Determination of the Optimum Storage Conditions of Plantain Flour

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Abstract: The study is to determine optimum storage stability of plantain flour at different material packages. The results showed that the packaging materials and duration of storage had an effect on all the proximate parameters and functional properties of the stored plantain flour within 12 weeks. The bulk density, swelling power, water absorption capacity, oil absorption capacity, solubility index and dispersibility of plantain flour decreased in plastic container (PC), low density poly ethylene (LDPE) and laminated paper bag (LPB) from 2 to 12 weeks of storage except in bulk density that had an increase in both LDPE and LPB (0.69g/mL^{-1} in 2 weeks to 0.72g/mL^{-1} in 12-weeks and 0.56g/mL^{-1} in 2 weeks to 0.67g/mL^{-1} in12 weeks) and also water absorption capacity and solubility index that had an increase only in LPB(143.23% to 168.18% and18.94% to 19.09% from 2 to 12 weeks respectively) within the storage period. An increase in ash content (1.03% to 1.47%, in LDPE and 1.47% to 1.62% in PC), protein content (1.20% to 2.24%, in LDPE, 0.90% to 2.03% in PC and 1.20% to 1.89% in LPB) fat content (1.35% to 2.45%, in LDPE, 0.97% to 1.91% in PC and 1.24% to 1.89% in LPB) and crude fibre (3.24% to 3.60%, in LDPE, 3.14% to 3.79% in PC and 2.96% to 3.88% in LPB) were discovered within 2 to 12 weeks of storage. The moisture content (7.43% to 4.87%, in LDPE, 6.46% to 5.23% in PC and 7.02% to 4.86% in LPB) and carbohydrate (72.67% to 50.80%, in LDPE, 68.92% to 51.03% in PC and 73.92% to 50.89% in LPB) decreased within the storage period. Based on the results of the study, we discovered that shelf life of plantain flour depends on the functional properties and proximate composition of the flour, packaging materials and storage durations. The results showed that (LPB) would be most effective for shelf-life stability of plantain flour within the storage period.

Keywords: Determination, Optimum, Storage, Conditions, Plantain Flour

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1 Introduction

Plantain is a major group of banana varieties that are staple foods in many tropical areas. The edible fruit of plantain bananas has more starch than the common dessert banana and is not eaten raw. Plantain is versatile and has excellent nutritional value. It is less sweet variety of banana that can be used either ripe or unripe and are an invaluable source of carbohydrate, comparable in nutritive value to yam or potato. Because plantains are mostly starchy before they ripen, they are usually cooked green, either boiled or fried, in savory dishes.

The ripe fruits are mildly sweet and are often cooked with coconut juice or sugar as a flavouring. They are consumed mainly in Nigeria as snacks in the form of chips, dodo ikire, and or plantain amala (Vivienn et al., 2016). It was estimated that about 2.9 million metric tons of plantains are produced in

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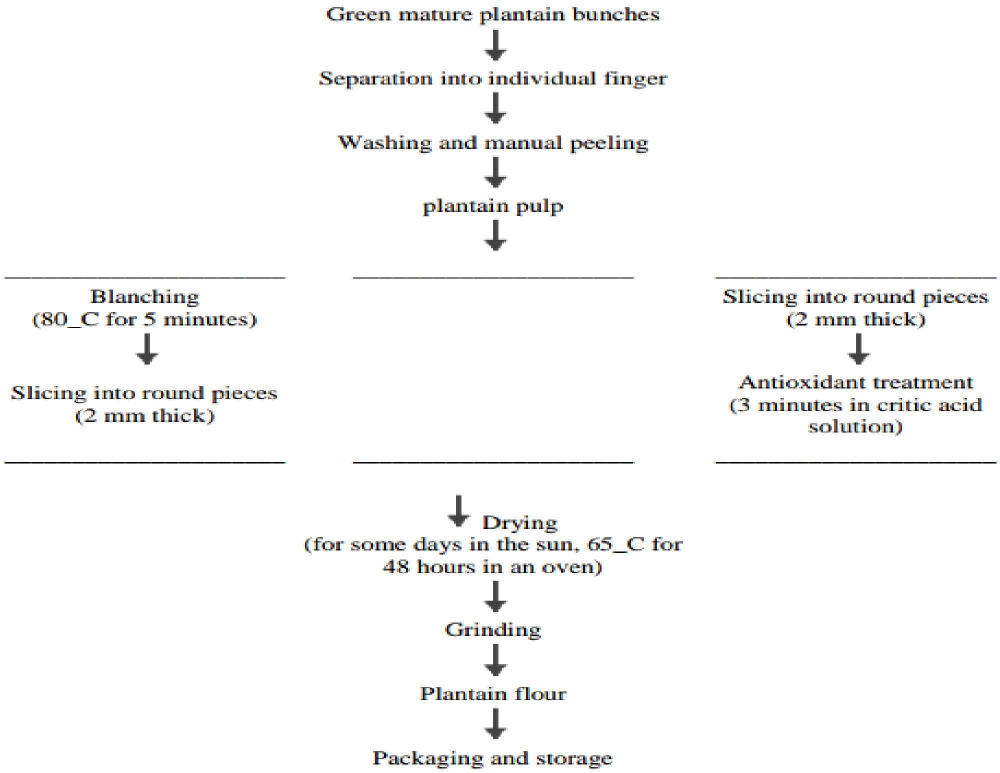
Nigeria annually, with about 45% to 67% post-harvest losses reported and attributed to lack of storage facilities and inappropriate technologies for food processing (Food and Agriculture Organization [FAO], 2012). According to FAO (2012), Nigeria is ranked first in Africa and fifth in the world, producing 2,822,000 metric tonnes of plantain in 2012 and consumed by the entire population. Plantain has rich source of nutrients containing 34.8% carbohydrate, 0.19% to 0.48% fats, 1.19% protein, and 0.79% ash (International Institute of Tropical Agriculture [IITA], 2014).

Plantains are highly perishable, with a substantial proportion of the harvested crop lost from the farm to the market place, because of poor post harvest handling. Though work has been done on the utilization of plantain fruits for different food ration varieties, therefore, post harvest losses may occur in peak periods when farmers do not harvest the entire crop because of market saturation (Adeolu and Enesi, 2013). In many African countries, including Nigeria plantains are used as an inexpensive source of calories (Adegunwa et al., 2017). Unripe plantain finger (UPF) is processed traditionally into flour. The flour is used for several traditional dishes ranging from akara, ukpo ogede, soups, baked products and may be reconstituted in boiled water to make amala which is eaten with any Nigerian soup (Onuoha et al., 2014).

The spoilage of plantain flour is usually attributed to the moisture content of the product, water activity and relative humidity of the storage room, as well as the permeability of the packaging materials to air and moisture (Adebowale, et al., 2008; Lawal et al., 2014). Various studies have been reported on the effect of different packaging materials (high and low-density polyethylene bags, polypropylene woven sacks and container) and storage conditions on the quality attributes of floury products. For instance, Adebowale, et al. (2008) reported that the best packaging material with less quality losses in the storage of water yam flour at 25 ℃ and 36% relative humidity for 24 weeks was the plastic container, which was attributed to its good barrier properties. Yam flour should be packaged in less permeable plastic packaging materials such as polyethylene and polypropylene bags for shelf-life extension, and not in Hessian bags (Lawal et al., 2014). Awoyale et al. (2020a) also reported that packaging yam flour in polyvinyl chloride container may keep most of the sensory properties preferred by the consumers when stored for up to 4 months. However, no work has been reported on the sensory acceptability of the amala from unripe plantain flour as it relates to the effect of different packaging materials and storage periods.

Fagbemi (1999) studied the effect of blanching and ripening on functional properties of plantain flour. He observed that blanching reduced the emulsion capacity and viscosity, while bulk density, water and oil absorption capacities were increased by blanching. Unripe plantain could be used as an emulsifier and thickener in a food system. He also observed that ripening had a negative effect on all the functional properties examined except the bulk density, and gelation property.

Unripe plantain is traditionally processed into flour in Nigeria (Kulkarni et al, 1991) and in other west and central African countries. This traditional technology is equally present in Amazonian Bolivia. The preparation method consists of peeling of the fruits with the hands, then cutting the pulp into small pieces, and air drying them for few days. The dried pulp is then ground in a wooden mortar or a corn grinder. The flour produced is mixed with boiling water to prepare an elastic pastry (alama in Nigeria and foufou or fufu in Cameroon) which is eaten with various sauces. The colour of the flour obtained is more or less dark due to the action of browning enzymes. Some improvement of this traditional method is by blanching the plantain pulp at 80 C for 5 minutes and cutting them into round pieces (or by soaking the round pieces for about 3 minutes in a sodium metabisulfite solution containing 3 g citric acid, followed by draining and drying in a drying oven at 65C for 48 hours or in the sun for some days resulted in the production of a more or less whitish flour (Ngalani, and Crouzet,. 1995). Plantain flour containing 10 percentage of residual humidity and hermetically packed in plastic sachets can be kept for many months without deterioration of its qualities. The step for processing plantain into flour is illustrated in the flow chart (Figure 1) below.



Flgure 1 Plantain flour production flow chart

Flour made from ripe plantain has been used in making bread, biscuits and flour (Ngalani and Crouzet, 1995). Bread obtained by partial substitution of wheat flour by 7.5 percentage plantain flour was not significantly different from that made with wheat flour alone.

Poor storage facilities and perishable nature of plantain can pose a threat to the yield and market value of plantain; this is because plantains are without doubt affected by factors such as humidity, air composition and temperature. The rigorous handling of plantain bunches during harvesting, storage and transportation can make some plantain fingers to detach from the bunch. Improper handling of plantain bunch can bruise the plantain skin thereby reducing the quality of the plantain. A proper storage and handling materials should be adopted to avoiding deterioration and wastage of plantain flour. However, more studies need to be carried out to determine the effect of different processing conditions on the various qualities attributes of the plantain flour.

The major aim of the research work is to determine the optimum storage conditions of plantain flour which is useful in knowing the exact packaging material and other factors to maintain the shelf life of plantain flour for a long period of time. The specific objective of the study is to determine the best packaging material for storage life of plantain four.

2 Materials and method

Matured unripe plantain fruit was obtained from the plantain plantation farm of Okechukwu from Mgbagbu Owa in Ezeagu Local Government Area of Enugu State of Nigeria. Plantains of the same variety and maturity level were carefully selected. Eighty kilograms (80kg) of the unripe matured plantain fingers were processed into plantain. The packaging materials which include low density poly ethylene (LDPE), plastic container (PC) and laminated paper bag (LPB) were obtained from Ogbete Main market in Enugu, Enugu State of Nigeria.

2.1 Preparation of plantain fingers into plantain flour

Fresh and healthy green bunches of the plantain fruits were detached from the peduncle. The fruits were de-fingered from the hands and washed to remove adhering dirt and possible chemical residue and latex (which may have exuded from the cut surface of the crown). The plantain fingers were peeled manually with the aid of a stainless knife and submerged in water until the peeling process was completed. The fingers were sliced longitudinally to about 15mm thickness with a stainless steel knife to enhance dehydration. The sliced plantain was dried in a moisture extraction oven at 60 ℃ for about 48h, after which it was milled into flour using Philips blender (HR2001; Amsterdam, the Netherlands), and sieved using a 250 μm mesh to obtain the sample flour. The plantain flour was packed in different zip lock bags and stored at room temperature for the storage and analysis.

The two hundred and fifty grams (250g) of plantain flour were weighed and packaged separately in LDPE, PC and LPB and properly sealed. These packaging materials were stored at room temperature for 12-weeks. The functional properties and proximate composition of plantain flour were evaluated every 2-weeks of the 12-weeks storage periods.

2.2 Determination of Functional

2.2.1 Properties of Plantain Flour

(1) Bulk density

The bulk density was determined using the standard methods described by Ashraf et al. (2012). Flour sample (10g) was measured into a graduated 100 ml measuring cylinder and lightly tapped on the workbench for 50 times to attain a constant height and then reweighed. The Bulk density was calculated as the ratio of the bulk density and the volume of the container and expressed as grams per milliliter.

(2) Swelling power and solubility index

Swelling power and solubility index were determined as described by Awoyale et al. (2020b). 2.5 % flour solution was prepared and heated in a water bath (Gallenkamp Water Bath Model BKS-350-030; Gallenkamp, London, UK), maintained at 90 ℃ for 40 min with constant stirring and cooling. The suspension was centrifuged at 3000 rpm for 30min and the supernatant was decanted into a pre-weighed can and dried at 100 ℃ to constant weight. The dried can were weighed for calculation of solubility, while the weight of wet sediment in centrifuge tube was used to determine swelling power.

$$Sp = \frac{w_p}{w_o} - w_r \quad (1)$$

$$S_I = \frac{w_r}{w_o} \times 100\% \quad (2)$$

Where:

w_p = weight of precipitated paste (g)

w_o = weight of sample (g)

w_r = weight of residue in supernatant (g)

S_p = swelling power (w)

S_I = swelling index (%)

(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 plantain flour was determined as described by Oyeyinka et al. (2013) with a few modifications. Flour sample of 10g was weighed into a clean pre-weighed dried centrifuge tube and mixed adequately with 10ml distilled water by vortexing after which the suspension was allowed to stand for 30min and centrifuged (Thelco GLC- 1, 60647: Chicago, USA) at 3,500rpm for 30min. The supernatant was decanted after centrifugation, with the tube and, the sediment weighed. The weight of water (g) retained in the sample was reported as WAC.

(4) Oil absorption capacity

The plantain flour sample of 10g was suspended in 5ml of vegetable oil in a centrifugal tube, after which the slurry was shaken on a platform tube rocker for 1.5 min at room temperature and centrifuged at 3000rpm for 15min. 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/initial weight of the sample (g/g) (Niba et al., 2002).

(5) Dispersibility

The ten gram (10g) sample of plantain flour was dispersed in a measuring cylinder (100 mL), and distilled water was added up to the 50ml mark. The mixture was stirred vigorously and allowed to settle for 2.5 hours as reported by Kulkarni et al. (1991). The volume of settled particles was noted, and the percentage of dispersibility was calculated as:

$$Dispersibility(\%) = \frac{(50 - volume\ of\ the\ settled\ particle)}{50} \times 100\% \quad (3)$$

2.3 Proximate Composition of Plantain Flour

2.3.1 Moisture content determination

Moisture content of the plantain flour was determined using air-oven method as described Niba et al.,(2002). A Gallenkamp hot air oven CHF097 (model) was used to dry all samples to constant weight. The percentage moisture content was determined using the formula below:

$$Moisture\ content, MC_{wb} = \frac{M_w - M_D}{M_w} \times 100 \quad (4)$$

Where, MC_{wb} is the moisture content of the plantain in % wet basis, M_W is the initial weight of the flour sample in g, M_D is the weight of the flour sample after drying to constant weight in g.

2.3.2 Determination of ash content

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

$$Total\ mass\ of\ ash = Mass\ of\ crucible + Ash\ sample - Mass\ of\ empty\ crucible \quad (5)$$

$$Mass\ of\ ash(\%) = \frac{Total\ mass\ of\ ash}{Mass\ of\ sample\ used} \times 100\% \quad (6)$$

2.3.3 Determination protein content

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

2.3.4 Determination fat content

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

$$Fat\ content(\%) = \frac{x - y}{z} \times 100 \quad (7)$$

where:

x = is the sum of weight of fat and flask (g)

y = is the weight of flask; (g) and

z = is the weight of sample (g)

2.3.5 Determination total crude fibre content

Crude fibre content of the plantain flour was determined using the method described by AOAC (2010).

2.3.6 Determination carbohydrate content

The total carbohydrate content of the plantain flour was calculated by difference method using the formula below:

$$\%Carbohydrate = 100 - (Protein + Moisture + Fat + Fibre + Ash) \quad (8)$$

Table 1 Initial functional properties and proximate compositions of plantain flour

Moisture content (%)	Crude ash content (%)	Crude protein content (%)	Crude fat (%)	Fibre content (%)	Carbohydrate content (%)
6.89	1.50	2.68	1.09	3.08	74.67
Bulk density (g/mL^{-1})	Swelling power (%)	Water absorption capacity (%)	Oil absorption capacity (%)	Solubility Index (%)	Dispersibilty (%)
0.70	15.07	141.86	160.35	27.86	72.47

3 Results and discussion

The optimum storage conditions of plantain flour were determined by comparing the parameters of functional properties and proximate compositions of plantain flour stored with different packaging materials, which include LDPE, PC and LPB at 12 weeks' storage period. The values of functional properties and proximate composition of plantain flour before storage were presented in Table 1. The results of functional properties of plantain flour stored with three different packaging materials at 2week, 4weeks, 6weeks, 8weeks, 10weeks and 12weeks storage periods were shown in Table 2.

The proximate composition of plantain flour stored at 12 weeks' period with three packaging materials were presented in Table 3.Figures 1 to 6 were used to determine exactly how each proximate parameter of the flour was affected with respect to the packaging materials and duration of storage.

Table 2 Effect of storage time and packaging materials on the functional properties of Plantain flour stored for a period of 12 weeks

Parameter	Storage duration (weeks)	Plantain stored in LDPE	Plantain stored in PC	Plantain stored in LPB
Bulk density (g/mL^{-1})	2	0.69	0.73	0.56
	4	0.71	0.73	0.71
	6	0.67	0.63	0.66
	8	0.59	0.58	0.71
	10	0.66	0.64	0.59
	12	0.72	0.66	0.67
Swelling power (%)	2	14.76	14.92	13.87
	4	14.76	12.39	13.63
	6	12.78	12.16	13.14
	8	13.01	12.98	12.79
	10	11.98	12.09	12.02
	12	11.90	11.98	12.02
Water absorption capacity (%)	2	156.45	152.89	143.23
	4	157.48	140.38	160.50
	6	143.65	122.43	162.34
	8	142.86	132.43	161.98
	10	142.86	121.75	165.75
	12	131.53	110.76	168.18
Oil absorption capacity (%)	2	155.68	168.23	168.46
	4	157.89	171.34	177.03
	6	146.11	162.34	151.66
	8	123.08	163.04	140.21
	10	120.23	131.90	141.73
	12	121.32	110.97	132.01
Solubility index (%)	2	20.65	20.32	18.94
	4	20.14	20.11	19.02
	6	20.12	20.77	18.90
	8	19.86	21.22	18.33
	10	21.04	20.54	20.07
	12	20.55	19.64	19.09
Dispersibilty (%)	2	65.87	71.45	66.97
	4	66.09	71.03	67.19
	6	66.22	69.87	66.79
	8	64.34	70.23	66.46
	10	64.99	70.75	65.65
	12	65.77	71.30	60.98

Table 3 Effect of storage time and packaging materials on the proximate composition of plantain flour stored for a period of 12 weeks

Week	Packaging material	Moisture (%)	Ash (%)	Protein (%)	Fat (%)	Fibre (%)	Carbohydrate (%)
2 weeks	LDPE	7.43	1.03	1.20	1.33	3.24	72.67
	PC	6.46	1.47	0.90	0.97	3.14	68.92
	LPB	7.02	1.46	1.20	1.24	2.96	73.92
4 weeks	LDPE	7.42	1.03	1.34	1.22	3.24	72.00
	PC	6.12	1.47	0.90	0.97	3.14	68.92
	LPB	7.04	1.46	1.20	1.24	2.96	71.64
6 weeks	LDPE	6.24	1.33	1.12	1.84	3.87	72.37
	PC	5.08	1.72	1.32	1.72	3.93	58.88
	LPB	6.02	1.72	1.54	1.94	4.03	59.25
8 weeks	LDPE	5.82	1.30	1.12	2.32	3.87	61.21
	PC	5.00	1.58	1.12	2.14	3.82	60.21
	LPB	5.32	1.22	1.10	2.09	3.86	60.14
10 weeks	LDPE	5.22	1.47	1.89	2.32	3.75	54.82
	PC	4.89	1.62	1.67	1.98	3.73	56.43
	LPB	5.02	1.03	1.61	1.89	3.88	55.14
12 weeks	LDPE	4.87	1.47	2.24	2.45	3.60	50.08
	PC	5.23	1.62	2.03	1.91	3.79	51.03
	LPB	**4.86**	**0.98**	**1.89**	**1.89**	**3.88**	**50.89**

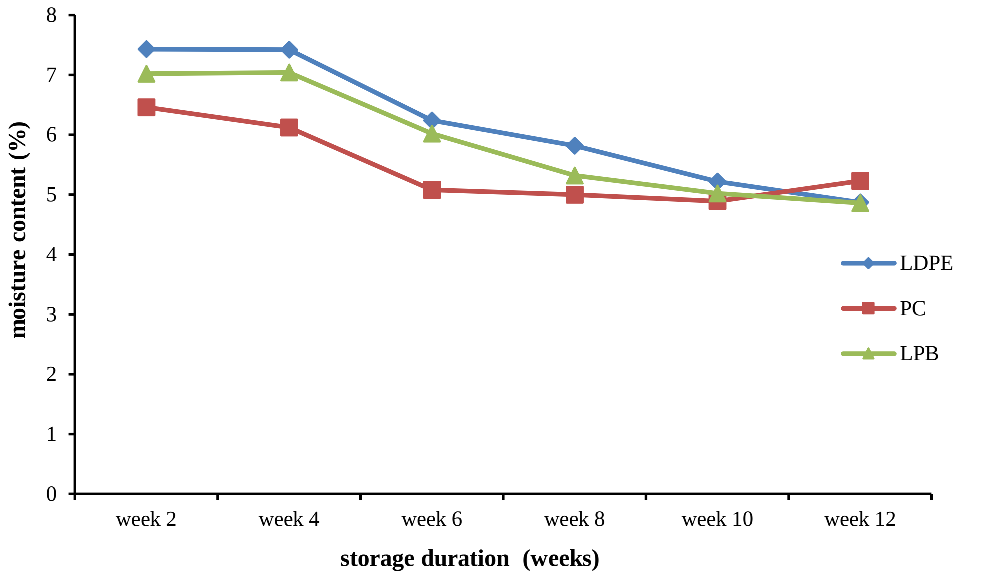


Figure 1 Effect of packaging materials on the moisture contents of plantain flour

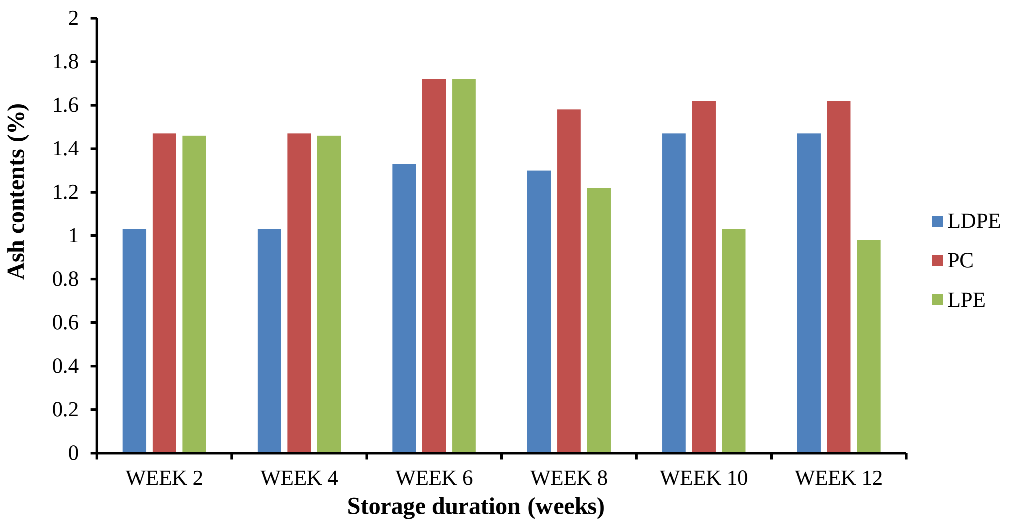


Figure 2 Effect of packaging materials on the ash contents of plantain flour

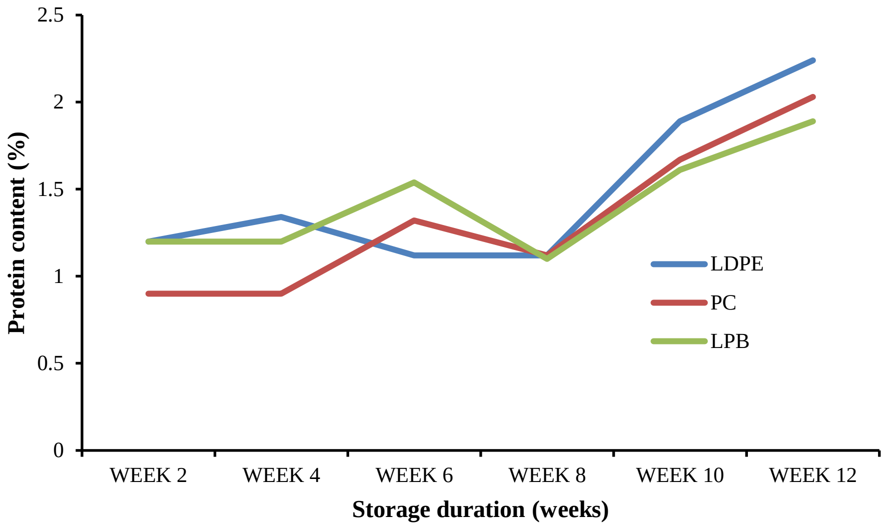


Figure 3 Effect of packaging materials on the crude protein contents of plantain flour

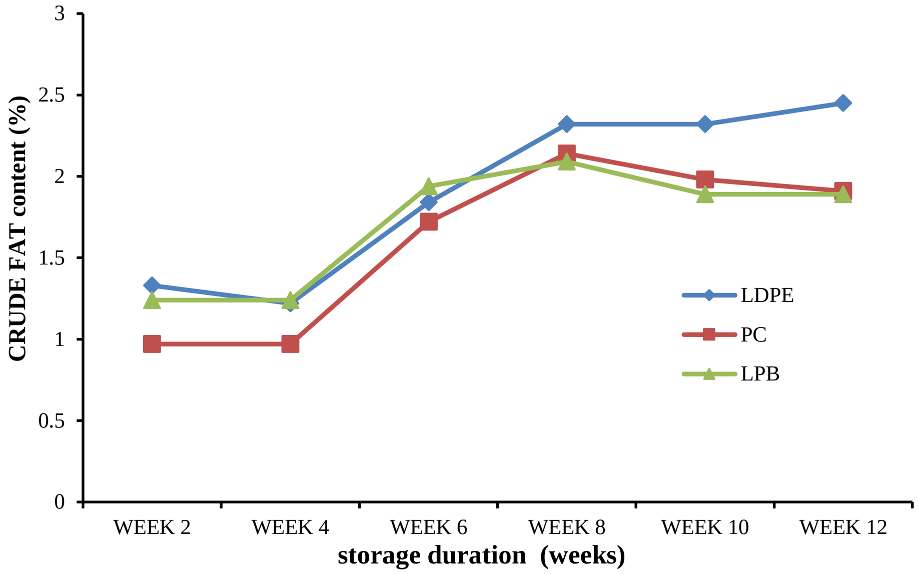


Figure 4 Effect of packaging materials on the crude fat contents of plantain flour

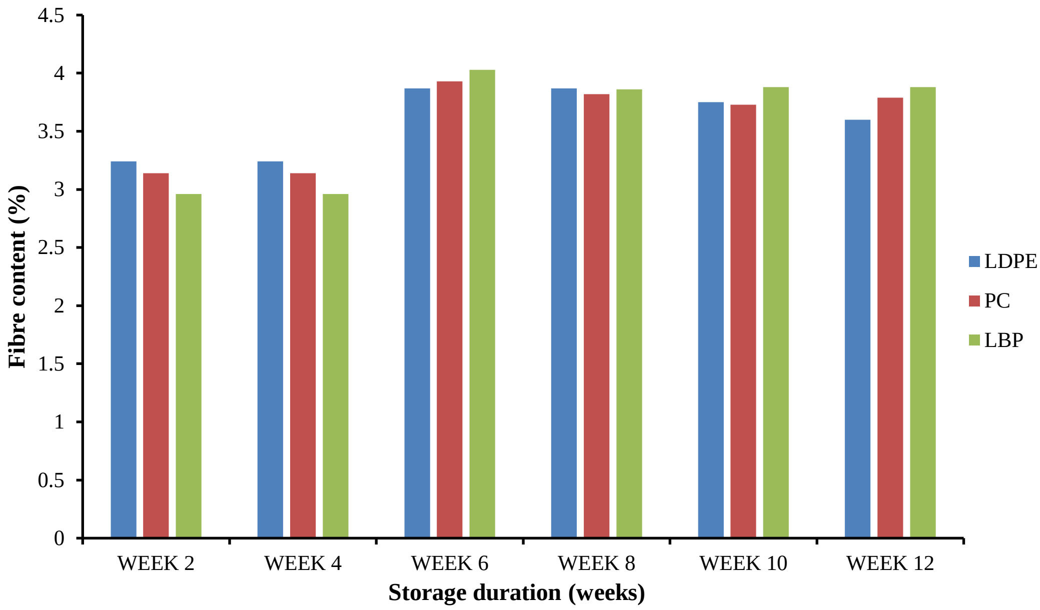


Figure 5 Effect of packaging materials on the fibre contents of plantain flour

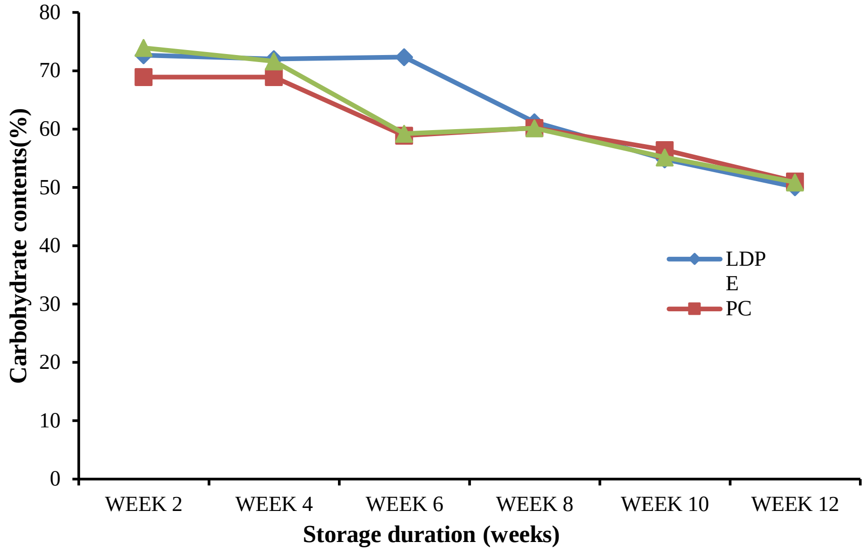


Figure 6 Effect of packaging materials on the carbohydrate contents of plantain flour

3.1 Discussion

The functional properties of a material are parameters that determine its application and end-use. That is, the functional properties indicate how the food materials under examination will interact with other food components directly or indirectly, affecting the processing applications, food quality, and ultimate acceptance (Adeleke and Odedeji, 2010).

The bulk density of a product is an essential parameter in determining packaging materials and materials handling to adopt during food processing. The bulk density of plantain flour, from Table 2, decreased from 0.73g/mL^{-1} (2 weeks) to 0.66g/mL^{-1} (12-weeks) in PC, and increased from 0.69g/mL^{-1} (2 weeks) to 0.72g/mL^{-1} (12-weeks) in LDPE, also increased in LPB from 0.56g/mL^{-1} (2 weeks) to 0.67g/mL^{-1} (12 weeks) It was discovered by Abeshu et al. (2016) that that low bulk density of granular materials would be an advantage in the formulation of complementary foods for storage. This implied that plantain 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 plantain flour. The plastic container has the best storage quality of plantain flour within 12-week storage period followed by LBP.

Swelling power indicates the degree of exposure of the inner structure of starch granules to the action of water, i.e., a measure of hydration capacity. The swelling power of the plantain flour decreased from 14.76% (2 weeks) to 11.90% (12-weeks) in LDPE, and from 14.92% (2 weeks) to 11.98% in PC and also from 13.87% (2 weeks) to 12.02% (12 weeks) in LPB as shown in Table 2. The differences in packaging materials and storage periods may be responsible for the changes in SWP during storage, though, the reduction in swelling power were high in both LDPE and PC than LPB.

The 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 plantain flour decreased from 156.45% (2 weeks) to 131.53% (12 weeks) in LDPE, and from 152.89% (2 weeks) to 110.70% (12 weeks) in PC, and increased from 143.23% (2 weeks) to 168.18% (12 weeks) in LBP which showed that LBP bag absorb more water than other and also showed best in storing plantain flour within the storage period. The WAC was observed to be lowest in plantain flour stored in PC than in LDPE, and this may be 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 was discovered that oil absorption capacity of the plantain flour decreased from 155.68% (2 weeks) to 121.32% (12 week) in LDPE, and from 168.23% (2 weeks) to 110.97% (12 weeks) in PC and also from 168.46% (2weeks) to 132.01% (12 weeks) in LPB. 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 plantain 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 progress 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 be attributed to a decrease in its protein content. The plantain flour that shows highest oil absorption capacity may be 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 is desired.

The Solubility index is related to the extent of leaching of amylose out of starch granules during swelling and affected by intermolecular forces and the presence of surfactants and other associated substances (Kumar & Khatkar, 2017). The solubility index of plantain flour decreased from 20.65% (2 weeks) to 20.56% (12 weeks) in LDPE, and from 20.32% (2 weeks) to 19.64% (12 weeks) in PC, but in LPB it was increased from 18.94% (2 weeks) to 19.09% (12 weeks).The Solubility index of the LPB packaged plantain flourhas the overall acceptability as regards to the storage duration.

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 plantain flour slightly decreased from 65.87% (2 weeks) to 65.77% (12 weeks) in LDPE, and from 71.45% (2 weeks) to 71.30% (12 weeks)in PC and drastically decreased from 66.02% (2 weeks) to 60.98(12 weeks) in LPB. These results showed that the reduction of the dispersibilty in LDPE and PC was due to storage period and but LPB material affect dispersibility. This implies that plantain flour stored in both LDPE and PC within 12 weeks may reconstitute faster without lump formation than the plantain flour stored in LPB.

The moisture content was inversely proportional to the storage duration. By the end of the storage period in week 12, the moisture content in Table 3 was found to decrease from 7.43% to 4.87 % in LDPE, also from 6.46% to 5.23% in PC and from 7.02% to 4.86% in LPB. The moisture content range did not correspond with the recommended moisture content (6% - 14%) for flour stability and in line with the reported range for moisture content of cassava flour (Awoyale et al., 2016). It was also found in Figure 1 that plastic container retained more moisture than other two packaging materials within the storage period. The acceptable moisture content of flour according to Amarachi was at the storage period of 6weeks using the three packaging materials.

The ash contents of the plantain flour samples were increased from 1.03% to 1.47% in LDPE and from 1.47% to 1.62%in PC and reduced from 1.46% to 0.98% in LPB within the storage period. It was discovered from Figure 2 that ash content increased to their highest level in 6 weeks' storage period and started decreasing after the period but the sample stored in LPB decreases faster than the other two.

The protein contents of the plantain flour samples were generally increased from 1.20% to 2.24% in LDPE, also from 0.90% to 2.03% in PC and from 1.20% to 1.89% in LPB. The significant increase in protein contents of the flour was in agreement with Mpotokwane et al. (2008).

From Figure 3, it was deduced that plantain flour sample packaged with low density polyethylene increases protein content faster than the two packaging materials within storage duration.

There was drastic increase in fat contents of the plantain flour stored in three different packaging materials as shown in Table 3. The fat contents increased from 1.35% to 2.45% in LDPE, from 0.97% to 1.91% in PC and from 1.24% to 1.89% in LPB respectively. The increased in fat contents within the storage period could be attributed to packaging materials used. The Figure 4 also showed that fat content of plantain flour stored with low density polyethylene increases higher than PC and LPB. It was discovered that LPB bag was the best packaging material to store plantain flour within the storage period.

The Table 3 shows that crude fibre content of plantain flour varied from 3.24% to 3.60% in LDPE, from 3.14% to 3.79% in PC and from 2.96% to 3.88% in LPB. There were slight increase in crude fibre contents of plantain flour stored within 12 weeks, which was in line with Kumar and Khatkar (2017). Consumption of diets high in dietary fibre 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 was found that the best packaging material for storing plantain flour within 12 weeks was LPB as presented in Figure 5.

Carbohydrate contents, which is also total starch content of plantain flour decreased drastically from 72.67% to 50.80% in LDPE, from 68.92% to 51.03% in PC and from 73.92% to 50.89% in LPB as shown in Table 3. The three packaging materials showed similar decrease in carbohydrate contents of plantain flour stored within 12 weeks as presented in figure 6, but varies slightly in 6 weeks of storage. The decreases in carbohydrate contents were related to depolymerization of some amylose chains and formation of trans glucosidation products within the flour.

4 Conclusion

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

It was also discovered that the packaging materials and storage duration had significant effect in all the proximate parameters of plantain flour stored at 12 weeks. The packaging materials and duration contributed in the decrease of moisture and carbohydrate contents, but plastic contain retained more moisture and carbohydrate contents than the other two packaging materials. The increase in ash content, protein content, fats contents and crude fibre contents from 2 weeks to 12 weeks were influenced by packaging materials, where LDPE showed the highest in protein and fats content of the flour. LPB showed highest in crude fibre content and lowest in ash contents of the flour.

Based on the results of the study, we concluded that shelf life of plantain flour depends on the properties and proximate composition of the flour, packaging materials and storage durations.

Storage duration and packaging materials of the flour had showed significant effect on the functional and proximate composition, which will be used to determine the stability of the flour nutrients. The results of functional properties and proximate composition showed that LPB would be most effective for shelf-life stability of plantain flour.

It is recommended that the functional properties and proximate composition of different species of plantain flour should be compared and finds out any variation in optimum storage conditions. The unripe, intermediate ripe and full ripe of plantain flour should be compared and find out their shelf life. It is also advising to store plantain flour with LPB rather than other packaging materials.

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