroma, mouth feel and overall consumers' acceptability.

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Declaration of Competing Interest
The authors declare no conflict of interest.

We the authors hereby declare our conflict of interest. No part of this publication has been published in another journal.

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