Discovery

Effect of Packaging Materials and Storage Conditions on the Proximate Composition and Functional Properties of Guinea Corn Flour

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ABSTRACT

The effect of material packages on the proximate composition and functional properties of guinea corn flour was determined. The results showed that the packaging materials and duration of storage significantly affect all the proximate parameters and functional properties of the stored guinea corn flour within 12 weeks of storage. An increase in ash content (1.98% to 2.42%, in HDPE, and 2.42% to 2.57% in PC), protein content (10.02% to 10.90%, in HDPE, 9.50% to 10.58% in PC and 10.00% to 10.52% in BPB) fat content (3.34% to 4.44%, in HDPE, 2.96% to 3.90% in PC and 3.23% to 3.91% in BPB), and crude fiber (2.94% to 3.30%, in HDPE, 2.83% to 3.48% in PC and 2.65% to 3.58% in BPB) was discovered within 2 to 12 weeks of storage. The moisture content (8.48% to 5.34%, in HDPE, 6.87% to 5.61% in PC and 6.98% to 5.33% in BPB), and carbohydrate (69.66% to 46.07%, in HDPE, 65.91% to 48.02% in PC and 70.90% to 47.88% in BPB) decrease within the storage period. The bulk density, swelling power, water absorption capacity, oil absorption capacity, solubility index and dispersibility of guinea corn flour decreases in PC, HDPE and BPB from 2 to 12 weeks of storage except in bulk density that had an increase in both HDPE and BPB (0.71g/ml in 2 weeks to 0.75 g/ml in 12-weeks and 0.60 g/ml in 2 weeks to 0.71g/ml in12 weeks) and also water absorption capacity and solubility index that had an increase only in BPB(81.33% to 101.27% and14.97% to 15.11% from 2 to 12 weeks respectively) within the storage period. Based on the results of the study, it was discovered that shelf life of guinea corn flour was dependent on the functional properties and proximate composition of the flour, packaging materials and storage durations. The packaging materials had no significant effect on the bulk density and swelling power and had effect on proximate parameters of the stored guinea corn flour within 12 weeks. Plastic containers retained more moisture and carbohydrate contents than the other two packaging materials. The results showed that the brown paper bag (BPB) would be most effective for the shelf-life stability of guinea corn flour within the storage period.

Keywords: Effect, Packaging Materials, Storage, Proximate, Functional, Guinea Corn Flour

DISCOVERY SCIENTIFIC SOCIETY

1. INTRODUCTION

Guinea corn (*Sorghum bicolor (L) Moench*) is a cereal crop commonly known as grain sorghum, and belongs to the general class of sorghum. Sorghum grain is the fifth most important cereal in the world after wheat, rice, maize and barley (FAO, 2008). Sorghum is higher in protein and starch but lower in fat content than maize. Sorghum grains are also eaten by horses, and poultry, while cattle feed on the dry leaves of the plants after the grains is been harvested. Sorghum is the third most important grain food in the world. Sorghum grows well where the rainfall is 380 — 640 mm during the period of growth and where the weather is hot and dry when the grains are ripening. A mean temperature of about 28°C is ideal. Sorghum grows well on a wide variety of soils, with a pH range of 5.5 to 8.5, at the exception of pure sands and clays (Chukwu et al., 2011).

Sorghum is an important staple in the diets of Nigerians, where it is a principal food crop. It is used for bread making, and as source of food for cattle, horses and poultry birds, and also in brewing industries (Devi et al., 2011). Nigeria produces up to 65 to 70% of sorghum in West Africa. The Nigeria producing states includes; Katsina, Kano, Bauchi, Borno, Zamfara, Yobe, Gombe, Adamawa, Kaduna, Jigawa, Niger, Kebbi, Taraba, Plateau, Sokoto and Nasarawa (Umar, 2016).

Guinea corn has different species; it is naturally grown in pastureland, and useful as fodder plants. Essentially, sorghum as a grain contained valuable nutrient, and it withstands heat and drought. The nutrient contains different minerals such as potassium, phosphorus, iron, magnesium, thiamine, copper, riboflavin, niacin, and calcium (Sambusiti et al., 2013).

The people of Nigeria especially the northern, and middle belts, use guinea corn grain as a source of food, portage, Jollop, and local brewed wine (Burkutu). The modern usage in the industries is to produce biscuits, and other edible product from the sorghum (Sani, et al., 2011). Guinea corn is valuable in arid terrain, because of its resistance to drought. Guinea corn is a nutrient-rich grain that is often ground into flour to make bread, porridge and pancakes. Including it in our diet offers numerous nutritional and therapeutic benefits. Like other cereal, sorghum are predominately starchy, making them suitable for brewing industries, and 70 - 80% of sorghum starch is amylopectin, a branched –chained polymer of glucose, and the remaining 20 - 30% is amylose. It contains carbohydrate, protein, and minerals such as calcium, selenium, manganese, and iron in which the bioavailability depends on the level of interactions with various antinutrients (Dykes and Rooney, 2006). It is also rich in B-complex vitamins. Apart from its use as food, it contains some chemical compounds that are protective against cancer, heart disease, heavy menstrual flow, and tumor growth. It contains no gluten, which makes it an excellent nutrient source for individuals with celiac disease (Khady et al., 2010).

The principal aim for storing sorghum is to maintain the crop in prime condition, for as long as possible until the economic market value has risen, and also for food security. Sorghum are mainly stored in threshed form, and in granaries. The granaries should be rat-proof to prevent grain from being damaged. If sorghum are stored as grain, it is usually placed in drums or gunny bags, and then packed in a store on pallets. Bags must be stacked on pallets at about 15 cm above the ground, and about 75cm away from walls damage due to molds resulting from high moisture content. The advantages of proper stacking are to prevent dampness from floor and wall been absorbed by the stored sorghum grains, ease of cleaning the floor and the walls, ease of counting of the bags in the store, and ease of inspection of produce attack by pests. The seeds should be treated with recommended chemical like Actellic, or Malathion dust. Some farmers mix grain with wood ash. Suitable grain packaging materials, such as jute bags, cloth bags, carton boxes, and tins should be used. The harvested crop can be stored in cribs, or in warehouses (Chukwu et al., 2011).

Packaging is an integral part of food processing. It provides the proper environmental conditions for long shelf life. It protects the products against microbiological, chemical, or physical deterioration (Komolafe, 2005). Processed foods are preserved for extended periods by a combination of aseptic packaging to exclude microbes, and oxygen, as well as to maintain a moderate temperature (Ratnavathi and Patil, 2013).

It is also a means of achieving safe delivery of products in a sound condition to the final user. Some of these packaging materials are plastic, glass (bottle), aluminum foil, brick carton, polythene etc. Packages function as protection, transportation, sales, promotional services, and guarantee (Fellows, 2009). Packaging and handling of the products before and during sales to consumers are also a source of concern. Like most other ready to eat foods sold on streets, road sides, and market places are prone to contamination with kokoro (Ofor et al., 2009).

Produce should be stored in containers, with adequate cushioning materials, stacking strength, and durability to guard against crushing and to withstand high humidity conditions. Bulge-packed crates should be stacked on their sides or stripped between layers to keep weight off the commodity. During storage, one or more food characteristics can reach an undesirable state, and consequently the consumer may reject the product, or the product can be detrimental to the health of the consumer. At this moment, the food has reached the end of its shelf life. Packaging materials used for the household storage of flours such as those for pounded-yam, fufu, lafun, and ogi include high density polyethylene (HDPE), low density polyethylene (LDPE), and polypropylene (PP), laminated paper bags, brown paper bags, woven sacks, and plastic bags (Brink et al., 2006).

The poor storage facilities, packaging materials, and perishable nature of guinea corn flour can pose a threat to the processing and storage of the flour. Guinea corn flour is affected by factors such as moisture, humidity, air composition and temperature. A proper storage, proper packaging, and good material handling should be adopted to avoid deterioration and wastage of guinea corn flour. However, more studies need to done, to determine the effect of different processing conditions, on the various qualities attributes of the guinea corn flour. These led to carrying out studies on determination of best packaging materials, which will elongate the shelf life of guinea corn flour. The study aimed at the effect of packaging materials, and storage conditions on the functional properties and proximate composition of guinea corn flour. The specific objective is to, determine an optimum shelf life, particle size and packaging material for handling and storage of guinea corn flour.

2. MATERIALS AND METHODS

Guinea corn samples were obtained from Chikezie farm at Adani in Uzo Uwani Local Government of Enugu State, Nigeria. Ten kilograms (10 kg) each of the two varieties of guinea corn was selected for the experiments. The packaging materials which include high density poly ethylene (HDPE), plastic container (PC), and brown paper bags (BPB) were purchased from Onitsha main Market in Anambra State of Nigeria. The test analyses are carried out in the Bio Process Laboratory of the Agricultural and Bioresource Engineering Department and the Food Science Technology Department laboratory, both in Enugu State University of Science and Technology, Enugu State, Nigeria

2.1. Preparation of guinea corn into flour

The samples of Guinea corn obtained were decorticated, and sorted to remove any dirt, or foreign material present in them. Guinea corn samples was dried using Air oven method at 80 °C temperature, for about 10 hours, after which it was milled into flour using Hammer mill (N0 1 A, 446, 2012), and sieved using a 250 µm mesh to obtain the sample flour. The Guinea corn flour was .packaged in different zip lock bags, and stored at room temperature for the storage and analysis. The three hundred and fifty grams (350 g) of guinea corn flour was weighed, and packaged separately in high density poly ethylene (HDPE), plastic container (PC) and brown paper bag (BPB), and were properly sealed. These packaging materials was stored at room temperature for 12 weeks. The functional properties and proximate composition of guinea corn flour were evaluated, in every 2 weeks, of the 12 weeks storage periods.

2.2. Proximate Composition of Guinea Corn Flour

2.2.1. Moisture content determination

Moisture content of the guinea corn flour was determined using the air-oven method, as described by Niba et al., (2001). A Gallenkamp hot air oven CHF097 (model) is used to dry all samples to constant weight. The percentage moisture content was determined using the formula below,

$$M_{wb} = \frac{M_{wt} - M_{Dr}}{M_{wt}} x\ 100 \qquad 1$$

Where, M_{wb} is the moisture content of the guinea corn in % wet basis, M_{Wt} is the initial weight of the flour sample in g, M_{Dr} is the weight of the flour sample after drying to constant weight in g.

2.2.2. Determination of ash content

Ash content is the mineral material in flour and is determined as described by AOAC, (2010).

Total weight of Ash = weight of crucible + Ash sample – weight of empty crucible 2

$$\%\ \text{weight } of\ Ash = \frac{\textbf{Total weight of Ash}}{\textbf{Weight of Sample Used}} \times 100\% \qquad 3$$

2.2.3. Determination protein content

Total nitrogen in the guinea corn flour was determined using the micro-Kjedhal method as described by AOAC (2010). A conversion factor of 6.25 is used for the determination of crude protein present in the samples

2.2.4. Determination fat content

Fat content was determined using the Soxhlet method as described by AOAC (2010). Petroleum ether was used for the extraction, and the percentage of the fat present was determined using the formula below:

$$Fat\ content(\%) = \frac{W_x - W_y}{W_z} x\ 100 \qquad 4$$

where:
W_x = weight of fat + flask;(g)
W_y = weight of flask; (g)
W_z = weight of sample (g)

2.2.5. Determination total crude fibre content

Crude fiber content of the guinea corn flour was determined, using the method described by AOAC (2010).

2.2.6. Determination carbohydrate content

The total of carbohydrate content of the guinea corn flour was calculated by the difference method using the formula below:
%Carbohydrate = 100 – (Protein + Moisture + Fat + Fibre + Ash) 5

2.3. Determination of Functional Properties of Guinea Corn Flour

2.3.1. Bulk density

The bulk density of the flour was determined using the standard methods described by Ashraf et al., (2012). Flour sample (15 g) was measured into a graduated 100 ml measuring cylinder, and lightly tapped on the workbench for 60 times to attain a constant height, and then reweighed. The bulk density is calculated as the ratio of the bulk density and the volume of the container and expressed as grams per milliliter.

2.3.2. Swelling power and solubility index

The swelling power and solubility index of the flour was determined as described by Wasiu et al., (2020). 3.5 % flour solution was prepared, and heated in a water bath (Gallenkamp Water Bath Model BKS-350-030; Gallenkamp, London, UK), maintained at 85°C for 50 min with constant stirring and cooling. The suspension is centrifuged at 3000 rpm for 25 min, and the supernatant was decanted into a pre-weighed can, and dried at 100 °C to constant weight. The dried can was weighed for calculation of solubility, while the weight of wet sediment in centrifuge tube was used to determine swelling power.

$$\text{Sp} = \frac{\textbf{weight of precipitated paste } (\mathbf{w_c})}{\textbf{weight of sample } (\mathbf{w_s})} - \textbf{weight of residue in supernatant}(\mathbf{w_g}) \qquad \mathbf{6}$$

$$\text{SI} = \frac{\textbf{weight of residue in supernatant}(\mathbf{w_g})}{\textbf{weight of sample } (\mathbf{w_s})} \times \mathbf{100\%} \qquad \mathbf{7}$$

2.3.3. Water absorption capacity

The water absorption, which measures the capacity of flour to absorb water, and swell for enhanced consistency, is desirable in food systems as it helps to improve yield and consistency (Adepeju et al., 2011). Water absorption method, or capacity of the guinea corn flour was determined as described by Oyeyinka et al., (2013), with a few modifications. Flour samples of 20 g of flour was weighed into a clean, dried centrifuge tube, and mixed adequately with 20 ml distilled water by vortexing, after which the suspension was allowed to stand for 40 min and centrifuged (Thelco GLC- 1, 60647: Chicago, USA) at 3,500 rpm for 40 min. The supernatant is decanted after centrifugation with the tube, and the sediment weighed. The weight of water (g) retained in the sample is reported as WAC.

2.3.4. Oil absorption capacity

The guinea corn flour sample of 10 g was suspended in 5 ml of vegetable oil in a centrifugal tube, after which the slurry was shaken on a platform tube rocker for 2 min at room temperature, and centrifuged at 3000 rpm for 15 min. The supernatant was decanted and discarded. The adhering drops of oil were removed and reweighed. The oil absorption capacity (OAC) was expressed as the weight of the sediment, and initial weight of the sample (g/g) (Niba et al., 2001).

2.3.5. Dispersibility

A fifteen gram (15 g) sample of guinea corn flour is dispersed in a measuring cylinder (100 ml), and distilled water is added up to the 55 ml mark. The mixture was stirred vigorously and allowed to settle for 2 hours, as reported by Kulkarni et al., (1991). The volume of settled particles is noted, and the percentage of dispersibility is calculated as:

$$\text{Dispersibilty (\%)} = \frac{(\mathbf{50} - \textbf{volume of the settled particle})}{(\mathbf{50})} \times \mathbf{100\%} \qquad 8$$

3. RESULTS

The storage conditions of guinea corn flour was determined by comparing the parameters obtained from the proximate compositions, and functional properties of guinea corn flour, stored with different packaging materials, which include high density polyethylene (HDPE), plastic container (PC) and brown paper bag (BPB) at 12 weeks' storage period. The values of the proximate composition and functional properties of guinea corn flour before storage are presented in Table 1. The results of the proximate composition of guinea corn flour stored with three different packaging materials at 2 week, 4 weeks, 6 weeks, 8 weeks, 10 weeks and 12 weeks storage periods are shown in Table 2.

Table 1. The initial proximate compositions and functional properties of guinea corn flour

Moisture content (%)	**Crude ash content (%)**	**Crude protein content (%)**	**Crude fat (%)**	**Fiber content (%)**	**Carbohydrate content (%)**
7.36	2.45	11.33	3.09	2.78	71.67
Bulk density (g/ml)	Swelling power (%)	Water absorption capacity (%)	Oil absorption capacity (%)	Solubility Index (%)	Dispersibilty (%)
0.73	12.06	76.83	110.16	23.73	73.82

Table 2. The effect of storage time and packaging materials on the proximate composition of guinea corn flour stored for a period of 12 weeks

Week	Packaging material	Moisture (%)	Ash (%)	Protein (%)	Fat (%)	Fibre (%)	Carbohydrate (%)
2 weeks	HDPE	8.48	1.98	10.02	3.34	2.94	69.66
	PC	6.87	2.42	9.50	2.96	2.83	65.91
	BPB	6.98	2.41	10.00	3.23	2.65	70.90
4 weeks	HDPE	8.12	1.99	9.98	3.21	2.94	69.01
	PC	6.65	2.42	9.50	2.96	2.85	65.91
	BPB	7.51	2.41	9.85	3.23	2.65	68.63
6 weeks	HDPE	6.71	2.23	9.74	3.85	3.48	69.36
	PC	5.68	2.87	10.01	3.74	3.64	55.87
	BPB	6.59	2.67	10.21	3.95	3.73	56.24
8 weeks	HDPE	6.19	2.25	10.22	4.33	3.57	58.20
	PC	5.65	2.53	9.78	4.15	3.52	55.20
	BPB	5.72	2.17	9.71	4.10	3.56	55.13

10 weeks	HDPE	5.71	2.42	10.51	4.40	3.44	51.81
	PC	5.35	2.57	10.31	3.97	3.45	53.42
	BPB	5.60	1.98	10.24	3.90	3.58	52.13
12 weeks	HDPE	5.34	2.42	10.90	4.44	3.30	46.07
	PC	5.61	2.57	10.68	3.90	3.48	48.02
	BPB	5.33	1.97	10.52	3.91	3.58	47.88

The functional properties of guinea corn flour stored at 12 weeks' period in three different packaging materials are presented in Table 3. The figures 1 to 6 are used to determine exactly how each proximate parameter of the flour was affected with respect to the packaging materials, and duration of storage.

Table 3. The effect of storage time and packaging materials on the functional properties of guinea corn flour stored for a period of 12 weeks

Parameter	Storage duration (weeks)	Guinea corn stored in HDPE	Guinea corn stored in PC	Guinea corn stored in BPB
Bulk density (g/ml)	2	0.71	0.74	0.60
	4	0.72	0.73	0.70
	6	0.68	0.65	0.67
	8	0.62	0.60	0.70
	10	0.64	0.62	0.69
	12	0.75	0.68	0.71
Swelling power (%)	2	11.78	10.92	10.07
	4	11.62	09.74	10.64
	6	09.87	09.24	10.34
	8	10.12	09.99	09.91
	10	08.78	09.22	09.20
	12	08.87	08.90	09.31
Water absorption capacity (%)	2	88.50	89.91	81.33
	4	92.24	75.55	95.45
	6	78.56	59.78	95.78
	8	77.92	68.34	96.88
	10	77.88	57.69	99.67
	12	66.64	49.77	101.27
Oil absorption capacity (%)	2	105.87	117.33	117.61
	4	107.91	121.44	127.09
	6	96.24	111.33	101.64
	8	74.06	112.09	90.25
	10	70.32	81.81	92.87
	12	71.44	61.98	82.12
Solubility index (%)	2	16.58	16.44	14.97
	4	16.19	16.18	15.09
	6	16.16	16.80	14.91
	8	15.88	17.33	14.29
	10	17.12	16.60	16.13
	12	16.50	15.61	15.11
Dispersibility (%)	2	66.79	72.55	67.88
	4	67.11	72.09	68.21

	6	67.30	70.79	67.81
	8	65.40	71.33	67.51
	10	65.89	71.80	66.68
	12	66.80	72.41	61.95

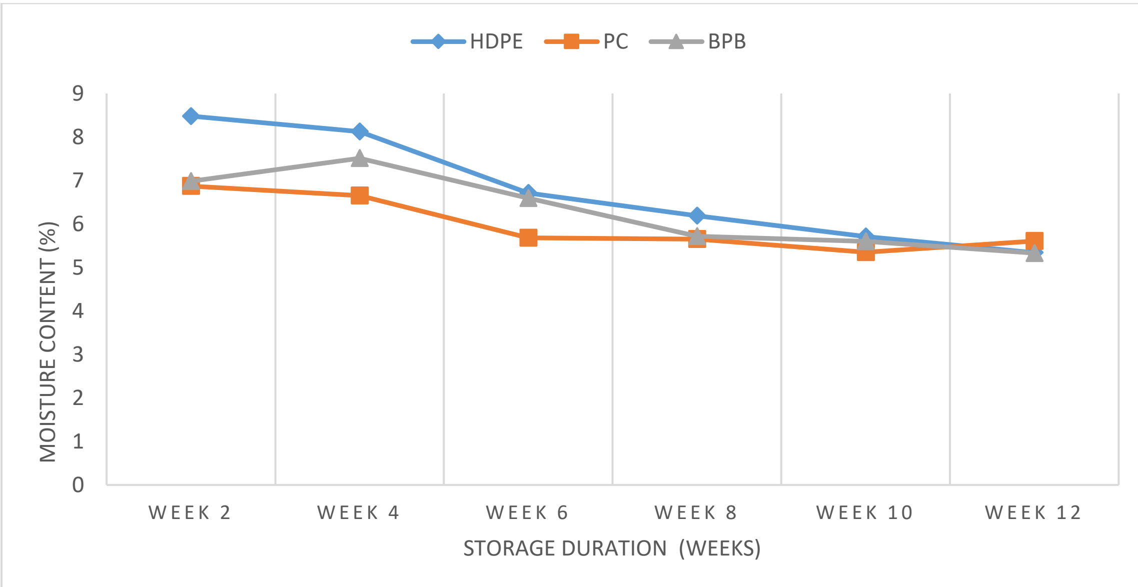

Figure 1. Effect of packaging materials on the moisture contents of guinea corn flour

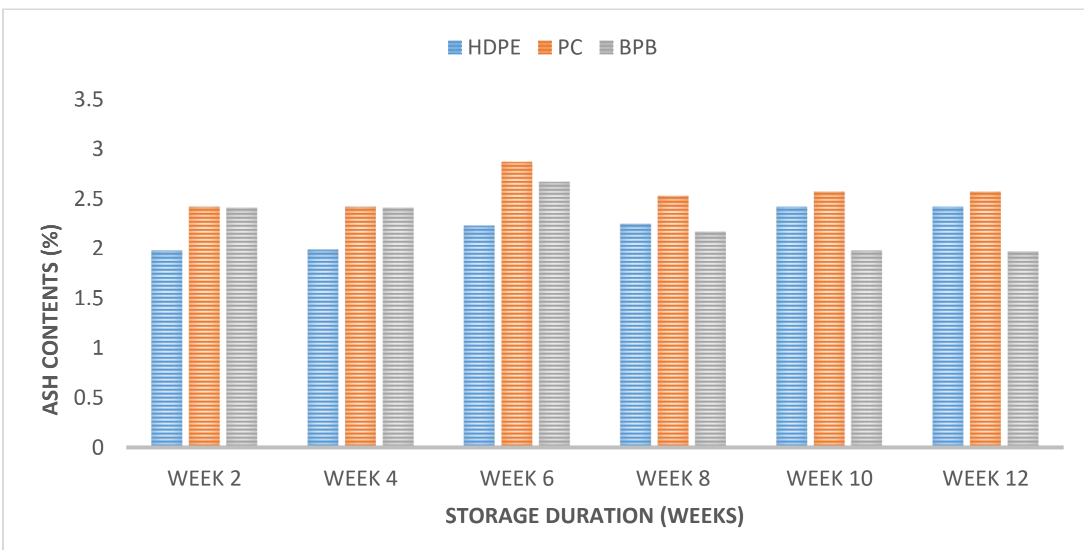

Figure 2. Effect of packaging materials on the ash contents of guinea corn flour

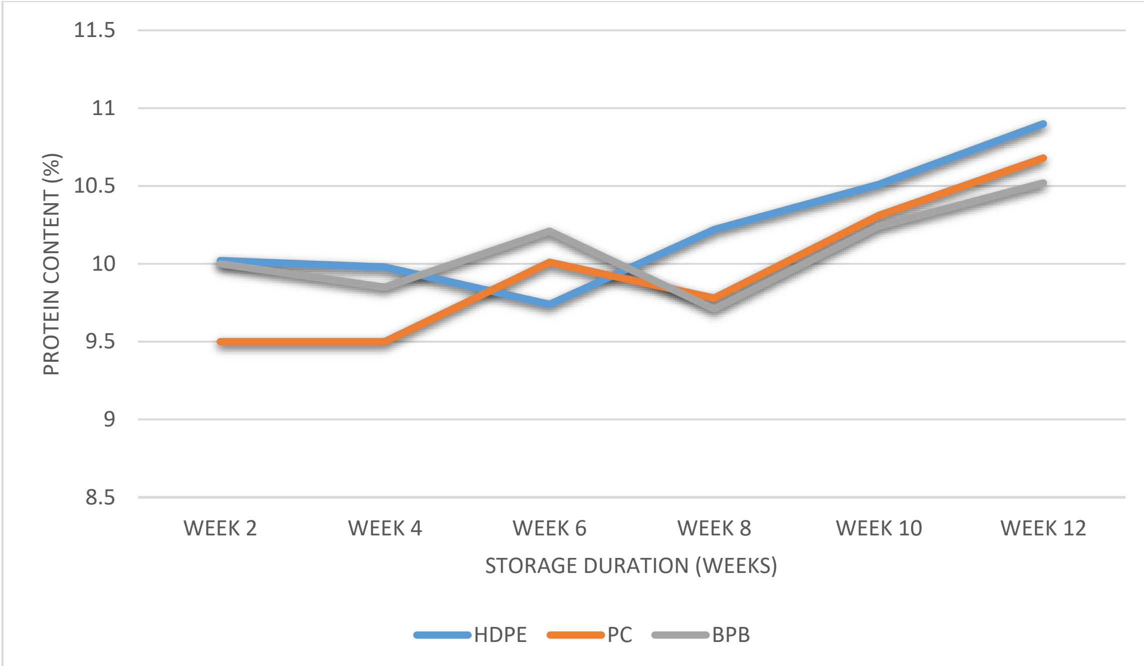

Figure 3. Effect of packaging materials on the crude protein contents of guinea corn flour

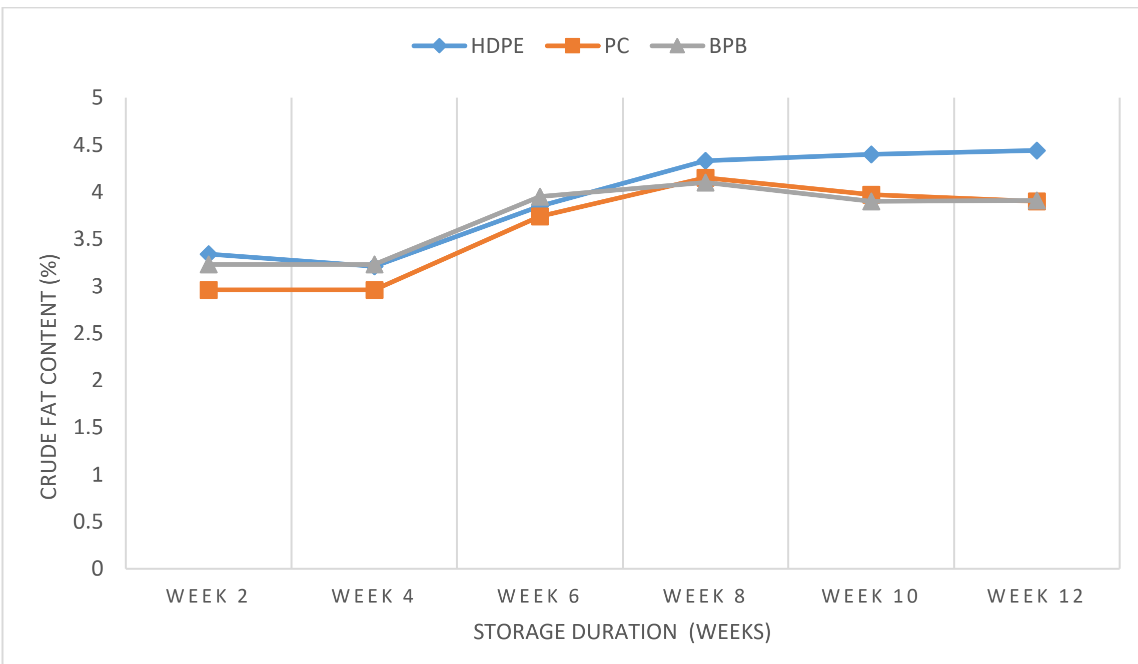

Figure 4. Effect of packaging materials on the crude fat contents of guinea corn flour

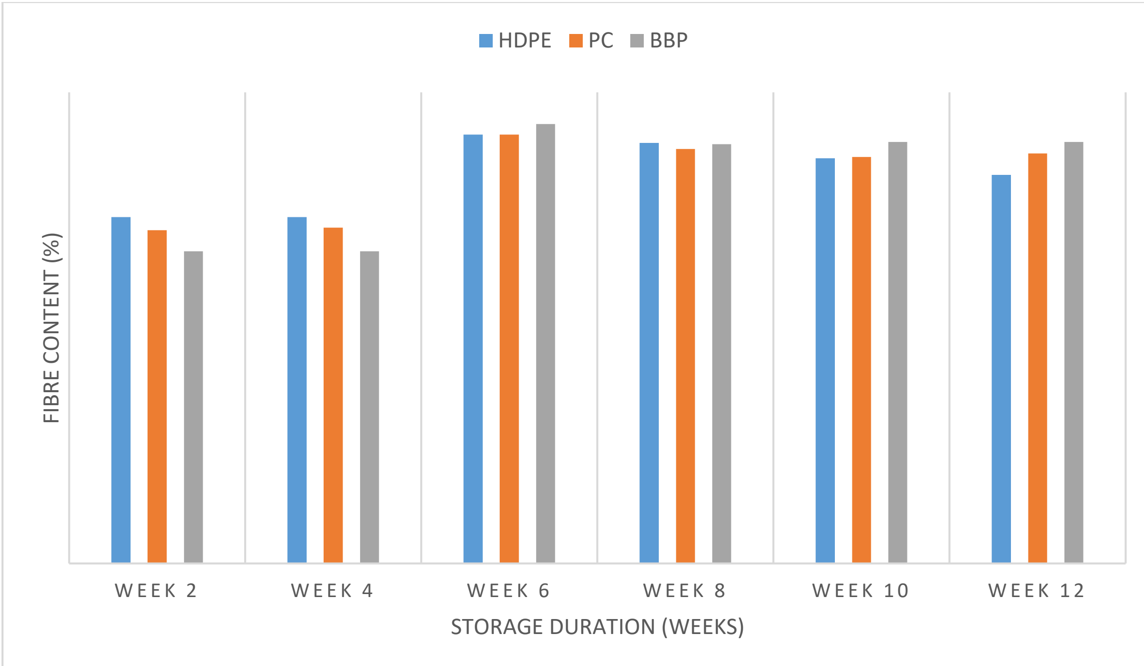

Figure 5. Effect of packaging materials on the fiber contents of guinea corn flour

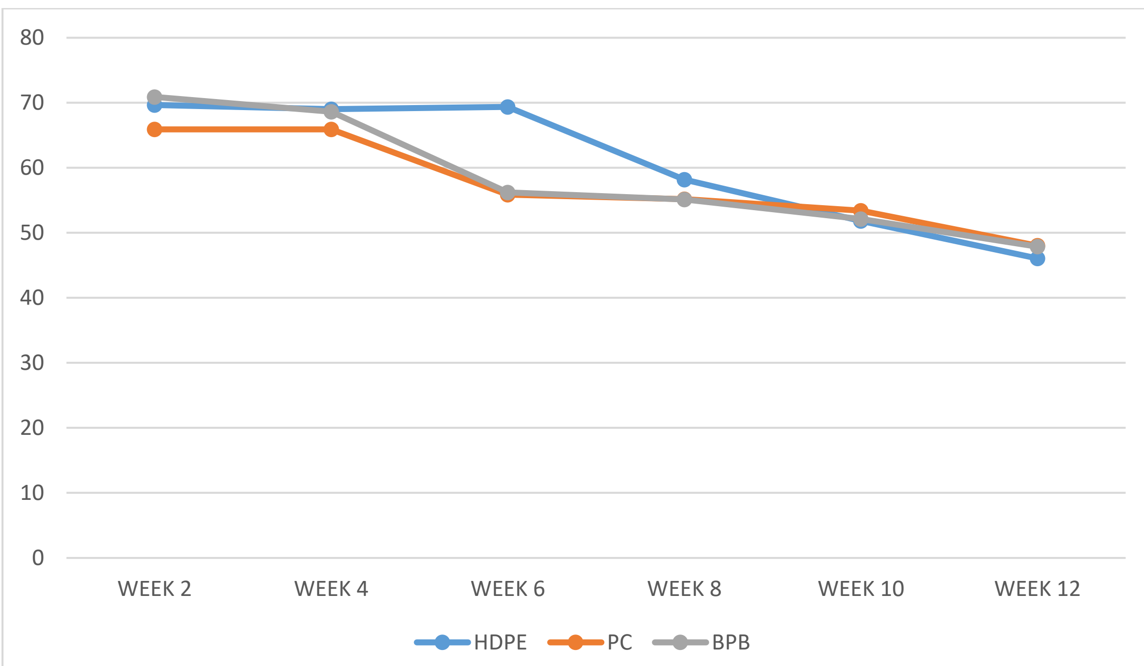

Figure 6. Effect of packaging materials on the carbohydrate contents of guinea corn flour

4. DISCUSSION

Moisture content was inversely proportional to the storage duration. By the end of the storage period in week 12, the moisture content in Table 2 was found to decrease from 8.48% to 5.34% in HDPE, also from 6.87% to 5.61% in PC, and from 6.98% to 5.33% in BPB. The moisture content range, did not correspond with the recommended moisture content (6-14%) for flour stability, and was in line with the reported range for the moisture content of cassava flour (Awoyale et al., 2016). It is also found in figure 1 that plastic containers retained the highest moisture than the other two packaging materials within the storage period. The acceptable moisture content of flour according to Amarachi, was at the storage period of 6 weeks using the three packaging materials.

The ash contents of the guinea corn flour samples were increased, from 1.98% to 2.42% in HDPE, and from 2.42% to 2.57% in PC, and reduced from 2.41% to 1.97% in BPB within the storage period. It was discovered from figure 2 that ash content increased to the highest level in 6 weeks' storage period, and started decreasing on further storage period, still, the sample stored in brown paper bag decreases faster than the other two.

The protein contents of the guinea corn flour samples were generally increased from 10.02% to 10.90% in HDPE, also from 9.50% to 10.68% in PC, and from 10.00% to 10.52% in BPB. The significant increase in protein contents of the flour was in agreement with Mpotokwane et al., (2008). From figure 3, it was discovered, that guinea corn flour sample packaged with high density polyethylene, increases protein content faster than the other two packaging materials within storage duration.

There was significant increase in fat contents of the guinea corn flour stored in three different packaging materials as shown in Table 2. The fat contents increases from 3.34% to 4.44% in HDPE, from 2.96% to 3.90% in PC, and from 3.23% to 3.91% in BPB respectively. The increased in fat contents, within the storage period is attributed to packaging materials used. Figure 4 also showed, that fat content of guinea corn flour stored with high density polyethylene, increases highest of plastic container and brown paper bag. It is discovered that a brown paper bag was the best packaging material, to store guinea corn flour within the storage period.

The Table 2 shows that crude fiber content of guinea corn flour increased from 2.94% to 3.30% in HDPE, from 2.83% to 3.48% in PC and from 2.65% to 3.58% in BPB. There are slight increase in crude fiber contents of guinea corn flour stored within 12 weeks, which was in line with Kumar and Khatkar, (2017). Consumption of diets high in fiber is emphatically identified with various physiological and metabolic impacts, because it contributes lower calories, and helps in flushing cholesterols, carcinogens and unwanted chemicals from the body. It is found that the best packaging materials for storing guinea corn flour, within 12 weeks of storage was brown paper bag as presented in figure 5.

The Carbohydrate content, which is also total starch content of guinea corn flour decreases significantly from 69.66% to 46.07% in HDPE, from 65.91% to 48.02% in PC, and from 70.90% to 47.88% in BPB as shown in Table 2. The three packaging materials showed similar decrease in carbohydrate contents of guinea corn flour stored within 12 weeks, as presented in figure 6, but slightly decreased in 6 weeks of storage. The decrease in carbohydrate contents was related to depolymerization of some amylase chains, and formation of Trans glucosidation products within the flour.

The bulk density of a product is an essential parameter for choosing packaging materials, and materials handling to adopt during food processing and storage. The bulk density of guinea corn flour, from Table 3, decreases from 0.74 g/ml (2 weeks) to 0.68 g/ml (12-weeks) in PC, and increased from 0.71g/ml (2 weeks) to 0.75 g/ml (12-weeks) in HDPE, also increased in BPB from 0.60 g/ml (2 weeks) to 0.71g/ml (12 weeks). It was also discovered by Abeshu et al., (2016), that low bulk density of granular materials would be an advantage in the formulation of complementary foods for storage. This implies that guinea corn flour, with lower bulk density using the storage duration, and materials might be used as complementary foods in composite with other foods rich in protein. The storage periods and packaging materials, had an effect on the bulk density of guinea corn flour. The plastic container showed the best storage quality of guinea corn flour within 12-week storage period, followed by brown paper bag.

The Swelling power indicates the degree of exposure of the inner structure of starch granules to water, i.e, a measure of hydration capacity. The swelling power of the guinea corn flour decreases from 11.78% (2 weeks) to 8.87% (12 weeks) in HDPE, and from 10.92% (2 weeks) to 8.90% in PC, and also from 10.07% (2 weeks) to 9.31% (12 weeks) in BPB, as shown in Table 3. The differences in packaging materials and storage periods may be responsible for the changes in SWP during storage, though, the swelling power reduced significantly in both HDPE and PC than BPB.

Water absorption capacity represents the ability of a product to associate with water, under conditions where water is limited, and it was observed to be affected by storage periods. The water absorption of the guinea corn flour decreases from 88.50% (2 weeks) to 66.64% (12 weeks) in HDPE, and from 89.91% (2 weeks) to 49.77% (12 weeks) in PC, and increases from 81.33% (2 weeks) to 101.27% (12 weeks) in BPB which showed that brown paper bag absorb more water than others and also showed best in storing guinea corn flour within the storage period. The WAC was observed to be lowest in guinea corn flour stored in PC, than in HDPE, and this is attributed to the differences in the percentage water absorption of the packaging materials, which is rated as polypropylene > polyethylene > polyvinyl chloride (Awoyale et al., 2016).

The oil absorption capacity is a measure, of the ability of food material to absorb oil. It is discovered that the oil absorption capacity of the guinea corn flour decreases from 105.87% (2 weeks) to 71.44% (12 weeks) in HDPE, and from 117.33% (2 weeks) to 61.98% (12 weeks) in PC, and also from 117.61% (2weeks) to 82.12% (12 weeks) in BPB. The high value of oil absorption capacity, obtained for this study may be linked to the presence of protein, and might have exposed more non-polar amino acids to the fat, and enhances hydrophobicity as a result of which the guinea corn flour absorbs more oil (Oluwalana et al., 2011). The reduction in oil absorption in the flour, for all the packaging materials was noticed, as storage progressed, and this may be, as a result of the reduced ability of the flour to entrap fat to the polar end of its protein chain, which may is attributed to a decrease in its protein content. The guinea corn flour that showed highest oil absorption capacity is useful in the baking industry, or pastry as a flavour retainer, and the ability of this flour to bind with oil makes it useful in a food system where optimum absorption are desired.

Solubility index is related to the extent of leaching of amylase out of starch granules during swelling and is affected by intermolecular forces and the presence of surfactants and other associated substances (Kumar and Khatkar, 2017). The solubility index of guinea corn flour decreases from 16.58% (2 weeks) to 16.50% (12 weeks) in HDPE, and from 16.44% (2 weeks) to 15.61% (12 weeks) in PC, but in BPB it was increased from 14.97% (2 weeks) to 15.11% (12 weeks). The Solubility index of the BPB packaged guinea corn flour has the overall acceptability, as regards the storage duration.

The dispersibility is a measure of the reconstitution of floury products in water, and the higher the dispersibility, the better the samples reconstitute in water. The dispersibility of the guinea corn flour slightly decreases from 66.79% (2 weeks) to 66.80% (12 weeks) in HDPE, and from 72.55% (2 weeks) to 72.41% (12 weeks) in PC, and drastically decreases from 67.88% (2 weeks) to 61.95(12 weeks) in BPB. These results showed that the reduction of the dispersibilty in HDPE, and PC was due to storage period, but BPB material affect dispersibility. It implies that guinea corn flour stored in both HDPE, and PC within 12 weeks may reconstitute faster without lump formation, than the guinea corn flour stored in BPB.

The study showed, that the packaging materials and duration of storage had an effect on all the functional properties of the stored guinea corn flour. It was also discovered, that the packaging materials had no significant effect on the bulk density, and swelling power of the stored guinea corn flour within 12 weeks. The water absorption capacity and oil absorption capacity are significant affected on the packaging materials used for storing guinea corn flour within the storage period, but brown paper bag was the best packaging material on both water and oil absorption capacity for the flour within 12 weeks. It is observed that the packaging materials and duration of storage slightly affected the solubility index and dispersibility of guinea corn flour within 12 weeks, but showed high effect of dispersibilty in brown paper bag.

5. CONCLUSION

It was also discovered, that the packaging materials and storage duration had significant effect in all the proximate parameters of guinea corn flour stored at 12 weeks. The packaging materials and duration of storage contributed in the decrease of moisture and carbohydrate contents, but plastic container retained moisture and carbohydrate contents than the other two packaging materials. The increase in ash content, protein content, fats contents and crude fiber contents from 2 weeks to 12 weeks were influenced by packaging materials, where high density polyethylene showed the highest in retained protein and fats content of the flour. Brown paper bag showed highest, in retaining crude fiber content, and lowest in retaining ash contents of the flour.

Based on the results of the study, we conclude, that shelf life of guinea corn flour depends on the level of proximate composition and functional properties of the flour, packaging materials and storage durations. Storage duration and packaging materials of the flour had shown a significant effect, on the proximate composition and functional properties, which is used to determine the stability of the flour nutrients. The results of proximate composition and functional properties showed that the brown paper bag would be most effective for shelf-life stability of guinea corn flour. It was recommended, that the proximate composition and functional properties of different species of guinea corn flour, should be compared, and finds out any variation in optimum storage conditions. The differences in moisture contents of guinea corn flour should be compared, and finds out its influence in shelf life determination.

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Author Contributions

Engr. Dr. Ugwu Kenneth Chikwado participated in determination of all the Proximate Composition of Guinea Corn Flour and analysis of the results obtained.

Engr. Dr. Audu Shianya Ngabea participated in determination of all the Functional Properties of Guinea Corn Flour and analysis of the results obtained.

Engr. Princewill Leo Egba participated in preparation of samples of the flour, recording and typesetting of the whole work.

Informed consent

Not applicable.

Conflicts of interests

The authors declare that they have no conflicts of interest, competing financial interests or personal relationships that could have influenced the work reported in this paper.

Ethical approval & declaration

In this article, the product ethical regulations are followed as per the ethical committee guidelines of Department of Agricultural and Bioresource Engineering, Enugu State University of Science and Technology, 01660, Enugu, Nigeria; the authors observed the Effect of Packaging Materials and Storage Conditions on the Proximate Composition and Functional Properties of Guinea Corn Flour. The "brand name" of the product is not mentioned in content and also the "brand image" not displayed as figure in the article. The product ethical guidelines are followed in the study for product observation, identification & experimentation.

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Data and materials availability

All data associated with this work are present in the paper.

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