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Shelf life assessment of hot smoked African catfish stored under different storage conditions at Lake Kenyatta, north coast, Kenya

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Abstract

Catfish (Family Clariidae) from Lake Kenyatta in coastal Kenya was smoked using an improved smoking (Chorkor) oven and subjected to storage under different packaging conditions. Biochemical, proximate composition and sensory parameters were used to determine the shelf life of the product for a period of 30 days. Peroxide values for samples stored under open, ambient air, and vacuum packaging increased significantly ($p < 0.05$) from 7.296 $megO_2$/kg to 24.890 $meqO_2$/kg, 28.940 $meqO_2$/kg and 18.729 $meqO_2$/kg, respectively. Thiobarbituric acid reactive substances increased from 0.459 mg/kg to 4.653 mg/kg, 1.473 mg/kg and 0.339 mg/kg during storage under open, ambient air, and vacuum packaging, respectively. Total volatile bases-nitrogen increased significantly with storage days, from 1.349 mgN/100g to 5.182 mg N/100g, 6.700 mgN/100g and 2.001 mgN/100g for open, ambient air, and vacuum packaging, respectively. During storage, proximate composition for the stored samples differed significantly between the open and ambient air package only, while sensory changes were observed on day 30 only. Texture remained the same to day 30 for all samples stored under difference storage conditions. Water activity ranged between 0.7 and 0.79 during the same period in the three packaging conditions. In general, the 30 days storage period did not compromise the acceptability of smoked products.

Keywords: storage, smoking, Chorkor, Lake Kenyatta, shelf life, packaging

Introduction

Fisheries and aquaculture remain important sources of food, nutrition, income and livelihoods for hundreds of millions of people around the world (FAO, 2016). Recent reports have highlighted the tremendous potential of the oceans and inland waters as significant current and future contributors to food security and adequate nutrition for a global population expected to reach 9.7 billion by 2050 (FAO, 2016). However, fish is classified as a highly perishable food commodity whose shelf life depends on the initial quality as well as the subsequent storage conditions under which it is kept. Reports indicate that 46% of total direct human consumption of fish is in the live, fresh or chilled form (FAO, 2016). However, the rest of the edible production is in various processed forms, with about 12% (17 million tonnes) dried, salted, smoked or cured in other ways, while 13% (19 million tonnes) is in prepared and preserved forms, and 30% (about 44 million tonnes) is frozen (FAO, 2016).

Smoking forms one of the oldest methods used to process and preserve fish (Bilgin *et al.,* 2008). It can inhibit the formation of toxins in products and reduce growth of bacteria due to lower water activity (Rørvik, 2000). Smoking also gives special colour and flavour to food (Alcicek and Alar, 2010; Hattula *et al.,* 2001) and extends its shelf-life via the effect of dehydration, and the antimicrobial and antioxidant properties of the smoke compound (Goulas and Kontominas, 2005; Alcicek and Atar, 2010; Pagu *et al*., 2013). Huss *et al*. (1995) stated that methods used to produce

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smoked fish varies among different producers within one country, and throughout world. This means that production parameters vary, and also the quality and shelf life of the product. It has been reported that since 1990, the consumption of smoked fish in the market has increased, and smoked salmon is the most consumed product followed by smoked trout and herring (Cardinal *et al.,* 2006).

Even though live, fresh or chilled fish is preferred in most markets, developing countries have challenges as far as infrastructure for this type of preservation is concerned. Poor roads and inadequate electricity supply in the fishing areas hamper the use of cold rooms, freezers and refrigerators. This leaves many developing countries with the option of practising mainly sun-drying and smoking methods of fish processing. In Kenya, fishermen face the same challenges, with most areas practising sun drying, deep frying and smoking as the major preservation methods. Processing procedures vary from one region to the other with no standardized processing methods or hygienic conditions.

At Lake Kenyatta in the Kenyan north coast region, smoking is carried out in traditionally built smoking kilns. Wood from various tree species is used for smoking with very little consideration of hygienic conditions and smoking temperature. Salting and duration of smoking is not standard. Reports indicate that the quality of smoked fish depends on the raw material (Cardinal *et al.,* 2001), condition of processing (Duffes, 1999), composition of smoke (Cardinal *et al.,* 2006) and storage conditions. This study was therefore designed to determine the quality and shelve life of smoked fish products using an improved smoking oven, and to determine the shelf life of the product under different storage conditions. Community participation was encouraged so as to empower the communities economically and to enhance food security.

Materials and Methods

Study area

This study was conducted at Mpeketoni fish landing site at Lake Kenyatta in Lamu County on the north coast Kenya (Fig. 1). Fishermen in this area are mainly artisanal and are engaged in both farming and fishing. Fish smoking is mainly done by women while fishing activities are dominated by men. Traditional smoking kilns of different sizes are used for smoking fish. Cichlidae (*Tilapia* sp.) and Clariidae (catfishes) are the main fish species smoked for marketing. Smoking is done in settlement areas with the majority preferring to smoke fish in their homes. The smoked products are kept in bags (gunny bags) awaiting customers who are mainly wholesalers. The smoked products are transported to nearby (Mombasa) and distant markets (Nairobi and Kisumu) for sale.

Study design

Three smoking kilns were selected at random as replicates from the eight improved smoking ovens previously constructed by the Kenya Marine and Fisheries Research Institute (KMFRI) for this study. Pieces of catfish (150) of approximately equal sizes were bought from the fishermen and processed. In each kiln the fire was lit and left to char off for the production of smoke. Fifty pieces of catfish were placed on a wire mesh on top of each kiln, covered with ply wood to avoid contamination, and allowed to smoke dry. Smoking was done for a period of 30 hours.

Fish handling and processing

Quality fish was selected and weighed using a top loading electronic weighing balance. The fish was then eviscerated, washed using 5% brine salt for 1 hour, and then left to drain for another 1 hour on a drying rack. During this period the fire was lit in each of the three ovens and a known amount of fuel introduced into each smoking oven for smoking. Acacia wood was used in all the three ovens for uniformity.

Smoke-Drying

In each oven, three pieces of fish of equal sizes were marked for monitoring. Temperatures were monitored using a hand held thermometer with temperatures ranging from 70°C to 90°C. The three pieces of fish were weighed at an interval of 2 hours until no change in weight was detected. This marked the end of the drying period. The smoked fish were collected, placed in gunny bags and carried to the laboratory for quality determination and shelf life evaluation under different storage conditions.

Laboratory treatment

Three replicates were chosen (one from each oven) and ground using a blender for analysis of biochemical, proximate and water activity parameters. The remaining samples were divided into three portions with each being stored under three different storage conditions. One portion was vacuum packed using vacuum packer (vacuum package). The second portion was place in polythene bags and sealed under ambient atmospheric conditions (ambient air

Figure 1. Map showing Lake Kenyatta study sites on the North coast of Kenya

package) using a sealing machine, while the third portion was placed in open containers (open package). All samples were stored in the laboratory at ambient air temperature (27°C ± 4°C) for a period of 30 days. Sampling from each was done every 10 days for biochemical, sensory and water activity parameters.

Laboratory Analysis

Each sample was presented to 10 pre-trained panellists at the beginning of storage. The attributes tested were taste, texture, appearance, and general acceptability. The attributes were based on a 5-point scale for each attribute according to Haider *et al.* (2011). Water activity readings were obtained in replicates using a water activity meter. Total volatile basic-nitrogen (TVB-N) was determined according to the method adopted from Siang and Kim (1992) using Conway's Micro Diffusion Unit, while the extraction of crude fat was carried out according to the method of Bligh and Dyer (1959). Peroxide values (PV) were determined according to Kirk and Sawyer (1991).

Crude protein content was determined based on the Kjeldahl method (AOAC, 1990), whereas crude fat content was determined by the AOCS (1997) official method of analysis.

Dry matter was calculated by analysing moisture content according to the AOCS (1997) official method of analysis. Moisture content was then subtracted from 100% to get dry matter content (%). Ash content was determined according to the AOCS (1997) official method of analysis.

Data Analysis

Data were analysed using MINITAB® 14 statistical software. All data were tested for normality using Shapiro Wilk (1965) before being subjected to analysis of variance (ANOVA). Where differences were noted, tests for significance differences in means was conducted using Turkey's pair-wise comparison analysis. All tests were considered significant at a confidence level of 95% ($\alpha = 0.05$).

Results

Effect of storage on biochemical parameters

Peroxide Values (PV)

The results (Table 1) show an increase in peroxide values with storage period.

Table 1. Turkey's pairwise comparison on mean Peroxide values (PV) of fish during storage under different packaging conditions.

Packaging conditions	Storage Period			Limit of acceptability
	Day 0	Day 15	Day 30	
Open Packaging	7.296 ± 2.316[a]	32.583 ± 3.458[b]	24.890 ± 9.838[b]	10-16 meqO_2/kg
Ambient air packaging	7.296 ± 2.316[a]	19.324 ± 4.652[b]	28.940 ± 4.905[c]	
Vacuum packaging	7.296 ± 2.316[a]	16.573 ± 3.458[b]	18.729 ± 3.585[c]	Okpala *et al.* (2014)

Different superscript letters in the same row indicate significant difference ($p < 0.05$). The values are expressed as Mean ± standard deviation. Units are expressed in meq O2/kg.

The lowest PV was observed on Day 0 and the highest on Day 30 (Table 1). All packaging conditions showed increased PV with storage time. However, ambient air packaging had the highest PV of 28.940 ± 4.905 meqO_2/kg after 30 days storage, followed by the open packaging, while the lowest value during the same storage time was observed in the vacuum packaged samples at 18.729 ±3.585 meqO_2/kg. There was a significance difference ($p < 0.05$) in all PVs during the storage period, except for day 15 and 30 for open packaging. Both open and ambient air samples surpassed the PV limit of acceptability (10-16 meqO2/kg) by day 15 of storage, while the vacuum packaged samples were still within the acceptable range on day 15 of the storage period. PVs for all products under the three packaging conditions however surpassed the limit of acceptability after 30 days of storage.

Thiobarbituric Acid Reactive Substances (TBARs)

The results showed an increase in TBARs values with storage days in products stored under open packaging conditions (Table 2). The highest value was observed on day 30 of the storage period (4.653 ± 0.832 mg/kg).

Vacuum packaging showed the least changes in TBARs values during the storage period of 30 days. This was followed by ambient air packaging while the highest values were observed on samples under open packaging. There were significant differences ($P<0.05$) in TBARS values for products stored under open packaging and ambient air packaging during the storage period. Products stored under vacuum packaging did not show any significance differences for the whole storage period. Open and ambient air packaged products surpassed the limit of acceptability (1mg/kg) at day 15 and day 30 respectively, while vacuum air packaged products remained within the limit of acceptability during the same period.

Total Volatile Bases-Nitrogen (TVB-N)

Results showed that ambient air packaging had the highest value of TVB-N on day 30 (6.700 ± 0.284 mg N/100g), followed by open packaging (5.182 ± 0.284 mg N/100g), while the lowest value was vacuum packaging (2.001 ± 0.214 mg N/100g). All packaging conditions showed significance differences in TVB-N values over the 30 day storage period. All the TVB-N values for all packaging conditions remained within the acceptability limits (<25mgN/100g) during the rest of the storage period. In all biochemical parameters, the ambient air storage conditions show comparatively higher values than those stored under open and vacuum packaging conditions on day 15 and day 30, respectively.

Table 2. Turkey's pairwise comparison on mean Thiobarbituric acid reactive substances (TBARS) of fish during storage under different packaging conditions.

Packaging condition	Storage period			Limit of acceptability
	Day 0	Day 15	Day 30	
Open	0.459 ± 0.059[a]	1.941 ± 0.269[b]	4.653 ± 0.832[c]	< 1 mg/kg
Ambient air	0.459 ± 0.059[a]	0.233 ± 0.012[a]	1.473 ± 0.335[b]	(Kezban and Nuray, 2003)
Vacuum	0.459 ± 0.059[a]	0.473 ± 0.057[a]	0.339 ± 0.091[a]	

Different superscript letters in the same row indicate significant difference ($p < 0.05$). The values are expressed as Mean ± standard deviation. Values are expressed in mg/kg.

Table 3. Turkey's pairwise comparison on mean Total Volatile Bases-Nitrogen of fish during storage under different packaging conditions.

Packaging conditions	Storage period			Limit of acceptability
	Day 0	Day 15	Day 30	
Open Packaging	1.349 ± 0.082[a]	3.721 ± 0.426[b]	5.182 ± 0.325[c]	< 25mgN/100g Bono & Badaluco, (2012)
Ambient air packaging	1.349 ± 0.082[a]	5.574 ± 0.741[b]	6.700 ± 0.284[b]	
Vacuum packaging	1.349 ± 0.082[a]	1.535 ± 0.139[a]	2.001 ± 0.214[b]	

Different superscript letters in the same row indicate significant difference ($p < 0.05$). The values are expressed as Mean ± standard deviation. Values are expressed in mg N/100g.

Water activity variations

The results (Fig. 2) on water activity of the samples ranged between 0.70 and 0.79 for the whole storage period, with the lowest value being observed in ambient air packaging on day 30. However, no significance difference was seen during the storage period in all storage conditions.

Temperature Variations

There was minimal changes in temperatures during the storage period (Table 4) with the highest value being 25.423 ± 0.282° C and the minimum being 24.953 ± 0.071° C.

Effect of storage on sensory attributes under different packaging conditions

Taste, texture, appearance, and overall acceptability was scored by the 10 panelists. As shown in Fig. 3, panelists detected no change in taste for the products stored for 15 days. However, day 30 resulted in a lower score in taste for all products stored under different packaging with a mean score of 3.0.

On the other hand, texture did not change in score rating for the whole storage period, having a mean score of 4.0. The scores on appearance also did not change for the whole storage period in all products, except for the product stored in the open, having a mean score of 3.0 on day 30. A lower score of 3.0 was observed on overall acceptability for open and ambient air packaged samples. However, vacuum packaged samples had no change in scores for the rest of the storage period.

Effect of storage on proximate composition

The results indicated a continuous decrease in protein content over the storage period in fish samples stored under open and ambient air packaging conditions. On the contrary, the values for vacuum packaged samples increased. Open packaging products gave protein value of 60.499% while ambient air packaging had a value of 61.154%, respectively. Percentage fat composition did not show any significance difference for both packaging and storage period. This was also observed in the ash (%) composition, except for the

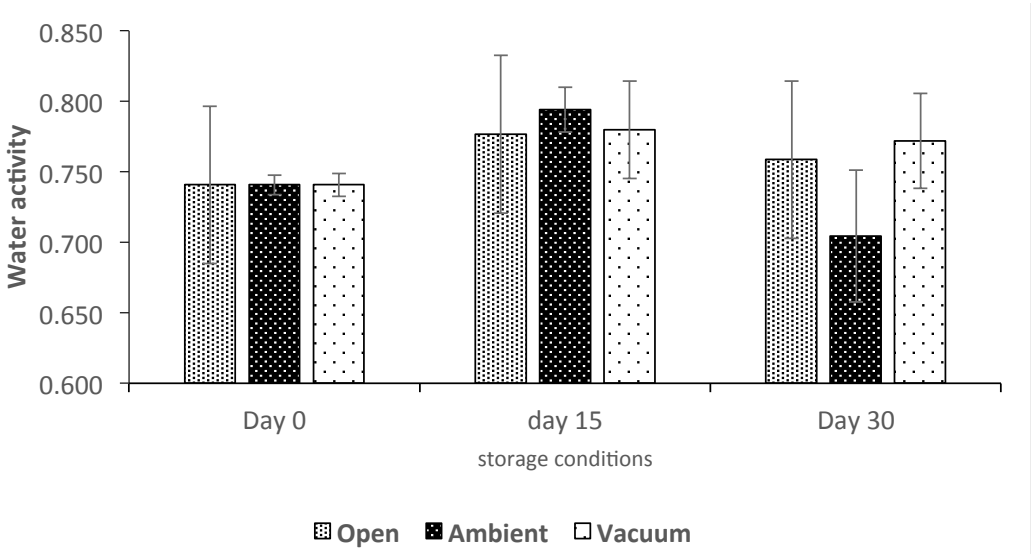

Figure 2. Changes in water activity during storage under open, ambient and vacuum packaging.

Table 4. Mean temperature variation during storage under different packaging conditions.

Days of storage	Mean Temp.^{0}C ± Stdev
Day 0	25.423 ± 0.282
Day15	25.193 ± **0.062**
Day 30	24.953 ± 0.071

open packaged samples, that had a significant difference on day 30 of storage. During the 30 days storage period, there was a significant change in percentage moisture content in fish products stored in the open and ambient air packaging (Table 5). However, the products stored under vacuum packaging did not show a significance difference in the moisture content over the 30 days storage period.

Discussion

Peroxide Value

The observed increase in PV in this study indicates an increase in rancidity of the oil leading to the "off" flavour of catfish samples. Similar observations were made by Nirmal and Benjakul (2009), and Chaijan (2011). Consumer acceptability of PV value in fish has been categorised as follows: 0-2 mmol/kg - very good; 2-5 mmol/kg – good; 5-8 mmol/kg – acceptable; and 8-10 mmol/kg - spoilt (Okpala *et al*., 2014). Conversion of these values to meq O_2/kg gives values of 0-4 meq O_2/kg as very good, 4-10 meq O_2/kg as good, 10-16 meq O_2/kg as acceptable, and 16 - 20 meq O_2/kg as spoilt. Peroxide value results showed that quality of the smoked fish products stored under open and ambient air packaging deteriorated beyond acceptable level at day 15. However, vacuum packaged sampled were at the end limit level of acceptability (16.573±3.458 meq O_2/kg). High values observed in the open package could be associated with free contact to air. On the other hand, the values observed in the ambient air packaging could be due to availability of sufficient air (oxygen) in the package leading to elevated PV in comparison to vacuum packaging. The lowest PVs observed in the vacuum packaging was mainly attributed to low oxygen in the package hence restricting the oxidation process of oil in the fish products.

Thiobarbituric Reactive Substances (TBARs)

TBARs is one of the most widely used assays for measuring lipid oxidation in the food industry. It is formed as a degradation product of fats (Malondialdehyde-MDA) present in a sample as well as

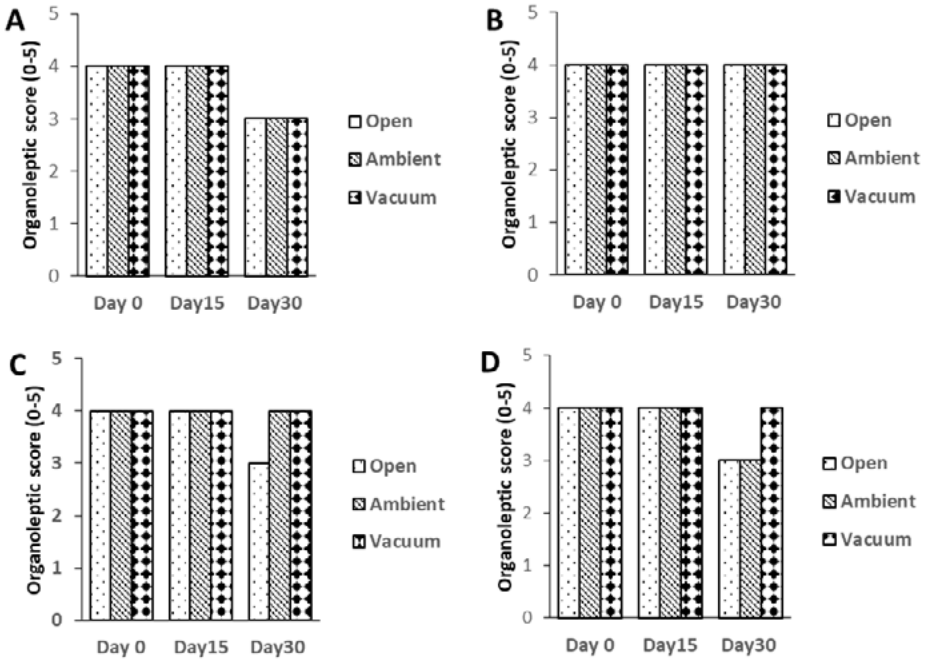

Figure 3. Changes in sensory scores and fish products for Taste (A), Texture (B), Appearance (C) and Overall acceptability (D) during storage

Table 5. Turkey's pairwise comparison on mean proximate composition of fish during storage under different packaging conditions.

Parameter	Packaging	Storage Days		
		Day 0	Day 15	Day 30
Moisture (%)	Open	17.911 ± 0.964[a]	18.597 ± 2.906[a]	29.002 ± 6.693[b]
	Ambient air	17.911 ± 0.964[a]	20.943 ± 3.489[a]	25.708 ± 4.342[b]
	Vacuum	17.911 ± 0.964[a]	19.381 ± 1.551[a]	20.017 ± 1.123[a]
Protein (%)	Open	77.318 ± 0.147[a]	71.792 ± 1.457[b]	60.449 ± 0.689[c]
	Ambient air	77.318 ± 0.147[a]	72.112 ± 1.636[a]	61.154 ± 0.000[b]
	Vacuum	77.318 ± 0.147[a]	74.719 ± 1.295[a]	82.044 ± 0.709[b]
Fat (%)	Open	6.328± 0.933[a]	5.222 ± 0.735[a]	5.174 ± 0.720[a]
	Ambient air	6.328 ± 0.933[a]	3.818 ± 0.385[b]	5.250 ± 1.059[a]
	Vacuum	6.328 ± 0.933[a]	6.673 ± 0.494[a]	5.551 ± 1.391[a]
Ash (%)	Open	3.369 ± 0.159[a]	4.123 ± 0.213[a]	4.047 ± 0.188[b]
	Ambient air	3.369 ± 0.159[a]	3.244 ± 1.565[a]	3.603 ± 0.805[a]
	Vacuum	3.369 ± 0.213[a]	3.499 ± 1.175[a]	4.440 ± 0.453[a]

Different superscript letters in the same row indicate significant difference ($p < 0.05$). The values are expressed as Mean ± standard deviation (%) composition. Values are expressed in % composition.

malodialdehyde generated from lipid hydro peroxides. The significant increase in TBARs values from day 0 to day 30 in open and ambient air conditions during storage indicated continued degradation of fats on the smoked product. This could be attributed to unlimited air (oxygen) contact in both open and ambient air packages. On the contrary, the insignificant change in the vacuum packaged samples indicated non-degradation of fats for the 30 days period. This could be due to restricted air contact due to the vacuum packaging condition during storage,

Total Volatile Bases-Nitrogen (TVB-N)

TVB-N serve as a quality indicator to estimate the level of freshness in fishery products. There was an increase in values of TVB-N with an increase in storage days in each packaging condition. This indicates a cumulative spoilage trend or quality loss with storage days. Similar observations were reported by Ali *et al.* (2013). Studies have reported scales of acceptability for TVB-N in shrimps to range as follows: <12 mg N/100 g for fresh raw shrimps; 12 – 20 mg N/100 g for edible but lightly decomposed shrimps; 20 – 25 mg N/100 g for borderline shrimps; and > 25 mg N/100 g for inedible and decomposed shrimps (Lannelongue *et al.*, 1982; Bono and Badaluco, 2012; Okpala *et al.*, 2014). TVB-N values in this study indicated that the fish samples did not surpass the limit of freshness for the whole storage period, despite the increase in value with time. Packaging conditions had a significant effect on the quality of the fish. However, the products in all the three packaging conditions remained fresh (<12 mg N/100g). Despite being within the limit of freshness in all packaging conditions, it was observed that vacuum packaging had the lowest values. It has been reported that vacuum packaging extends the shelf life in comparison to ambient air packaged products (Kumar & Ganguly, 2014). This was said to be attributed to the restricted quantity of air in the package leading to reduced bacterial activity (Kumar *et al.*, 2015). On the other hand, the availability of air in the open and ambient air packages allowed the bacterial activity to continue with little restrictions, leading to higher values.

Water activity

Water activity of any given food system is an important index to consider, particularly because of the resultant chemical effects during food processing. Richardson and Finley (1986) stated that water activity is able to influence the oxidation of fresh foods, particularly during storage. Water activity of less than 0.70 and 0.62 is able to retard the growth of bacteria and fungi respectively (Sandulachi, 2012). The water

activity levels of between 0.70 and 0.79 in this study were therefore likely to retard bacterial activity leading to prolonged shelf life, but fungal growth was not effectively retarded, and could still lead to spoilage. Therefore, more dehydration during drying to water activity level of < 0.62 is necessary.

Effect of storage on Sensory attributes under different packaging conditions

A range in scores of between 4.0 and 5.0 on the fish samples was considered a good response on product acceptability. Between day 0 and 15, the overall acceptability scores remained at 4.0. This indicated a good panelist response on the product quality for the 15 days period. However, the overall acceptability score of 3.0 for open and ambient packaging samples on day 30 indicated reduced quality of the product under these treatments.

Effect of storage on proximate composition

The highest value (29.002%) in moisture content for open packaging storage was noticed on day 30. During the same period vacuum packaging gave a value of 20.017% moisture content. This increase in moisture content could be attributed to absorption of air moisture, since the products were stored in open packages. Lack of air contact in the samples stored in vacuum packaging could be the contributor to insignificant change in moisture content over the storage period.

Protein content was significantly different in all packaging conditions during the 30 days storage, with the highest value being 82.044 for vacuum packaged samples. Both ash (%) and fat content showed no significant change during the entire storage period.

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