Croatian Journal of Food Science and Technology
journal homepage: www.ptfos.unios.hr/cjfst/

Original scientific paper DOI: 10.17508/CJFST.2022.14.2.10

Effect of packaging materials on selected quality attributes of cocoyam (*Xanthosoma sagittifolium* (L.) Schott) flour

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ARTICLE INFO

Article history:
Received: February 22, 2022
Accepted: June 9, 2022

Keywords:
cocoyam cormel
packaging
quality attributes
cocoyam flour

ABSTRACT

Cocoyam (*Xanthosoma sagittifolium* (L.) Schott) is an important crop which serves as a staple food for a large number of people in developing nations including Nigeria. Its perishability necessitates immediate processing after harvest to obtain products such as chips, flakes and flour with better storage stability. Proper selection of appropriate packaging materials for cocoyam flour is important to maintain the quality attributes during storage and to extend its shelf life. This study, therefore, examined the influence of packaging materials and storage period on the quality of cocoyam flour. Cocoyam flour was produced from fresh, wholesome cormels. The flour samples were stored in three packaging materials (polyethylene terephthalate [PET] bottles, polyethylene bags and woven polypropylene sacks) for six months under ambient conditions. The flour samples were then analyzed at four-week intervals for proximate composition, pH, colour and sensory analysis using standard methods. The results showed that packaging materials and length of storage significantly affected crude fibre and carbohydrate content of cocoyam flour. The moisture content of the flour packed in woven polypropylene decreased to a larger extent due to its higher water vapour permeability. The type of packaging did not significantly affect the crude fat content of the flour throughout the storage period. The PET bottle performed better in retaining the protein and ash content of the flour. Although significant differences were observed in the pH levels and colour of the cocoyam flour samples after storage in the different packaging materials, the type of packaging material did not affect these physicochemical properties. The sensory properties of the cocoyam flour in three packaging materials were found to be within acceptable limits at the end of storage. All the selected packaging materials performed well in retaining the quality attributes of the cocoyam flour throughout the period of storage.

Introduction

Cocoyam (*Xanthosoma sagittifolium* (L.) Schott) is a perennial plant belonging to *Araceae* family. It is primarily grown for its edible corms and cormels, and secondarily, for its leaves which serve as vegetables in different parts of the world. Cocoyam is rich in carbohydrates and contains other nutrients such as protein, vitamins, calcium, phosphorus, magnesium, potassium, manganese, zinc, and copper, in varying quantities (Nyochembeng and Garton, 1998; Oyefeso et al., 2021). Cocoyam corms and cormels are customarily consumed after frying in vegetable oils, boiling, or roasting in the fire. Cocoyam flour can also be produced from the corms for several purposes including soup thickeners and food ingredients (Oyefeso and Raji, 2021). The starch is also more easily digested compared to cassava and yam starch (FAO, 2013).

Fresh cocoyam cormels deteriorate rapidly after harvest due to their relatively high moisture content and this necessitates prompt processing into more

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stable products such as chips, flakes and flour with improved storage stability (Owusu-Darko et al., 2014; Raji and Oyefeso, 2017). Numerous physiological and biochemical changes also occur during the storage of food and agricultural materials, which can affect their quality parameters (Tschannen, 2003; Obadina et al., 2016). Therefore, assessment of the variations that occur in the quality attributes of agricultural products stored in different packaging materials is necessary to establish the optimum storage conditions for the product. This study, therefore, aimed at evaluating selected quality attributes, namely the proximate composition, physicochemical properties (pH, and colour), and sensory attributes of cocoyam flour in different packaging materials over the period ofsix months under ambient conditions to determine the suitability of the packaging materials and stability of the flour in storage.

Materials and methods

Cocoyam cormels used in this study were sourced from Okeluse town, Ondo State, Nigeria. The packaging materials (polyethylene terephthalate [PET] bottles, polyethylene bags and woven polypropylene sacks) as shown in Figure 1 were purchased from Bodija market in Ibadan, Oyo State, Nigeria. The procedure described by Babajide et al. (2006) was used for the production of flour from the cocoyam cormels. Figure 2 shows the freshly produced cocoyam flour before storage. This involved peeling the fresh cormels, slicing to produce chips of about 3 - 5 mm in thickness, soaking in hot water at an initial temperature of 80 °C for 15 hours and drying at 70 °C for 13 hours in an oven dryer before milling into flour. The quality attributes of the freshly produced cocoyam flour prior to packaging and storage were determined and used as control. The flour samples were put in three selected packaging materials, namely polyethylene terephthalate (PET) bottles, polyethylene bags and woven polypropylene sacks and stored at ambient conditions of average relative humidity of 80.5 ± 3.2 % and temperature of 27.5 ± 2.0 °C. The quality attributes of the stored flour samples were evaluated at four-week intervals for a period of twenty-four weeks.

(a) (b) (c)

Figure 1. Packaging materials: a) PET bottles; b) polyethylene bags; c) woven polypropylene sacks

Figure 2. Freshly produced cocoyam flour

Determination of proximate composition

The moisture content of the cocoyam flour was determined with the aid of a moisture analyser (Adam Equipment, USA, PMB 53, max = 50 g, d = 0.001 g). The crude fat and protein content was determined using Soxhlet and Kjeldahl methods, respectively (AOAC, 2006). Crude ash and fibre content was obtained using standard methods according to AOAC (2010). The carbohydrate content of the cocoyam flour was obtained using the difference method according to Eq. 1 (Nwabueze and Anoruoh, 2011). All the proximate compositions were determined in triplicates and presented in percentages.

$$\text{Carbohydrate content (\%)} = 100 - (\text{\% protein} + \text{\% fat} + \text{\% moisture content} + \text{\% ash}) \quad (1)$$

Determination of physicochemical properties

The pH values of the cocoyam flour were determined using AACC (2000) method while the colour of the flour involved the use of a colourimeter (CR-400/410 Konica Minolta Sensing Inc., Japan) to measure the 3-dimensional colour (lightness, yellowness and redness) values according to the procedure described by Rhim and Hong (2011). All the physicochemical properties of the flour samples were determined in triplicates.

Sensory evaluation of the cocoyam flour

The stored cocoyam flour was reconstituted in boiling water at a ratio of 1:2 until paste consistency was achieved (Daramola et al., 2010). Sensory analysis of the produced paste was carried out by a panel of 10 trained judges who indicated their preference for the flour using a 9-point hedonic scale (Iwe, 2002; Daramola et al., 2010). The sensory attributes of the flour assessed by the panellists include colour, taste, mouldability, texture and aroma. All the obtained data for the quality attributes were recorded as means of triplicates with standard deviations and subjected to statistical analysis using two-way analysis of variance (ANOVA) while least significant difference method was used to determine the levels of significance at a 95% confidence interval ($p \leq 0.05$).

Results and discussion

Proximate composition of cocoyam flour

The results of the changes in the proximate composition of the cocoyam flour stored in the different packaging materials over the period of six months are presented in Table 1. The study showed that the crude protein and crude fat content increased while the moisture content, carbohydrate, crude fibre and ash content decreased during the storage period.

Initial moisture content obtained from the cocoyam flour before storage was 15.69, ± 0.11 % (wet basis). After a month of storage, a slight decrease in the moisture content was observed with the highest decrease being observed in polyethylene with a reduction rate of 1.16 %, while 0.16 and 0.98 % reduction was observed in PET bottles and woven polypropylene sacks, respectively. The moisture content of the flour in all three packaging materials increased after the 8th and 12th week of storage, but it decreased subsequently. The moisture content of the flour in the woven polypropylene sack increased from 14.71% after the 4th week to 17.29% and 17.80% after the 8th and 12th week respectively and it was higher than the moisture content reported for the other packaging materials. The increased moisture content could be attributed to the hygroscopic characteristics of the flour under the storage conditions and the higher water vapour transmission rate of the woven polypropylene sack, resulting in more moisture migration from the environment into the sack (Daramola et al., 2010; Agrahar-Murugkar and Jha, 2011). The increased moisture content of the flour during storage could have resulted in increased microbial activities which could, in turn, be responsible for higher demand for water caused by the growth of microorganisms and could result in the subsequent reduction in the moisture content of the flour in woven polypropylene sack at the expiration of the storage period compared with the other packaging materials (Agrahar-Murugkar and Jha, 2011). At the end of the six-month storage period, the moisture content of the flour was reduced to 14.86 ± 1.19, 14.39 ± 0.35 and 13.64 ± 0.78 % in the PET bottle, polyethylene bag and woven polypropylene sack, respectively. This indicates that cocoyam flour stored in the woven polypropylene sack had lower moisture content after the storage period and it may, therefore, be more suitable for prolonged storage with higher storage stability for the stored flour due to reduced microbial activities at such low moisture levels (Emperatriz et al., 2008). Data obtained for moisture content in this study are relatively higher than those reported by Ogunlakin et al. (2012) for cocoyam flour obtained from cormels dried by open air, solar and oven drying. However, the average moisture content of the stored cocoyam flour was within the safe limit recommended by FAO (1993).

The carbohydrate content was reduced from an average value of 76.46 % (before storage) to 70.47%, 71.22% and 73.21% in PET bottles, polyethylene bags and woven polypropylene sacks, respectively at the end of six-month storage. This reduction in the carbohydrate content may be due to the activities of microorganisms that utilize carbohydrate as an energy source for their metabolic activities (Agrahar-Murugkar and Jha, 2011). The fat content of the cocoyam flour ranged from 0.47 to 9.73 % with the PET bottle having the highest value while the woven polypropylene sack had the lowest value over the six-month storage period. Activities of microorganisms could be responsible for the lower fat content of the flour sample in the woven polypropylene sack compared with the PET bottle and the polyethylene bag. The fat and protein content of the flour in all packaging materials increased throughout the period of storage, contrary to the report of Agrahar-Murugkar and Jha (2011). The fat content of the flour in the woven polypropylene sack was lower than the other packaging materials, thereby, indicating that there is a lower chance for the development of rancid flavour if flour is packaged in the woven polypropylene sack (*Ogundare-Akanmu et al.,* 2015). The protein content of all samples was within the range of 3.95-8.75 %, which is relatively low in comparison to flours from other sources. This is in line with the reports by Oyenuga (1992) and Okaka and Isieh (2002), who reported thatcocoyam is not a rich protein source. The highest protein retention was observed in the samples packaged in polyethylene bags at the end of the six-month storage period.

The initial ash content of the flour (2.11 ± 0.51 %) was within the range of 1.56 to 2.98 % obtained by Sefa-Dedeh and Agyir-Sackey (2004) for flours from tannia and taro cormels. At the end of the six-month storage period, the ash content was 2.26 ± 0.16, 1.53 ± 0.67 and 1.66 ± 0.20 % for cocoyam flour stored in PET bottles, polyethylene bags and woven polypropylene sacks, respectively. This indicates that the flour sample in the PET bottle had more mineral elements and, therefore, higher ash content than the other packaging materials. The fibre content for the cocoyam flour throughout the period of storage ranged between 0.30 and 1.31%. The flour in the woven polypropylene sack had the lowest fibre content (0.30%) at the sixth month of storage while the PET bottle had the highest value (0.35%). This indicates that flour samples in the PET bottle with higher fibre content at the end of the storage period are more digestible than those in the other packaging materials (Obadina et al., 2016).

There was significant differences ($p \leq 0.05$) between the moisture, crude fibre and carbohydrate content of the freshly produced cocoyam flour (week 0) and the flour samples packaged in three packaging materials at the end of the storage period. This showed that the combined effects of packaging materials and the length of storage period significantly affected these proximate attributes. Although there were variations in the values recorded during storage, no significant difference ($p \leq 0.05$) was observed in the crude fat content of the flour at week 0 and the samples packaged in three packaging materials throughout the storage period. The protein and ash content of the flour samples in polyethylene bags and woven polypropylene sacks was significantly different ($p \leq 0.05$) from the flour in the plastic bottle at the end of the storage period. The protein and ash content of the freshly produced flour at week 0 was not significantly different ($p \leq 0.05$) from those recorded for flour packed in the PET bottle at the end of the storage period. This indicates that PET bottles as a packaging material performed better in retaining the protein and ash content of the flour at the end of the storage period than the other packaging materials.

Physicochemical properties of cocoyam flour

The results of the variations in the selected physicochemical properties of the cocoyam flour stored in the selected packaging materials over six-month storage period are presented in Table 2. Changes in the pH level of the cocoyam flour stored in three packaging materials are presented in Figure 3. The pH levels of the stored cocoyam flour increased from an initial average value of 6.06 (week 0) to 6.38 ± 0.00, 6.56 ± 0.00 and 7.46 ± 0.00 in the PET bottle, polyethylene bag and woven polypropylene sack, respectively, at the expiration of the six-month storage period. The increase in the pH of the flour after storage may be attributed to the incipient accumulation of organic acids probably due to the activities of microorganisms (Daramola et al., 2010). There were significant differences ($p \leq 0.05$) between the pH of the flour before and after storage in three packaging materials. However, there was no significant difference ($p \leq 0.05$) between the pH of the flour packed in three packaging materials at the expiration of the storage period. This showed that only the length of the storage period significantly affected the pH of the flour and not the type of the used packaging materials.

In terms of changes in the colour of the flour, the lightness and yellowness of the flour increased while the flour redness decreased throughout the period of storage in all packaging materials. The lightness of the flour increased from 66.36 ± 0.01 (before storage) to 71.27 ± 0.06, 84.05 ± 2.06 and 70.14 ± 0.06 % while the yellowness of the stored flour increased from 9.29 ± 0.01 (week 0) to 12.60 ± 0.00, 15.03 ± 0.30 and 13.25 ± 0.06 at the end of the six months of storage in

PET bottles, polyethylene bags and woven polypropylene sacks, respectively. This increase in flour lightness and yellowness may be a result of the storage conditions such as the temperature, relative humidity and light intensity which affected the nature of the beta carotenes present in the flour and made the presence of the bright yellow pigments more pronounced at the end of the storage period. This is in contrast to the findings of Uchechukwu-Agua (2015) for cassava flour from the selected varieties. The statistical analysis (ANOVA) showed that there were significant differences ($p<0.05$) in the yellowness of the flour before and after the six-month storage period in three packaging materials although the values of yellowness of flour in three packaging materials were not significantly different ($p<0.05$). This indicates that choice of the type of packaging material did not affect the yellowness of the flour after the storage period.

Sensory properties of the cocoyam flour

The panellist score for all sensory attributes was 60% for the slightly brown colour, while 40% for brown colour. 80% thought that the taste was bland while 20% thought it was bitter. 80% of panellists thought that the the flour paste was mouldable, 10% thought it was extremely mouldable and 10% described it as moderately mouldable. 90% of the panellist thought the cocoyam flour paste texture to be smooth and 10% thought it was extremely smooth. Aroma of the paste was moderately liked (70%), liked (20%) and extremely liked (10%), respectively. Based on the results of the sensory evaluation, the sensory properties of the cocoyam flour were found to be within acceptable limits at the expiration of the six months of storage in three packaging materials.

Table 1. Proximate composition of the cocoyam flour

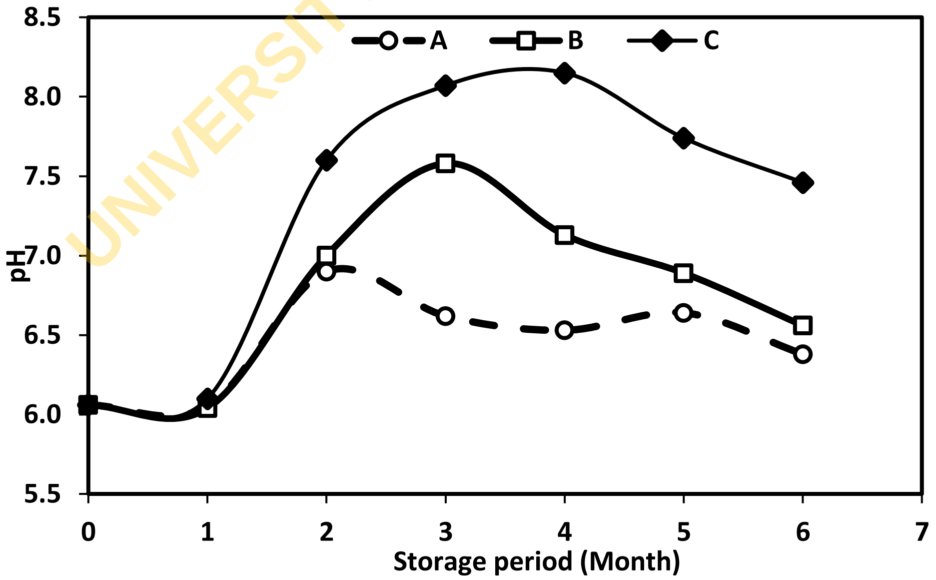
Storage period	Packaging materials	Proximate Composition					
		Moisture Content (%, wb)	Crude fibre (%)	Crude protein (%)	Crude Fat (%)	Ash content (%)	Carbohydrate (%)
Week 0	Nil	15.69±0.11^{aBCD}	0.58±0.09^{aCD}	5.20±0.13^{aB}	0.53±0.07^{Ae}	2.11±0.51^{aAB}	76.43±0.84^{aA}
Week 4	PET	15.53±0.10^{aBCD}	1.31±0.01^{aA}	6.56±0.92 ^{aA}	1.00±0.01^{Ae}	2.57±0.15^{aA}	73.03±1.06^{aBC}
	Polyethylene	14.53±0.66^{Ac}	1.08±0.26^{aA}	5.75±0.28 ^{aA}	0.53±0.06^{Ac}	1.72±0.11^{aA}	76.38±0.46^{aA}
	Polypropylene	14.71±0.18^{aBC}	0.68±0.15^{aA}	8.75±0.23^{Aa}	0.47±0.06^{Ac}	2.08±0.24^{aB}	73.31±0.49^{aBC}
Week 8	PET	16.84±0.14^{aA}	1.02±0.02^{aB}	4.65±0.09^{aBCD}	1.68±0.90^{Ade}	1.98±0.26^{aAB}	73.83±0.61^{aAB}
	Polyethylene	16.51±0.13^{aA}	0.87±0.00^{aAB}	4.12±0.38^{aBC}	3.79±0.51^{Ab}	2.59±1.81^{aA}	72.12±1.19^{aBC}
	Polypropylene	17.29±0.69^{aA}	0.46±0.10^{aAB}	4.47±0.18^{Ac}	4.32±0.02^{Ab}	1.95±0.11^{aB}	71.50±0.69^{aBCD}
Week 12	PET	16.81±0.78 ^{aA}	0.58±0.12^{aCD}	4.06±0.10^{aCD}	3.33±0.12^{Ac}	1.78±0.25^{aB}	73.44±0.92^{aB}
	Polyethylene	16.42±0.38 ^{aA}	0.55±0.12^{aBC}	3.98±0.13^{aC}	4.07±0.23^{Ab}	1.72±0.19^{aA}	73.26±0.24^{aBC}
	Polypropylene	17.86±0.34 ^{aA}	0.73±0.12^{aA}	3.95±0.09^{Ad}	4.27±0.12^{Ab}	1.89±0.59^{aB}	71.31±0.76^{aBD}
Week 16	PET	16.47±0.27^{abA}	0.63±0.21^{aC}	4.04±0.09^{aBCD}	9.73±0.98^{Aa}	1.65±0.09^{aB}	67.48±0.88^{abD}
	Polyethylene	14.72±0.24^{aBC}	0.69±0.13^{bBC}	4.09±0.13^{abBC}	5.09±1.24^{Ab}	1.73±0.10^{aA}	73.67±1.51^{abB}
	Polypropylene	12.58±0.13^{abD}	0.69±0.14^{bA}	4.33±0.13^{Acd}	5.89±0.86^{Aa}	3.17±0.08^{aA}	73.34±1.18^{aB}
Week 20	PlET	15.76±0.32^{aABCD}	0.54±0.02^{aCD}	4.65±0.09^{aBCD}	3.17±0.58^{Acd}	2.15±0.32^{aAB}	73.75±0.80^{aB}
	Polyethylene	14.37±0.34^{aC}	0.52±0.01^{aC}	4.56±0.09^{aB}	4.83±0.76^{Ab}	2.18±0.11^{aA}	73.53±0.36^{aBC}
	Polypropylene	13.82±0.56^{aCD}	0.52±0.00^{aAB}	5.09±0.09^{Ab}	4.51±0.67^{Aab}	2.11±0.16^{aB}	73.98±0.98^{aAB}
Week 24	PET	14.86±1.19^{aBCD}	0.35±0.02^{aD}	5.38±0.13^{aB}	6.68±0.57^{Ab}	2.26±0.16^{aAB}	70.47±1.32^{aC}
	Polyethylene	14.39±0.35^{aC}	0.35±0.00^{aC}	5.47±0.13^{aA}	7.05±0.97^{Aa}	1.53±0.67^{aA}	71.22±1.10^{aBC}
	Polypropylene	13.64±0.78^{aCD}	0.30±0.09^{aB}	5.41±0.05^{Ab}	5.78±0.96^{Aab}	1.66±0.20^{aB}	73.21±1.87^{aBCD}

Mean values in rows with different lower cases (a, b, c, etc) are significantly different ($p<0.05$) and those in columns with different upper cases (A, B, C. etc) are significantly different ($p<0.05$) using Tukey (HSD) test

Table 2. Physicochemical properties of the cocoyam flour

Storage periods	Packaging materials	pH values	Colour parameters		
			Lightness	Redness	Yellowness
Week 0	Nil	6.06 ± 0.00^{aF}	66.36 ± 0.01	-3.28 ± 0.01	9.29 ± 0.01
Week 4	PET	6.05 ± 0.00^{aC}	67.26 ± 0.01^{aC}	-4.42 ± 0.01^{aB}	10.18 ± 0.01^{aE}
	Polyethylene	6.04 ± 0.00^{aB}	72.06 ± 0.05^{aB}	-4.64 ± 0.01^{aB}	11.11 ± 0.01^{aD}
	Polypropylene	6.10 ± 0.00^{Ad}	68.78 ± 0.00^{aD}	-4.52 ± 0.01^{aB}	10.54 ± 0.01^{aF}
Week 8	PET	6.90 ± 0.00^{aA}	71.20 ± 0.01^{aA}	-4.82 ± 0.01^{aC}	12.33 ± 0.05^{aB}
	Polyethylene	$7.00\ \pm0.00\ ^{aB}$	71.85 ± 0.01^{aB}	-4.77 ± 0.02^{aB}	12.25 ± 0.01^{aB}
	Polypropylene	7.60 ± 0.00^{Aa}	71.91 ± 0.10^{aA}	-4.67 ± 0.00^{aC}	12.25 ± 0.04^{aC}
Week 12	PET	6.62 ± 0.00^{aE}	66.58 ± 0.02^{aE}	-5.76 ± 0.01^{aD}	11.10 ± 0.01^{aD}
	Polyethylene	7.58 ± 0.00^{aB}	70.43 ± 0.08^{aB}	-6.02 ± 0.01^{aC}	11.56 ± 0.02^{aC}
	Polypropylene	8.07 ± 0.00^{Ad}	68.69 ± 0.01^{aD}	-5.56 ± 0.01^{aD}	11.66 ± 0.02^{aE}
Week 16	PET	6.53 ± 0.00^{abD}	67.08 ± 0.06^{abD}	-7.47 ± 0.01^{aE}	11.85 ± 0.01^{aC}
	Polyethylene	7.13 ± 0.00^{aC}	65.16 ± 0.01^{aC}	-7.10 ± 0.01^{aD}	11.22 ± 0.01^{aD}
	Polypropylene	8.15 ± 0.00^{abC}	69.29 ± 0.05^{abC}	-7.27 ± 0.01^{aF}	12.52 ± 0.02^{aB}
Week 20	PET	6.64 ± 0.00^{aB}	70.40 ± 0.00^{aB}	-8.60 ± 0.01^{aF}	12.32 ± 0.01^{aB}
	Polyethylene	6.89 ± 0.00^{aC}	66.89 ± 0.01^{aC}	-7.88 ± 0.01^{aE}	11.74 ± 0.01^{aC}
	Polypropylene	7.74 ± 0.00^{Af}	61.70 ± 0.00^{aF}	-6.47 ± 0.01^{aE}	11.94 ± 0.01^{aD}
Week 24	PET	$6.38\pm0.00\ ^{aA}$	71.27 ± 0.06^{aA}	-10.40 ± 0.02^{aG}	12.60 ± 0.00^{aA}
	Polyethylene	$6.56\pm0.00\ ^{aA}$	84.05 ± 2.06^{aA}	-11.63 ± 0.27^{aF}	15.03 ± 0.30^{aA}
	Polypropylene	7.46 ± 0.00^{Ab}	70.14 ± 0.06^{aB}	-9.34 ± 0.01^{aG}	13.25 ± 0.06^{aA}

Mean values in rows with different lower cases (a, b, c, etc) are significantly different ($p<0.05$) while those in columns with different upper cases (A, B, C, etc) are significantly different ($p<0.05$).



A - PET bottle; **B** – Polyethylene bag; **C** - Woven polypropylene sack

Figure 3. Changes in pH of cocoyam flour during storage

Conclusions

The results of this study showed that the combined effects of packaging materials and the length of storage period significantly affected crude fibre and carbohydrate content of cocoyam flour. The moisture content of the flour packed in woven polypropylene decreased to a larger extent due to its higher water vapour permeability than PET bottles and polyethylene bags which have a higher barrier against moisture migration. The type of packaging did not significantly affect the crude fat content of the flour throughout the storage period. The PET bottle as a packaging material performed better in retaining the protein and ash content of the flour at the end of the storage period. Although significant differences were observed in the pH levels and colour of the cocoyam flour samples after six months of storage in the different packaging materials, the type of the used packaging material did not affect these physicochemical properties. The sensory properties of the cocoyam flour in three packaging materials at the expiration of the six months of storage were found to be within the acceptable limits. All three packaging materials performed well in retaining most of the quality attributes of the investigated flour.

Author Contributions: This research work was conceptualized and supervised by Author AK and Author BO, manuscript written by Author BO while the experiments and statistical analysis were carried out by Author KM.

Funding: This research received no external funding.

Conflict of Interest: The authors declare no conflict of interest.

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