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# The Effects of packaging materials on keeping quality of cassava root - leaf flakes

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Processing and value addition is necessary for fresh agricultural commodities in order to reduce perishability and prolong shelf-life. Shelf life is enhanced with proper packaging because packaging materials influence storage period, preserve nutrients and sensory qualities. This paper objectively determined the effects of packaging materials on nutrients quality of cassava flakes. The methodology of the work involved the use of blends of cassava flakes packaged in Kraft, insulated polythene and plastic, and stored in an incubator at 550C and 75 % relative humidity for 5 days. Three blends of cassava flakes identified by panelists as the most preferred (20 % leaf, 100 % fresh root, 100 % fermented roots were developed and studied on accelerated shelf life trial. Storage period and packaging material were determined. The results showed moisture content to be significantly influenced by packaging material whereby it increased over the storage period, across the blends, with highest levels (10.75-%) registered in kraft material on day 3. After day 3 all nutrients showed a drastic decreasing trend with the most affected being protein that dropped from; 22.94 mg / 100g to 8 mg / 100g in the blend containing 20 % leaf in and 6.65 mg / 100g to 2. 8 in the blend of 100 % fresh root packaged in kraft materials. There was Paper insulated polythene (gunny) was shown to contain highest nutrients' levels by day 5 with; protein at 27.68 mg /100g vitamins A (576.85 mg/100 kg), Zinc (1.17 mg /100 g), iron 3.69 mg /100g), fibre 6.12 mg /100g. Fat was highest at 9.71 mg/100g in the plastic material. The study therefore concluded that insulated polythene is the best packaging material for cassava flakes and the product's shelf life is up to 3 months.

**Keywords:** *Cassava flakes blends; packaging material; nutrients; Kaft; polythene; plastic*

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## Introduction

Agricultural commodities and especially fresh commodities are known to have common characteristics that include seasonality, bulkiness, and high perishability (FAO, 2001). Perishability is however mitigated through processing that equally enables value addition, product diversification, leading to enhanced utilization and marketing and, market segmentation (Nweke, 2001). Processing also reduces commodity bulkiness and improves shelf life. Shelf life is mostly rated as the most important factor that necessitates processing. However, in order to effectively improve product shelf life, the product storage has to be carried out under suitable temperatures as well as packaging materials. Packaging and packaging materials are most appropriate for storage and portability of a product besides the preservation (Kulcu, 2018). It is important to note that the packaging is an act of value addition as well.

Cassava roots and leaves are agricultural commodities whose common characteristics pose a challenge to producers. Cassava roots are consumed to supply much needed calories while leaves are moderately consumed but are a rich source of a range of nutrients including protein, (Achidi *et al.,* 2005; FAO, 2000). Both the roots and leaves are highly perishable. This therefore necessitates processing, packaging and storage as a means to improve shelf life.

Shelf life has been defined by the consumer to mean a number of connotations that include; the time limit, that a product retains its sensory, intrinsic and physical qualities (Manzocco, and Nicoli, 2011: Hammond *et al.,* 2015). Shelf life represents the length of time before the food is considered to be unsuitable for human consumption (Manzocco, and Nicoli, 2011; Conte, *et al.,* 2013). Suitability and safety of a product are factors embedded in the quality of the product. Quality of a product includes the level of nutrients in a particular product (nutritive value of a product). A product that passes its shelf life date does not immediately become dangerous for human consumption, but rather no longer conforms to a set of given quality parameters (Moschopoulou *et al.,* 2019). Other factors that affect shelf- life besides the product itself include the micro environment in which the food or product is packaged (Higgs, 2019). Shelf life is termed to have expired once the micro-environment within a packaged product begins to be conducive for microbial growth. Therefore, storage temperatures and packaging are some of the other factors that affect shelf life.

The efficiency of packaging in extending shelf life of foods and products depends on packaging material that are majorly; metals, glass, paper, polythene and plastics (Manzocco, and Nicoli 2007). Packaging materials are known to have influence on chemical reactions within the packaged food / products. These reactions can be monitored through parameters such as peroxide value, acid value and microbial count (Nychas *et al.,* 2016). A definition of peroxide value is given as; the amount of oxygen consumed in the reaction that reduces all the unsaturated carbon bonds (C=C) in a given amount (mass) of a lipid mixture during autoxidation Bandyo, (2017). The oxygen ultimately forms peroxides. By use of peroxide method one can measure how unsaturated the fat/oil is (Bandyo, 2017). Another parameter measured in shelf life is acid value that simply means the number of milligrams of potassium hydroxide (KOH) necessary to neutralize the fatty acids in 1 gram of sample (Zailer, 2019).

Chemical reactions and microbial growth on food and food products bring about spoilage that end up compromising the products quality. Spoilage and its extent is normally evaluated through, the use of microbial count, among other methods. Key microorganisms depend on the nature of the product in question.

The objective of the study was to determine the effect of packaging materials (Kraft paper, insulated polythene packets and plastic jars) on cassava root - leaf flakes. It under took to determine; nutrients levels of three blends of cassava flakes as affected by packaging materials over 5 days of accelerated shelf-life trial under ambient temperature.

**Materials and methods**

The statistical design used in the study was Complete Randomized Design, where cassava flakes blends and packages (by material) were independent variables. Data were collected on the following parameters: peroxide value and acid value and, total viable count (TVC) and yeast and molds (Y&M). Blends of cassava flakes were formulated from 100% fresh roots, 100% fermented roots and 20% leaf + fermented root. Formulation of the flakes was carried out at KALRO Mtwapa food laboratory and transported to the University of Nairobi for shelf life trial. The choice of 20-% leaf material to be incorporated in the root was guided by an acceptability test that was carried out by 30 panelists on a variety of blends that contained varied ratios of cassava leaf added on to root material. The three blends of cassava flakes were differently packaged in duplicates in 200g standard packages made from different materials namely: Kraft paper bags, insulated polythene – packets (gunny) and plastic jars. Packages were put in a laboratory incubator at 55$^{o}$C / 75-% rh (relative humidity) for commencement of accelerated shelf life trial. This activity was carried out in the university of Nairobi food laboratories.

Nutrients in the stored blends were monitored using laboratory procedures in order to determine their levels during the storage period. Nutrient analyses were carried out on alternative days, 1, 3 and 5.

***Analytical methods***

***Determination of Moisture content***

Moisture content determination was carried out using gravimetric method with a few modifications. About 5 g of pounded sample were weighed in crucibles and dried for 4 hours at 105 $^0$C in an air oven as guided in AOAC. (2001) method 925.10.

***Crude Fat Determination***

Approximately 2 g sample was extracted using sohxlet extractor for 8 hours using 200 ml petroleum ether (40 – 60 $^0$C). Crude fat content was calculated after evaporating the solvent and the residue dried in an air oven at 105 $^0$C for 1 hour as guided in AAFCO, (2014).

***Protein Determination***

Protein content in the flakes samples was determined as per AOAC, (2005) method number 979.09.

***Determination of Crude Fibernot necessary in storage***

A duplicate of approximately 2.5g sample of flakes samples were weighed and transferred to sohxlet extractor and extracted using petroleum ether, one after the other. The rest of the procedure was then followed according to AOAC, (2000) method 985.29.

***Determination of Ash Content not necessary in storage***

Briefly 4 g sample of cassava flakes (per blend), weighed in duplicate was burnt in porcelain crucible using Bunsen burner (low flame) for 10 minutes then transferred to a Muffle furnace, ashed at 550°C for 4 hours as guided in AOAC, (1995) method 923.03.

***Determination of Carbohydrates not for storage***

Carbohydrates were determined by difference. The total of moisture content, fat, ash, protein and fibre contents were subtracted from 100 as guided in FAO. (2003).

***Determination of Hydrogen Cyanide***

Hydrogen cyanide determination was carried out using distillation method. Cassava flakes were crashed using motor and pestle, and samples of 10 g per blend were placed into distillation flask and allowed to stand for three hours before distillation. Distillation and consequent determination of hydrogen cyanide was carried out as in AOAC. (2016) method number 915.03.

***Determination of Vitamin C***

Approximately 15 ml (10%) TCA, was added into flat bottomed flask containing cassava flakes samples and filtered. A total of 15 ml filtrate sample was collected. The filtrate sample was then mixed with 5 ml of 4% potassium iodide solution then titrated with N-bromisumccinimide solution. The rest of procedure was followed as described in AOAC, (2012) method number 967.21.

***Determination of beta carotene***

Approximately 2 g sample of crushed flakes was weighed, 25 ml added to extract colour, and the rest of steps followed were as guided in AOAC, (2006) method number 98.25.

***Determination of Iron and Zinc Content***

Cassava flakes sample (4g) for determining mineral Iron was ashed in a muffle furnace at 500 $^0$C for 4 hours. This was then digested by adding 10ml of 20-% HCL and heated to boiling, then filtered into 100 ml volumetric flask and topped to mark using distilled water. Using atomic absorption spectrophotometer (A.A.S) mineral iron and zinc were determined according to AOAC, (2016) method 99. 10.

***Determination of Peroxide value and Acid value***

A total of 18 packages were removed on alternative days 1, 3, and 5 to determine Peroxide value as guided in AOCS, (1997) Cd 8b - 90 and acid value was done according to AOCS, (1997) Ca 5a - 40.

***Data Analysis***

Results from laboratory analyses were subjected to the analysis of variance (ANOVA), using the General Linear Model (GLM) of the Statistical

Analysis System (SAS version 9.1). Means were separated using Least Significant Difference (LSD), the differences being significant when p≤0.05.

## Results

### *Variation in moisture content within packaging materials*

The three packaging materials Kraft (Kraft paper bag), insulated polythene packets and plastic jars had significant effect (P ≤ 0.05) on moisture content of all the three blends of flakes; 20-% cassava leaf blended with cassava root material, 100-% fresh cassava root and 100-% fermented cassava root (Table 1). The effect of packaging materials on moisture content was registered across the storage period from day 1 to day 5. The blend with 20-% cassava leaf material had a fluctuating trend in its moisture content. It showed a moisture decrease on day 3 but there was an increase of moisture content on day 5, in the insulated plastic packets. A similar trend was shown in the plastic package. There was, however, a consistent increase of moisture content in the Kraft package across the entire storage period.

The packaging materials also had significant effect (P ≤ 0.05) on protein content of in all the blends across the packaging materials over the storage period. Protein content was shown to reduce as the blends were stored longer. All the packaging materials registered declined levels of protein in the blend containing 20-% cassava leaf and the blend containing 100 % roots flakes. The blend containing 100-% fermented root showed to be stable in all the three packaging materials. There was shown to be a decrease in protein content in the blend containing 20-% leaf material blended with root materials packaged in paper insulated polythene packets. By day 5, 20-% cassava leaf blended with cassava root material packaged in insulated polythene was shown to contain higher levels of protein (on a decreasing rate) compared to other packaging materials, the blend containing 100 % fresh root was shown to contain more protein in Kraft and the blend containing 100-% fermented roots had no significant (P ≤ 0.05) difference across the packaging materials.

Carbohydrates content in all the three blends were significantly (P ≤ 0.05) affected by the packaging materials over the storage period. The blend containing 20-% cassava leaf material blended with cassava root material had significant (P ≤ 0.05) difference in carbohydrates content in day 3 compared to day 5. The significant (P ≤ 0.05) effect was demonstrated by a drastic drop of carbohydrates levels in this particular blend across the three packaging materials. The blend containing 100 % fresh root material showed a fluctuation trend with carbohydrates contained in kraft registering an increase. There was decrease in carbohydrates in the laminated polythene and plastic packages. The blend containing 100-% fermented root material showed a significant (P ≤ 0.05) drop by day 5 especially in kraft and paper insulated polythene packets, but there was an increase in the plastic material package.

There was significant effect (P ≤ 0.05) of packaging material on fat content across the three blends. Significant (P ≤ 0.05) difference was also shown within one blend packaged in the different packaging material. Equally significant difference in fat content was registered across the storage period from day 1 to day 5. 20-% cassava leaf blended with cassava root material was showed significantly (P ≤ 0.05) higher levels of fat content in plastic than in kraft and gunny packages. Fat content in plastic was higher at 21% than in Kraft and 20.7-% than in gunny. However, this difference was not significant (P ≤ 0.05). It was found that X0 had higher fat content in the plastic package than in Kraft and gunny. Similarly, the blend containing 100% fermented root had significantly (P ≤ 0.05) higher fat content in gunny than in kraft and plastic packages.

Ash content was significantly (P ≤ 0.05) affected by packaging materials. There were variations registered within one blend packaged in different packages, especially for the blend containing 100-% fresh root material and the blend containing 100-% fermented root material. These variations were however registered in day 1 and 5. The blend containing 100-% fresh roots packaged in gunny had significantly (P ≤ 0.05) higher ash levels than in kraft and plastic. A similar trend was depicted in the blend containing 100% fermented root material.

*Table 1. Means of nutrient contents (mg/1000dwb) in 3 blends of casava blends as affected by packaging materials*

| S - life / Nutrients | | 20% cassava leaf flakes | | | 100% fresh cassava root flakes | | | 100% fermented cassava root flakes | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | **Kraft** | **Ins′ polythene** | **Plastic** | **Kraft** | **Ins′ polythene y** | **Plastic** | **Kraft** | **Ins′ polythene** | **Plastic** |
| | **MC** | 9.00±1.138$^{bcdefg}$ | 9.28±0.00$^{bcdefg}$ | 9.77±0.02$^{abcd}$ | 10.07±0.22$^{abc}$ | 7.13±0.48$^{h}$ | 7.68±0.70$^{fgh}$ | 9.89±0.63$^{abcd}$ | 6.80±0.69$^{h}$ | 8..94±0.06$^{bcdefg}$ |
| | **Protein** | 25.26±0.43$^{d}$ | 27.68±0.141$^{a}$ | 25.72±0.05$^{c}$ | 6.66±0.30$^{h}$ | 6.47±0.61$^{hi}$ | 6.83±0.09$^{h}$ | 5.39±0.13 $^{kl}$ | 5.76±0.26 $^{jk}$ | 4.56±0.01$^{m}$ |
| **Day 1** | **Carb** | 40.39±0.52$^{a}$ | 40.28±0.57$^{a}$ | 39.80±2.72$^{a}$ | 28.78±3.81$^{h}$ | 25.92±0.19$^{kl}$ | 26.32±0.82$^{k}$ | 25.23±0.82$^{mn}$ | 26.18±0.04$^{kl}$ | 28.81±3.76$^{h}$ |
| | **Fibre** | 6.54±0.10$^{cd}$ | 6.79±0.00$^{bc}$ | 7.21±0.13$^{ab}$ | 7.47±0.19$^{a}$ | 4.88±0.86$^{hij}$ | 5.38±0.15 $^{gh}$ | 7.31±0.54$^{ab}$ | 4.58±0.63$^{ijk}$ | 6.50±0.05$^{cd}$ |
| | **Fat** | 5.73±0.20$^{m}$ | 5.75±0.14$^{m}$ | 7.25±0.28$^{h}$ | 5.57±0.13$^{mn}$ | 6.35±0.00$^{kl}$ | 7.81±0.09$^{f}$ | 5.38±0.23$^{no}$ | 6.28±0.00$^{kl}$ | 6.93±0.08$^{ij}$ |
| | **Ash** | 2.24±0.35$^{c}$ | 2.23±1.04$^{c}$ | 2.69±0.32$^{c}$ | 2.13±0.27$^{c}$ | 3.62±0.24$^{b}$ | 6.99±3.17$^{a}$ | 2.85±0.13$^{a}$ | 2.38±0.71$^{c}$ | 3.14±0.42$^{b}$ |
| | **MC** | 9.70±0.42$^{abcd}$ | 8.20±1.09$^{defgh}$ | 9.48±1.39$^{abcd}$ | 7.50±2.12$^{gh}$ | 7.16±0.25$^{h}$ | 8.45±0.07$^{cdefgh}$ | 8.47±0.75$^{cdefgh}$ | 7.23±0.39$^{gh}$ | 8.23±1.74$^{defgh}$ |
| | **Protein** | 22.94±0.01$^{f}$ | 25.46±0.78$^{cd}$ | 24.27±0.00$^{e}$ | 6.65±0.32$^{h}$ | 6.48±0.61$^{hi}$ | 6.85±0.09$^{h}$ | 4.40±0.120$^{m}$ | 4.66±0.26$^{m}$ | 4.44±0.12$^{m}$ |
| **Day 3** | **Carb** | 24.76±1.29$^{n}$ | 29.94±0.20f$^{g}$ | 30.93±1.14$^{de}$ | 30.57±1.46$^{ef}$ | 26.14±0.594$^{kl}$ | 25.65±0.93l$^{m}$ | 29.31±1.61$^{gh}$ | 27.65±0.74$^{ij}$ | 30.79±2.85$^{de}$ |
| | **Fibre** | 3.52±0.03$^{m}$ | 5.46±0.08$^{fgh}$ | 3.58±0.06$^{m}$ | 4.08±0.05$^{klm}$ | 5.19±0.08$^{ghi}$ | 5.57±9.23$^{efg}$ | 3.31±0.04$^{n}$ | 5.80±0.06$^{ef}$ | 3.48±0.04$^{m}$ |
| | **Fat** | 7.09±0.08$^{hi}$ | 8.28±0.09$^{d}$ | 7.88±0.03$^{ef}$ | 8.08±0.06$^{de}$ | 10.31±0.042$^{a}$ | 9.13±0.04$^{c}$ | 7.21±0.01$^{h}$ | 7.91±0.03ef | 7.53±0.07g |
| | **Ash** | 3.12±0.22$^{a}$ | 2.99±0.35$^{a}$ | 3.00±9.56$^{a}$ | 2.48±0.33$^{a}$ | 3.32±0.20$^{a}$ | 3.38±0.18$^{a}$ | 2.50±0.01$^{a}$ | 2.97±0.33$^{a}$ | 2.67±0.21$^{a}$ |
| | **MC** | 10.21±0.20$^{ab}$ | 9.70±2.97$^{abcd}$ | 10.17±0.35$^{abc}$ | 10.75±0.35$^{a}$ | 8.47±0.71$^{cdefgh}$ | 9.44±1.39$^{abcde}$ | 9.96±0.71$^{abc}$ | 7.71±0.41$^{efgh}$ | 7.72±0.35 $^{efgh}$ |
| | **Protein** | 8.49±0.27$^{g}$ | 27.25±0.27$^{c}$ | 24.15±0.06$^{e}$ | 2.8±0.24$^{l}$ | 5.56±0.01$^{kl}$ | 5.32± 0.24$^{l}$ | 4.74±0.12$^{m}$ | 4.52±0.035$^{m}$ | 4.41±0.13$^{m}$ |
| | **Carb** | 27.94±1.22$^{i}$ | 33.36±1.40$^{b}$ | 29.20±1.30$^{h}$ | 31.30±0.42$^{d}$ | 27.15±0.55$^{j}$ | 25.65±0.93$^{lm}$ | 26.42±0.26$^{k}$ | 24.88±0.18$^{n}$ | 32.27±0.76$^{c}$ |
| **Day5** | **Fibre** | 5.58±0.05$^{efg}$ | 6.12±0.05$^{de}$ | 5.38±0.07$^{gh}$ | 6.08±0.05$^{def}$ | 6.10±0.06$^{def}$ | 6.20±0.11$^{cde}$ | 3.89±0.03$^{lm}$ | 4.62±0.03$^{ijk}$ | 4.41±0.04$^{jkl}$ |
| | **Fat** | 5.10±0.03$^{p}$ | 6.47±0.05$^{k}$ | 7.78±0.05$^{f}$ | 4.34±9.02$^{q}$ | 6.40±0.04$^{kl}$ | 9.71±0.04$^{b}$ | 5.180.03$^{op}$ | 6.79±0.06$^{j}$ | 6.21±0.35$^{l}$ |
| | **Ash** | 3.53±0.67$^{a}$ | 3.10±0.32$^{b}$ | 2.64±0.22$^{c}$ | 3.14±0.34$^{b}$ | 3.25±0.14$^{a}$ | 1.87±0.67$^{c}$ | 1.44±0.44$^{c}$ | 3.31±0.76$^{a}$ | 2.31±0.04$^{b}$ |

**Table 2; Means of micro-nutrient contents (mg/100-dwb) in 3 blends of cassava flakes as affected by packaging materials**

| S - life / Nutrients | | 20% cassava leaf flakes | | | 100% fresh cassava root flakes | | | 100% fermented cassava root flakes | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Kraft | Ins' polythene | Plastic | Kraft | Ins' polyethene | Plastic | Kraft | Ins'-polythene | Plastic |
| Day 1 | Vit C | 315.03±49.94$^{b}$ | 476.54±11.40$^{a}$ | 323.09±22.85$^{b}$ | 387.71±91.3$^{a}$ | 298.86±1$^{b}$ | 306.93±0.$^{b}$ | 290.80±$^{b}$ | 355.4±$^{b}$ | 460.40±5$^{a}$ |
| | Vit A | 4852.13±178.43$^{b}$ | 6640.58±58.69$^{a}$ | 4886.34±105.58$^{b}$ | 70.00±9.11$^{hi}$ | 269.00±7.$^{f}$ | 249.95±7.$^{g}$ | 96.24±1$^{i}$ | 107.5±7.78$^{hi}$ | 152. 63±6.52$^{gh}$ |
| | Zinc | 0.39±0.21f | 1.10±0.40$^{def}$ | 0.28±0.05$^{f}$ | 7.92±0.10$^{a}$ | 7.77±0.05$^{b}$ | 8.86±0.24$^{a}$ | 0.69±0.67$^{f}$ | 0.20±0.04$^{f}$ | 0.19±0.02$^{f}$ |
| Day 3 | Iron | 7.12±1.35$^{ab}$ | 7.85±0.72$^{a}$ | 5.93±0.79$^{bc}$ | 2.49±0.96$^{fg}$ | 2.18±0.59$^{h}$ | 2.28±0.84$^{h}$ | 0.99±0.02$^{hij}$ | 1.34±0.58$^{ghj}$ | 1.80±0.13$^{gh}$ |
| | Vit C | 323.09±45.69$^{b}$ | 395.78±39.88$^{a}$ | 322.68±45.11$^{b}$ | 242.32±0.0$^{b}$ | 177.70±9$^{c}$ | 249.82±9$^{b}$ | 242.32±0.00$^{b}$ | 210.02±68.56$^{b}$ | 137.31±34.27$^{c}$ |
| | Vit A | 361.97±16.96$^{f}$ | 807.11±22.83$^{c}$ | 582.40±0.00$^{d}$ | 70.00±29.1$^{hi}$ | 65.75±23.$^{i}$ | 55.65±32.$^{i}$ | 14.37±0.820$^{i}$ | 44.74±28.76$^{i}$ | 49.48±23.32$^{i}$ |
| | Zinc | 0.96±0.38$^{def}$ | 2.39±0.39$^{cd}$ | 1.49±0.18$^{def}$ | 3.32±0.76$^{c}$ | 1.30±0.03$^{f}$ | 6.38±3.00$^{b}$ | 1.52±0.78$^{def}$ | 1.23±0.18$^{def}$ | 2.21±0.30$^{cde}$ |
| Day 5 | Iron | 6.12±0.21$^{bc}$ | 6.24±0.27$^{bc}$ | 6.95±1.27$^{ab}$ | 2.48±0.63$^{fg}$ | 2.54±1.00$^{g}$ | 2.08±0.25$^{h}$ | 1.52±0.79$^{ghij}$ | 1.08±0.28$^{hij}$ | 1.80±0.03$^{gh}$ |
| | Vit C | 161.56±22.85$^{c}$ | 145.39±22.84$^{c}$ | 177.70±28.53$^{c}$ | 193.85±22.$^{c}$ | 127.62±2$^{c}$ | 129.24±2$^{c}$ | 177.695±22.85$^{c}$ | 113.08±0.00$^{c}$ | 161.55±22.85$^{c}$ |
| Vit A | | 457.85±82.38$^{e}$ | 576.85±5.87$^{d}$ | 278.58±33.76$^{f}$ | 0.00±000$^{j}$ | 81.61±8.7$^{i}$ | 67.88±9.2$^{i}$ | 0.00±0.00$^{j}$ | 94.40±13.81$^{hi}$ | 24.59±11.59$^{i}$ |
| | Zinc | 0.08±0.04$^{f}$ | 0.18±0.09$^{f}$ | 0.15±0.00$^{f}$ | 0.80±0.$^{f}$ | 1.17±1.32$^{f}$ | 1.11±0.23$^{f}$ | 0.34±0.24$^{f}$ | 0.20±0.14$^{f}$ | 0.28±0.11$^{f}$ |
| | Iron | 0.40±0.21$^{j}$ | 0.99 ±0.33$^{hij}$ | 0.46±0.271$^{j}$ | 2.28±0.$^{h}$ | 3.69±0.3$^{f}$ | 3.64±0.16$^{f}$ | 1.80±0.69$^{gh}$ | 1.34±0.41$^{ghij}$ | 0.395±1.71ghi |

The blend containing 20-% cassava leaf blended with cassava root material was least affected by packaging material across the storage period.

## Discussion

The scenario where moisture content varied across the storage period especially in the kraft packaging could have been caused by the fact that this particular material is porous and probably was imbibing moisture from within the incubator. A comparison across the three packaging materials by day 5 showed that the paper insulated polythene packets had the lowest moisture content in all the three blends of cassava flakes across the storage period. Akingbala *et al.,* (2005) however reported a decrease in moisture content of *gari* stored in polybags at ambient temperatures. On the other hand, the results of the current results agree with those reported by Shibby *et al.,* (2017) who recorded an increase in moisture content in stored pineapple lassi with a variation in the different packaging materials. The variation of the results reported by the two different researchers Akingbala *et al.,* (2005) and Shibby *et al.,* (2017) could have risen from the difference in the nature of the stored products. Abong'*et al.,* (2011); reported an increase in moisture content in their research on potato crisps. Zeeman and Kubik. (2007) on the other hand reported that an increase in thickness of polymers (polythene) material increased the barrier properties of the film material making it more efficient on inhibiting moisture permeation. This confirms the characteristics shown in the paper insulated polythene packets.

The results on stored protein as shown in the current study differs from the results reported by Haruna *et al.,* (2015). Haruna reported an increase in protein in *gari* stored in specialized ware house. On the other hand, Shahidi. (2019); Ozdal *et al.,* (2013), argued that proteins in foods commonly form complexes with other food components. This therefore points out that the presence or the absence of such chemical reactions could be the source of variations in the results reported in different studies, including the current study. On the other hand, Tunick *et al.,* (2016) reported protein drop after twelve months in whey stored for 20 months. These results of the current study show that packaging materials have effect on nutrient levels of stored products, a fact that was reported by Willige, (2002), Hao *et al.,* (2015) and Moneim *et al.,* (2007).

The scenario where carbohydrates were shown to register an increase in the levels could have been caused by the fact that kraft material is porous, a fact that could have caused a decrease or an increase in moisture content that consequently influence the carbohydrates levels. The blend 100% cassava roots showed varying trend of its carbohydrates content in the different packaging materials. These variations could have been caused by the nature of the product or the nature of the packaging materials. In a scenario where there is a moisture decrease, carbohydrates tend to show increased levels. The results of the current study compare well with results reported by Haruna *et al.,* (2015) and Ajayi *et al.,* (2015), the two researchers reported similar trends in their results where there were variations in carbohydrates levels of products packaged in different packaging materials. Haruna *et al.,* (2015) had his *gari* showing fluctuating trends, but registered a peak increase of carbohydrates levels after 1year storage. Ajayi's study showed carbohydrates packaged in aluminum laminated packages, to be higher than levels in other packages.

Hao *et al.,* (2015), studied effect of packaging films on canola oil under photo oxidation conditions. Hao reported packaging films to have high effect on the canola oil. Hao's study confirmed that packaging films have effect on oils, a fact that is also confirmed in the current study. Wellige, (2002) on his study argued that rancidity of food is mostly minimized when the packaging material ensures good barrier to oxygen and also protects the food product from light.

The scenario where the blend 20-% leaf had minimal variations of ash content across the packaging materials and storage period could be indicating that it is more shelf stable product than the blend containing 100-% fresh root material and the blend containing 100-% fermented root material. The varied results of the different packaging material across the blends could be arising from the difference in compositions contained in different blends and the difference in the method of processing. The three blends showed significant ($P \leq 0.05$) variation in their vitamin C content, especially in day 1 and 3 across the three packaging materials. 20-% cassava leaf blended with cassava root material showed significant deference in vitamin C packaged in gunny (Table 2; appendix 2). Gunny package showed higher levels of vitamin C than in Kraft and plastic. The blend with 100-% fresh roots showed significant ($P \leq 0.05$) difference in vitamin C packaged in gunny. However, this blend had the lowest levels of vitamin C content gunny. The blend containing 100-% fermented root material packaged had in the plastic jars had significant ($P \leq 0.05$) deference in the levels of vitamin C. The levels of vitamin C in this package was the lowest in levels. This scenario where each product is affected differently by the type of packaging material could be due to the product structural difference resulting from their composition and the method of processing, as postulated by Tunick *et al.,* (2016). By virtue of structural variations in the different blends, consequently each of the blends had different texture, thus different capacities of moisture permissibility whereby vitamin C is water soluble. Moisture in the packages originates from different sources that include, the air that is normally trapped at the top of each packaging in the absence of vacuum sealing, moisture contained in the packaged product, and moisture laden in the air that may seep through the packaging materials or seals as argued by Tunick *et al.,* (2016). Fluctuations in vitamin C levels could be an indirect indication of moisture permeability in the different packages resulting to the effect that different packaging material have on packaged food. Abong *et al.*, (2011); Burgos *et al.*, (2009) and Galani *et al.,* (2017) reported fluctuation of vitamin C that was caused by high storage temperatures -above 25$^{o}$C. There was however wide variation of vitamin C content across the blends, registered by day 5 that showed vitamin C to be significantly ($P \leq 0.05$) low. Islam *et al.,* (2015) also reported a similar trend in his studies on effect of packaging material as affecting carrot stored under different conditions. Kaleen *et al.,* (2015) went further to explain that 2-% of vitamin C is lost every time a storage container is opened, this was in relation to orange juice stored in different containers.

There was significant ($P \leq 0.05$) effect of packaging material on vitamin A content in all the three blends of cassava flakes. However, 20-% cassava leaf blended with cassava root material was shown to retain more vitamin A content when packaged in gunny than when stored in plastic and Kraft. A major difference was however registered between day 1 and day 3. The blends containing 100-% fresh cassava roots and 100-% fermented root were least affected by packaging material as they showed non-significant difference in the levels of vitamin A across the different packages. This an indicator that pure root products are more stable during storage, inasmuch as they initially contained low levels of vitamin A. All the blends however had extremely low vitamin A across the different packages by day 5. The variation in the levels of vitamin A shown within the blends could have been caused by the nature and composition and, the method of processing the products. The results also showed paper laminated polythene packets to contain higher levels of vitamin A therefore demonstrating to be a more suitable package than the other packages. The results of the current study agree to results reported by Ayowale *et al.,* (2016). Ayowale reported vitamin A content to be well retained in high density polythene However, Oluwalana *et al.,* (2015) reported drastic drop of vitamin A levels stored under different temperatures. This probably could mean that even if vitamin A is packaged well in a suitable packaging material it is still mandatory that the storage is done under predetermined suitable temperatures too.

There was significant effect ($P \leq 0.05$) of packaging material on mineral zinc content that was shown in blend 20-% cassava leaf blended with cassava root material. Zinc levels in 20-% cassava leaf blended with cassava root material stored in gunny remained significantly ($P \leq 0.05$) higher across the storage period when compared with levels of the same blend stored in Kraft and plastic materials. A significant effect ($P \leq 0.05$) was also shown in the blend containing 100 % fresh root material when packaged and stored in paper laminated polythene packets. Zinc content in the blend containing 100-% fermented root material was however shown to be higher in the plastic material. The nature and composition and, the processing method of the products could have been the source of the variation since factors cause physical and biodegradation difference thus affecting the retention of the mineral zinc. All the three blends had zinc content that significantly (P ≤ 0.05) dropped by day 5 in all the packages. Olayiwola *et al.,* (2012) reported similar trend on studies carried out on vegetables packaged in different packaging materials,

There was significant effect (P ≤ 0.05) of packaging material on mineral iron content across the three blends over the storage period of five days. The results however showed that each blend was affected differently by each packaging material. 20-% cassava leaf blended with cassava root material packaged in gunny had the highest iron content while the lowest iron content in 20-% cassava leaf blended with cassava root material was shown to be in plastic package. A similar trend was shown in the blend containing 100 % fresh root material whose iron levels were also found to be higher in the gunny package than in plastic and Kraft. However, iron content in the blend containing 100-% fermented root material was found to be lowest in the paper laminated polythene package though not significantly different from the levels found in the Kraft package. Significant variations were however registered between day 1 and 3. By day 5 all the packages showed non-significant (P ≤ 0.05) difference in each of the blends across the different packages. The results conform to results reported by Huma *et al.,* (2007). The iron levels in fortified whole meal wheat flour, packaged in tin boxes and polypropylene bags showed variations. Huma reported variation of iron content as affected by days of storage and type of packaging material.

**Conclusion and recommendations**

The three blends of cassava flakes are of good quality up to 3 months, where most nutrients are at average levels, while packaging materials have significant effect on nutrients' levels in the packaged cassava based flakes, packaging materials also have effect on the length of storage period, the study hereby concludes that best time to store cassava flakes is up to 3 months, and the best packaging material is paper insulated polythene. It is recommended that further studies be carried out to identify storage pests for cassava root-leaf flakes that were not covered in the current study.

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