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EFFECTS OF PROCESSING METHODS AND PACKAGING MATERIALS ON THE SHELF-LIFE OF YELLOW ROOT CASSAVA FLOUR

[1]Ubbor, S. C. and [1]Nwose, O. N.
[1]Department of Food Science and Technology,
Michael Okpara University of Agriculture, Umudike, Abia State
Corresponding Author's email: stellaubbor@gmail.com

Abstract
Cassava is a staple crop that is consumed in almost every Community in Nigeria. It is a high perishable crop that deteriorates within few days after harvesting. Processing cassava into chips and flours reduces the moisture content to a very low level thus reducing post-harvest losses. It has been shown that biofortified yellow root cassava possesses great potential to alleviate vitamin A deficiency complementary to other interventions such as vitamin A supplementation and fortification. This study therefore, investigated the effects of processing methods and packaging materials on the shelf-life of yellow root cassava flour. Yellow root cassava (UMUCASS 36 (TMS 01/1368) was harvested, cleaned and processed into flour by chipping and grating. Flour samples obtained from each method was stored for 6 weeks in tin and black polyethylene, and evaluated weekly. Result of a preliminary study conducted on the moisture content of the raw cassava root and flour samples showed that both chipped and grated flour samples had lower moisture content (2.36% and 3.20% respectively) compared to the raw cassava root (71.63%). The results of the chemical properties of the flour samples showed no significant difference ($p>0.05$) in week 0. However, the physicochemical and functional properties of the grated and chipped flour samples packaged in tin and polyethylene varied significantly from week 1 through week 6. Carotenoids retention was highest (72.1%) in chipped flour sample packaged in polyethylene. Chipped flour sample in polyethylene had the lowest mould count (34.33-66.67 cfu/g). Moisture retention was highest in grated sample packaged in both tin and polythene. The result of this study revealed that flour processed from dried chips and packaged in black polythene was the best for storage stability and longer shelf-life.

Keywords: Yellow root cassava flour, grating, chipping, tin, polyethylene, carotenoids

Introduction

Cassava (*Manihot esculenta* Crantz) root is a staple food that serves as the main source of carbohydrates in the form of starch and energy for more than 2 billion people in the world (Ferraro *et al*., 2015). Previous researches revealed that it is highly perishable and deteriorates easily due to its high moisture content with a postharvest life of less than 72 hours. Other studies revealed that processing cassava into other forms, such as unfermented high quality cassava flour (HQCF), chips and pellet will extend the shelf-life, reduce the bulkiness and cyanogenic glucosides to a safe limit (Fadeyibi, 2012). The unfermented High Quality Cassava Flour (HQCF) is a very acceptable raw material in many food industries. It could be blended with other flours as composite or solely in the baking and beverage industries. Yellow-fleshed cassava genotypes rich in provitamin A (pVA), are part of the outputs of an International Biofortification effort by HarvestPlus, the International Institute of Tropical Agriculture (IITA), the International Center for Tropical Agriculture (CIAT) and other National Agricultural Research Institutions, to reduce vitamin A and other micronutrient deficiencies through the development of staple food crops with enhanced micronutrient content (Saltzman *et al*., 2016). Previous research revealed that biofortified yellow cassava possesses great potential to alleviate vitamin A deficiency complementary to other interventions such as vitamin A supplementation and fortification (Bouis *et al*., 2011). A study revealed that Vitamin A deficiency prevails, and 30% of preschool children in Developing Countries have vitamin A deficiency in sub-Saharan Africa despite National supplementation and food fortification programs, (UNSSCN, 2010).

Hamer and Keusch (2015) in their study observed that Vitamin A deficiency (VAD) is a widespread nutritional disorder in the Developing Countries, and is still a public health concern globally. It is seen as main causative factor of preventable blindness in children. Cassava flour, commonly known as high quality cassava flour (HQCF), is fine flour that is rapidly processed from cassava roots harvested 10 – 12 months after planting, following the process of peeling, washing, grating/chipping, dewatering, granulating/sifting, drying, and milling (Fig 1) (Abass, 2006). For low cyanide cultivars (those containing less than 100mg/kg tuber of hydrocyanic acid), two processing methods (chipping and grating) can be applied as developed by the International Institute of Tropical Agriculture (IITA) (Abass, 2006). High cyanide cultivars (those containing more than 100mg/kg tuber of hydrocyanic acid) can only be processed by grating. Up to 10% HQCF is used in replacement of wheat flour in bread, noodles, and in the adhesive industry (dextrin) (IITA, 2012). Processors of HQCF use different packaging materials chiefly polythene of different colours and densities. In spite of this, there is limited information on the specific amounts of nutrients lost or retained when different processing methods and packaging materials are used (Maziya-Dixon *et al.,* 2015). It is difficult to maximize the nutritional potentials of yellow root cassava if the shelf-life of its flour, as well as the factors affecting this shelf-life is unknown (Adeola *et al.,* 2017). Thus, this study was designed to determine the effects of processing methods and packaging materials on the shelf-life of yellow root cassava flour.

Materials and Methods

Ten (10) kg of freshly wholesome harvested Yellow Root Cassava of 9 months of age was obtained from the Biotechnology Programme of National Root Crops Research Institute (NRCRI), Umudike, Abia State, Nigeria. This was rapidly processed into flour, using the two methods of processing developed by IITA: chipping and grating. The roots were peeled manually with stainless kitchen knife, washed to remove adhering soils and dirt. One portion was chipped with a chipping machine fabricated at NRCRI, Umudike and spread thinly on hot air oven drying tray ready for drying. The other portion was mechanically grated using a Fieldmarshal model GFA- 3B, 5.5 KW, 7.5 hp, 1500 rpm grater (made in India), bagged, dewatered, granulated and sifted. The sifted semi dried mash and the chipped cassava samples were then dried respectively at 65°C for 48 hours using hot air electric drying oven (Memmert Gmbt, type UNB 500, 8.7A, 2000W Nen temperature 220 °C made in Germany). The dried samples were then milled using attrition mill (Yoshita model GX 390, 13.0 HP, made in China) and sieved into resultant flour with 500µm sieve as described in Figure 1. Exactly 250 g of the high quality cassava flour was packaged in tin and black polythene materials and stored in a cool dry rodent-free enclosure maintained at ambient temperature under aseptic conditions. Initial (week 0) analyses of cassava flour quality attributes were determined on the flour prior to packaging and storage. The duration of storage was 6 weeks and the content of each packaging material was taken for analysis weekly. The parameters evaluated include; proximate composition, total carotenoids (TC) content, total titratable acidity (TTA), functional properties and mould count.

Analysis

The carbohydrate, moisture, crude protein, crude fat, crude fibre, ash content of the flour samples were determined according to the methods described by Onwuka (2018). The total carotenoid content (TCC) was determined using the method described by Delia *et al*. (2004). Total Titratable Acidity (TTA) was determined according to the method described by Antony and Chandra (1997). The following functional properties including: water absorption capacity, bulk density, emulsion capacity, wettability and gelatinization temperature, were determined according to the methods described by Onwuka (2018). Mould count was determined using the method described by Adejumo and Ragi (2012).

Statistical analysis: The data obtained were analysed using SPSS 20.0 statistical packages, a one-way ANOVA was carried out to determine significant differences and Duncan's multiple range tests was used to separate means.

Results and Discussion

The results of the moisture content of the raw cassava roots and flour samples at week 0 are shown in Table 1. The raw cassava roots had average moisture content of 71.63%. It was observed that cassava root had much higher moisture content than the flour samples which had average value of 2.36% for the chipped cassava flour and 3.20% for the grated cassava flour. The result is not strange because previous researches had shown that raw cassava root contains high moisture content of the range between 63 to 87.1% (Harris and Koomson, 2011),which is even higher than the 71.63% obtained in this study. These values fall within the optimum range for moisture content of flours (≤ 10%) stipulated by SON and IITA (Sanni *et al*., 2005; Oti and Ukpabi, 2007). Cassava root is highly perishable due to its high moisture content, so converting it into flour will extend the shelf-life and reduce bulkiness. High moisture content is evidence that the flour could be easily attacked by mould. However, the result obtained from this study revealed that the moisture contents of the flour samples are within the accepted limit. Moisture content is critical in determining the shelf-life of flours since the presence of sufficient amount of moisture favours microbial growth (Onwuka, 2014).

The chemical and functional properties of the flour samples at week 0 are presented in Table 2. There was no significant difference ($p>0.05$) in the crude protein, fat, crude fibre, ash and carbohydrate contents of the flour samples. However, significant differences ($p<0.05$) were observed in the moisture and carotenoid contents. The carotenoid content ranged from 6.72 to 7.99µg/g, with the grated flour on week zero having the lowest value. The lower carotenoid content recorded in the grated flour sample (6.72µg/g) may be due to grating and pressing which must have exposed the carotenoids to degradation. Moreover, carotenoid is sensitive to light and heat, and must have been lost during the drying of the flour samples Maziya-Dixon *et al*. (2015), in their study observed that carotenoids are very sensitive to light, heat and physical handling, which leads to losses during the processing of yellow-fleshed cassava roots into commonly consumed products. A previous study by Jaramillo *et al*. (2018) reported that total carotenoid retention is largely dependent on specific genotypes and processing methods used to prepare products. The result also revealed that no significant difference existed in the titratable acidity of both the grated and chipped flour samples. The results of the functional properties varied significantly ($p<0.05$) amongst the flour samples except for water absorption capacity and bulk density (Table 2).

Functional properties are important to determine the behaviour of nutrients in food during processing, storage and preparation (Onwuka, 2018). The values obtained for water absorption capacity, and total titratable acidity compare well with those reported by Ogori and Gana (2013). The physicochemical and microbial properties of the flour samples are shown in Table 3. There were significant differences ($p<0.05$) amongst the parameters studied. The moisture content of the grated cassava flour packaged in tin ranged from 4.70 – 12.07%. This is an indication that the flour may begin to deteriorate after 6 weeks since the maximum moisture content for such flour is 10% (Sanni *et al.,* 2005). However, Codex standards for moisture content of cassava and wheat flours are 13% and 15.5% respectively although lower moisture limits are recommended for certain destinations in relation to climate, duration of transport and storage (Codex Alimentarius Commission, 1995; Rajapaksha *et al.,* 2017). Moisture content of grated cassava flour packaged in polyethylene ranged from 3.28 – 11.70% , while that of grated cassava flour packaged in tin ranged from 4.70 – 12.07%. Moreover, the result of this study also revealed that moisture content of chipped cassava flour packaged in polyethylene and tin ranged from 2.50-8.53% and 2.37-9.37% respectively. This implies that polyethylene has a higher tendency to maintain the shelf-life of cassava flour compared to the grated cassava flour packaged in tin with values ranging from 4.70 to 12.07%. Moisture content of chipped cassava flour packaged in tin ranged from 2.37 – 9.37% while that of flour packaged in polyethylene ranged from 2.50 – 8.53%. It was observed that moisture content increased as the storage period increased for both the grated and chipped flour samples. However, chipped flour samples had better shelf-life extension and also packaging in polyethylene tends to be the best. The progressive increase in moisture content observed as the storage period increases could be attributed to the relative humidity of the environment. This implies that processing method has effect on the moisture content and therefore on the shelf-life of the cassava flours.

Fat content of grated cassava flour packaged in tin decreased from 0.79 – 0.61% while that of grated cassava flour packaged in polyethylene decreased slightly from 0.36 – 0.33%. Similarly, fat content of chipped flour packaged in tin decreased from 0.69 – 0.52% while that of chipped flour packaged in polyethylene decreased from 0.64 – 0.42%. These values compare well with those of Chisenga *et al.* (2019) who reported lipid values of 0.15 – 0.63% for cassava flours. The reduction in fat as storage period increased is an indication that rancidity will hardly take place in the samples. Lipid may affect rate of hydration of flours (Chisenga *et al.,* 2019). The result obtained recorded progressive increase in the crude fibre as storage continued. There was no significant difference in the crude fibre as storage progressed (in week 1, 4 and 6). However, the crude fibre of the flour samples ranged from 0.64 – 1.13%, 0.58 – 1.43%, 0.69 – 1.29% and 0.64 – 1.28% for grated flour packaged in tin, grated flour packaged in polyethylene, chipped flour packaged in tin and chipped flour packaged in polyethylene respectively (Table 3). The increase in the values of crude fibre could be attributed to loss of some nutrients such as starch. Crude fibre is made up of cellulose and lignin, thus increases bulk and aid in bowel movement. These values are within the limits (2% m/m max) set by the Nigerian Industrial Standards (NIS) for cassava flour (Sanni *et al.,* 2005). However, they are less than that reported by Eleazu and Eleazu (2012) who recorded 2.32% crude fibre in yellow root cassava. The differences may be attributed to geographical location, maturity stage and environmental conditions (Chisenga *et al.,* 2019). There was progressive decrease in the ash content of the flour samples and in the different packaging materials 1.43 – 1.36%, 1.39 – 1.33%, 1.52 – 1.25% and 1.49 – 1.13% for grated flour packaged in tin, grated flour packaged in polythene, chipped flour packaged in tin and chipped flour packaged in polyethylene respectively. These values are slightly less than that reported by Eleazu and Eleazu (2012). Ash is an indication of the mineral (inorganic) content of the flour samples.

Carbohydrate decreased from 89.47 – 73.60%, 91.21 – 82.98%, 91.36 – 85.34% and 91.59 – 86.41% for grated flour packaged in tin, grated flour packaged in polyethylene, chipped flour packaged in tin and chipped flour packaged in polyethylene respectively. The decrease in carbohydrate could be attributed to degradation of starch. However, carbohydrate values obtained in this study compare well with those of Oyeyinka *et al.* (2019) who reported an average carbohydrate content of 84% in cassava flours. The total carotenoid content decreased with the storage duration in all the cassava flour samples (Table 3). The decrease ranged from 6.44 – 4.03 μg/g, 5.99 – 4.02 μg/g, 7.92 – 5.18 μg/g and 7.43 – 5.36 μg/g for grated flour packaged in tin, grated flour packaged in polyethylene, chipped flour packaged in tin and chipped flour packaged in polyethylene respectively. However, despite the progressive decrease observed as storage progressed, this study revealed that chipped flour samples recorded highest total carotenoid content for flours packaged in tin and polyethylene (7.92-5.18 μg/g and 7.43-5.36 μg/g respectively) than the grated flour samples (Table 3). A trend in the decrease in total carotenoid content observed in both methods used for processing the flours as well as the packaging materials shows that carotenoid has a short shelf-life. It is therefore deduced that carotenoid retention is a function of length of storage period. Thus, the longer the storage period, the higher the percentage loss of carotenoid. The presence of carotenoids in yellow root cassava confers some health benefits on the crop due to the antioxidant and free radical scavenging activities of carotenoids which reduce the risk of degenerative diseases such as cancer, cardiovascular diseases, etc (Eleazu and Eleazu, 2012). The total titratable acidity (TTA) of the flour samples varied significantly ($p > 0.05$). The result revealed a decrease in the TTA as the storage weeks increased, from 0.10 – 0.05% and 0.62 – 0.09% for grated flours packaged in tin and polyethylene respectively (Table 3). However, the values increased from 0.11 – 0.31% and 0.06 – 0.19% for chipped flours packaged in tin and polyethylene respectively. This could be attributed to the unfermented nature of the flour samples. Titratable acidity is the total concentration of acid in food and is a predictor of how organic acids impact flavour (Tyl and Sadler, 2017).

No mould growth/count was recorded in week 1. However, in week 4(Table 3), mould count (CM) increased significantly ($p > 0.05$) from 144 – 276 cfu/g, 40.67 – 80.33 cfu/g, 97.33 – 183 cfu/g and 34.33 – 66.67 cfu/g for grated flour packaged in tin, grated flour packaged in polyethylene, chipped flour packaged in tin and chipped flour packaged in polythene respectively. Grated flour packaged in tin had the highest mould count while chipped flour packaged in polythene had the lowest mould count. It was observed that mould count increased as the moisture content of the flour samples increased irrespective of the packaging materials. The result of the chipped flours packaged in polyethylene exhibited higher microbial stability with a lower mould count and is thus, preferable for maintaining microbial stability, other quality attributes and extension of the flour shelf-life. High mould count is also an indication of re-absorption of moisture during handling and storage ((Daramola *et al.,* 2010). It could also be deduced as an evidence of permeability of the packaging materials to the atmospheric gases. The result showed no evidence of mould growth in the first three weeks of storage (Table 3). The result of this study revealed that grated and chipped flours can be safely stored in tin and polyethylene without any sign of mould infestation.

The functional properties of the flour samples are shown in Table 4. There was general decrease in water absorption capacity (WAC), bulk density (BD) and emulsion capacity. Wettability decreased in grated cassava flour and increased slightly in chipped cassava flour. Higher wettability in chipped flour could be due to higher starch retention. There was general increase in gelatinization temperature across the flour samples. The chipped sample packaged in tin had the highest increase in gelatinization temperature (19.2%) while grated sample packaged in polyethylene had the smallest increase (1.7%). Increase in gelatinization temperature may be an undesirable property for baking in flours, and may have occurred due to starch degradation during storage. Bulk density and WAC values are higher and lower respectively than the values obtained by Oladunmoye *et al.* (2010). The variation may be due to differences in moisture, cultivar and maturity of cassava roots. The chipped sample packaged in polyethylene had the highest bulk density while the grated sample packaged in tin had the lowest BD. Bulk density is a function of mass and volume and is important in determining the handling requirements of flours such as transport and storage conditions (Oladunmoye *et al.,* 2010). WAC values obtained in this study agree with the 2.50 - 11.25 g/g reported by Ogori and Gana (2013) for cassava flour. WAC is a reflection of the baking quality of flours (Oladunmoye *et al.,* 2010). Finally, the chipped flour samples packaged in tin showed the highest percentage retention of water absorption capacity (80%), followed by the chipped flour samples packaged in polyethylene (46.8%), then the grated sample packaged in tin (42.4%) and the grated sample packaged in polyethylene (38.7%). This may be due to lower moisture content which enhanced the hygroscopic property of the chipped flour sample.

Conclusion

It can therefore be concluded that yellow root cassava flour can be processed using two methods: chipping and grating. It was observed that in terms of carotenoid retention, processing cassava flour from carefully dried chips and packaging in black polythene is the best treatment. The low fat content of the samples observed as storage progressed is an excellent attribute for controlling rancidity and enhancing the shelf-life stability of the flours. Changes in parameters did not follow a regular pattern. Processing method may be a more important factor affecting the functional properties of cassava flour as opposed to packaging material. In terms of microbial stability, it could be deduced that chipped cassava flour packaged in black polythene tends to provide a better keeping quality than packaging in tin, although Good Manufacturing Practice (GMP) and HACCP must be maintained during processing. Mould count increased as moisture content of the four samples increased during storage. This can be controlled by ensuring that the packaging materials are hermetically sealed to prevent re-absorption of moisture.

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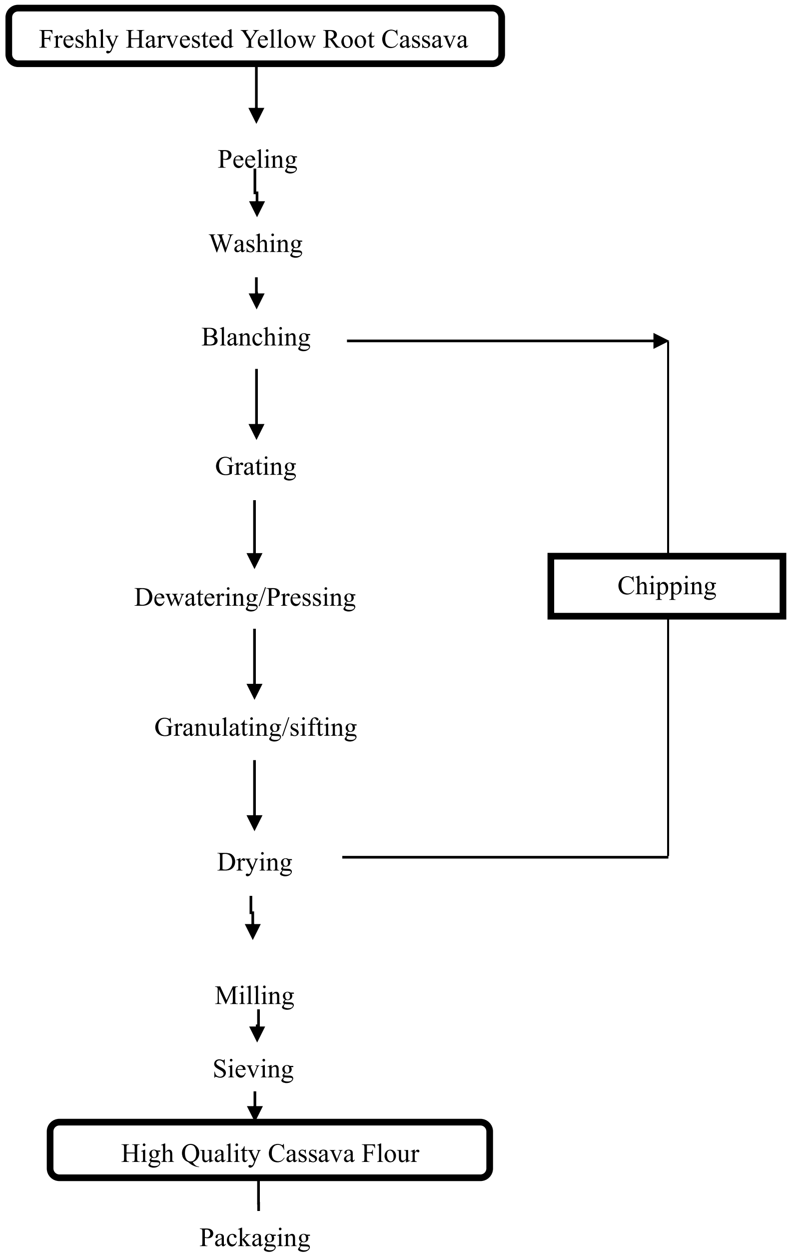

Figure 1: Flowchart for the processing of yellow root cassava flour

Table 1: Moisture content of raw yellow root cassava and flour samples

Sample	**Moisture content (%)**
Raw cassava roots	71.63
Grated cassava flour	3.20
Chipped cassava flour	2.36

Table 2: Chemical and functional properties of cassava flour samples at week 0

Chemical properties	**GFW0**	**CFW0**
Moisture content (%)	3.20^a±0.21	2.36^b±0.32
Crude protein (%)	1.73^a±0.05	2.24^a±0.12
Ether extract (%)	1.14^a±0.02	1.10^a±0.04
Crude fibre (%)	0.67^a±0.06	1.06^a±0.04
Ash (%)	1.49^a±0.04	1.68^a±0.08
Carbohydrate (%)	88.67^a±0.29	90.36^a±0.42
Carotenoid (µg/g)	6.72^b±0.10	7.99^a±0.32
TTA (%)	0.03^a±0.01	0.04^a±0.01
Functional properties		
WAC(ml/g)	2.79^a±0.09	2.18^a±0.23
Bulk density (g/cm^3)	0.54^a±0.03	0.63^a±0.03
Emulsion capacity (%)	14.08^a±0.10	8.00^b±1.00
Wettability (sec)	45.67^b±0.58	75.67^a±1.15
Gelatinization temp. (^{0}C)	70.17^a±0.29	66.00^b±1.73

Values are means±SD of duplicate determinations. Means within the same row not having the same superscript are significantly different (p<0.05). GFW0 - Grated flour evaluated at week 0, CFW0 - Chipped flour evaluated at week 0, WAC-Water absorption capacity. TTA – Total titratable acidity

Table 3: Physicochemical and microbial properties of flour samples

	Grated Cassava		**Chipped Cassava**	
	Tin	**Polythene**	**Tin**	**Polythene**
Week 1				
MC (%)	4.70^a±0.20	3.28^b±0.02	2.37^c±0.02	2.50^c±0.17
Fat (%)	0.79^a±0.16	0.36^b±0.03	0.69^a±0.03	0.64^a±0.03
Crude fibre (%)	0.64^a±0.03	0.58^b±0.02	0.69^a±0.06	0.64^a.±0.03
Ash (%)	1.43^c±0.01	1.39^d±0.01	1.52^a±0.02	1.49^b±0.00
CHO (%)	89.47^c±0.35	91.21^b±0.03	91.36^a±0.06	91.59^a±0.13
TCC (µg/g)	6.44^b±0.34	5.99^b±0.01	7.92^a±0.11	7.43^a±0.40
TTA (%)	0.10^b±0.01	0.62^a±0.03	0.11^b±0.01	0.06^c±0.01
CM (cfu/g)	0.00^a±0.00	0.00^a±0.00	0.00^a±0.00	0.00^a±0.00
Week 4				
MC (%)	8.83^a±0.12	6.68^b±0.20	5.77^c±0.25	4.60^d±0.17
Fat (%)	1.03^a±0.04	0.64^b±0.03	0.64^b±0.03	0.64^b±0.05
Crude fibre (%)	0.57^a±0.44	0.75^a±0.05	0.87^a±0.06	0.89^a±0.03
Ash (%)	1.96^a±0.02	1.98^a±0.01	1.91^b±0.03	1.87^c±0.01
CHO (%)	84.80^a±0.12	87.51^c±0.27	88.16^b±0.27	91.55^a±0.45
TCC (µg/g)	4.99^b±0.01	4.99^b±0.02	6.03^a±0.03	6.01^a±0.01
TTA (%)	0.06^d±0.01	0.11^c±0.02	0.30^a±0.01	0.20^b±0.00
CM (cfu/g)	144.00^a±1.00	40.67^c±1.15	97.33^b±1.15	34.33^d±1.53
Week 6				
MC (%)	12.07^a±0.03	11.70^b±0.00	9.37^c±0.21	8.53^d±0.21
Fat (%)	0.61^a±0.01	0.33^d±0.03	0.52^b±0.03	0.42^c±0.03
Crude fibre (%)	1.13^a±0.03	1.43^a±0.32	1.29^a±0.07	1.28^a±0.02
Ash (%)	1.36^a±0.02	1.33^a±0.02	1.25^b±0.03	1.13^c±0.03
CHO (%)	73.60^d±0.02	82.98^c±0.31	85.34^b±0.29	86.41^a±0.21
TCC (µg/g)	4.03^b±0.03	4.02^b±0.02	5.18^a±0.32	5.36^a±0.27
TTA (%)	0.05^d±0.01	0.09^c±0.01	0.31^a±0.01	0.19^b±0.01
CM (cfu/g)	276.00^a±1.00	80.33^c±0.58	183.00^b±0.58	66.67^d±1.53

Values are means±standard deviation of duplicate determinations. Means in the same row not having the same superscript are significantly different ((p<0.05). MC – Moisture content, CHO – Carbohydrate, TCC – Total carotenoid content, TTA – Total titratable acidity, CM – Colonies of mould

Table 4: Functional properties of flour samples

	Grated Cassava		Chipped Cassava	
	Tin	**Polythene**	**Tin**	**Polythene**
Week 1				
WAC(ml/g)	$3.11^{a}\pm0.01$	$2.84^{b}\pm0.06$	$3.25^{a}\pm0.35$	$3.55^{a}\pm0.07$
BD (g/cm^3)	$0.64^{b}\pm0.01$	$0.69^{b}\pm0.01$	$0.68^{b}\pm0.01$	$0.74^{a}\pm0.05$
EC (%)	$30.25^{c}\pm0.35$	$29.53^{c}\pm0.04$	$37.50^{a}\pm0.71$	$32.25^{a}\pm0.35$
Wett. (sec)	$36.50^{d}\pm0.71$	$44.00^{c}\pm1.41$	$96.00^{a}\pm1.41$	$84.00^{b}\pm1.41$
Gel.Temp (^{0}C)	$81.25^{b}\pm0.35$	$89.25^{a}\pm0.35$	$79.50^{c}\pm0.71$	$82.75^{b}\pm1.06$
Week 4				
WAC	$1.84^{b}\pm0.06$	$1.53^{c}\pm0.04$	$2.83^{a}\pm0.04$	$1.93^{b}\pm0.04$
BD (g/cm^3)	$0.61^{c}\pm0.01$	$0.61^{c}\pm0.00$	$0.66^{b}\pm0.01$	$0.71^{a}\pm0.01$
EC (%)	$30.25^{b}\pm0.35$	$28.25^{c}\pm0.35$	$36.40^{a}\pm0.57$	$37.00^{a}\pm0.00$
Wett. (sec)	$44.50^{d}\pm0.71$	$48.50^{c}\pm0.71$	$88.50^{b}\pm0.71$	$129..50^{a}\pm0.71$
Gel.Temp (^{0}C)	$88.75^{b}\pm0.35$	$86.50^{c}\pm0.71$	$91.50^{a}\pm0.71$	$88.25^{b}\pm0.35$
Week 6				
WAC	$1.32^{bc}\pm0.02$	$1.10^{c}\pm0.14$	$2.60^{a}\pm0.14$	$1.65^{b}\pm0.21$
BD (g/cm^3)	$0.59^{d}\pm0.01$	$0.61^{c}\pm0.01$	$0.63^{b}\pm0.01$	$0.68^{a}\pm0.01$
EC (%)	$13.35^{c}\pm0.07$	$15.64^{b}\pm0.05$	$13.65^{c}\pm0.49$	$20.55^{a}\pm0.78$
Wett. (sec)	$32.50^{d}\pm0.71$	$34.50^{c}\pm0.71$	$97.50^{a}\pm0.71$	$84.50^{b}\pm0.71$
Gel.Temp(^{o}C) (^{0}C)	$91.75^{bc}\pm0.35$	$90.75^{c}\pm1.06$	$94.75^{a}\pm0.35$	$93.50^{ab}\pm0.71$

Values are means±standard deviation of duplicate determinations. Means in the same row not having the same superscript are significantly different ($p < 0.05$); WAC – Water absorption capacity, BD – Bulk density, EC – Emulsion capacity, Wett. – Wettability, Gel. Temp. – Gelatinization temperature