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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
smoked fish varies among different producers within one country, and throughout the 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 shelf 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...
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 panelists 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% (α = 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.
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 meqO₂/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 meqO₂/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.

| Packaging conditions | Storage Period | Limit of acceptability |
|----------------------|----------------|------------------------|
|                      | Day 0          | Day 15             | Day 30 |
| Open Packaging       | 7.296 ± 2.316a | 32.583 ± 3.458b     | 24.890 ± 9.838b |
| Ambient air packaging| 7.296 ± 2.316a | 19.324 ± 4.652b     | 28.940 ± 4.905c  |
| Vacuum packaging     | 7.296 ± 2.316a | 16.573 ± 3.458b     | 18.729 ± 3.585c  |

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.

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

| Packaging condition | Storage period | Limit of acceptability |
|---------------------|----------------|------------------------|
|                      | Day 0          | Day 15             | Day 30 |
| Open                | 0.459 ± 0.059a | 1.941 ± 0.269b     | 4.653 ± 0.832c  |
| Ambient air         | 0.459 ± 0.059a | 0.233 ± 0.012a     | 1.473 ± 0.335b  |
| Vacuum              | 0.459 ± 0.059a | 0.473 ± 0.057a     | 0.339 ± 0.091a  |

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

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 |
|---------------------------|----------------|------------------------|
| Open Packaging            | Day 0          | 1.349 ± 0.082<sup>a</sup> |
|                           | Day 15         | 3.721 ± 0.426<sup>b</sup> |
|                           | Day 30         | 5.182 ± 0.325<sup>c</sup> |
| Ambient air packaging     | Day 0          | 1.349 ± 0.082<sup>a</sup> |
|                           | Day 15         | 5.574 ± 0.741<sup>b</sup> |
|                           | Day 30         | 6.700 ± 0.284<sup>b</sup> |
| Vacuum packaging          | Day 0          | 1.349 ± 0.082<sup>a</sup> |
|                           | Day 15         | 1.535 ± 0.139<sup>a</sup> |
|                           | Day 30         | 2.001 ± 0.214<sup>b</sup> |

<sup>a</sup> 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.

Figure 2. Changes in water activity during storage under open, ambient and vacuum packaging.
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 O₂/kg gives values of 0-4 meq O₂/kg as very good, 4-10 meq O₂/kg as good, 10-16 meq O₂/kg as acceptable, and 16 - 20 meq O₂/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 O₂/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 (oxyen) 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

| Days of storage | Mean Temp. °C ± Stdev |
|-----------------|------------------------|
| Day 0           | 25.423 ± 0.282         |
| Day 15          | 25.193 ± 0.062         |
| Day 30          | 24.953 ± 0.071         |

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

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

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**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 | 17.91 ± 0.964<sup>a</sup> | 18.59 ± 2.906<sup>a</sup> | 29.00 ± 6.693<sup>b</sup> |
| Ambient air | 17.91 ± 0.964<sup>a</sup> | 20.94 ± 3.489<sup>a</sup> | 25.70 ± 4.342<sup>b</sup> |
| Vacuum | 17.91 ± 0.964<sup>a</sup> | 19.38 ± 1.551<sup>a</sup> | 20.01 ± 1.123<sup>a</sup> |
| Protein (%) | | | |
| Open | 77.31 ± 0.147<sup>a</sup> | 71.79 ± 1.457<sup>a</sup> | 60.44 ± 0.689<sup>b</sup> |
| Ambient air | 77.31 ± 0.147<sup>a</sup> | 72.11 ± 1.636<sup>a</sup> | 61.15 ± 0.000<sup>b</sup> |
| Vacuum | 77.31 ± 0.147<sup>a</sup> | 74.71 ± 1.295<sup>a</sup> | 82.04 ± 0.709<sup>b</sup> |
| Fat (%) | | | |
| Open | 6.32 ± 0.933<sup>a</sup> | 5.22 ± 0.735<sup>a</sup> | 5.17 ± 0.720<sup>a</sup> |
| Ambient air | 6.32 ± 0.933<sup>a</sup> | 3.81 ± 0.385<sup>b</sup> | 5.25 ± 1.059<sup>a</sup> |
| Vacuum | 6.32 ± 0.933<sup>a</sup> | 6.67 ± 0.494<sup>a</sup> | 5.51 ± 1.391<sup>b</sup> |
| Ash (%) | | | |
| Open | 3.36 ± 0.159<sup>a</sup> | 4.12 ± 0.213<sup>a</sup> | 4.04 ± 0.188<sup>a</sup> |
| Ambient air | 3.36 ± 0.159<sup>a</sup> | 3.24 ± 1.565<sup>a</sup> | 3.60 ± 0.805<sup>a</sup> |
| Vacuum | 3.36 ± 0.213<sup>a</sup> | 3.49 ± 1.175<sup>a</sup> | 4.44 ± 0.453<sup>a</sup> |

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 % composition.
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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References
Alcicek Z, Atar HH (2010) The effects of salting on chemical quality of vacuum packed liquid smoked and traditional smoked rainbow trout (Oncorhyncus mykiss) fillets during chilled storage. Journal of Animal and Veterinary Advances 9: 2778-2783

Ali MY, Zakaria MM, Rashed A, Khanom M, Sarower MG (2013). Post-harvest quality loss of shrimps (Penaeus monodon) in the value chain of south western region (sakhira). International Journal, 3(2): 2305-1493.

AOAC (1990) Official methods of analysis of the association of official analytical chemists Association of Official Analytical Chemists Incorporation, Arlington 5 (1). 771 pp

AOCS (1997) Sampling and analysis of oil seed by-products. (With modification according to application note tector no AN 301). Official Method. pp 3-38

Bilgin S, Ulusayin M, Izcı, L, Gunlu A (2008) The determination of the shelf life and some nutritional components of Gilthead Seabream (Sparus aurata L, 1758) after cold and hot smoking. Turkish Journal of Veterinary and Animal Sciences 32: 49-56

Bligh EG, Dyer WJ (1959) A rapid method of total lipid extraction and purification. Canadian Journal of Biochemistry and Physiology 37 (8): 911-917

Bono G, Badaluco C (2012) Combining ozone and modified atmosphere packaging (MAP) to maximize shelf life and quality for stripped red mullet (Mullus surmuletus). LWT- Food Science and Technology 472 (2): 500-504

Cardinal M, Cornet J, Se’rot T, Baron R (2006). Effects of the smoking process on odour characteristics of smoked herring (Clupea harengus) and relationships with phenolic compound content. Food Chemistry 96: 137-146

Cardinal M, Knockaert C, Torrissen O, Sigurgisladottir S, Morkore T, Thomassen M, Valle JL (2001) Relation of smoking parameters to the yield, colour and sensory quality of smoked Atlantic salmon (Salmo salar). Food Research International 34: 537-550

Chaijan M (2011) Physicochemical changes of Tilapia (Oreochromis niloticus) muscle during salting. Food Chemistry 129: 1201-1210

Duffes F (1999) Improving the control of Listeria monocytogenes in cold smoked salmon. Trends in Food Science & Technology 10: 211-216

FAO (2016) The state of world fisheries and aquaculture; contributing to food security and nutrition for all. Rome. 200 pp

Goulas A, Kontominas M (2005). Effect of salting and smoking-method on the keeping quality of chub mackerel (Scomber japonicus): Biochemical and sensory attributes. Food Chemistry 93: 511-520

Haider MN, Faridullah M, Reza MS, Hossain MF, Kamal M, Islam MN (2011) Quality assessment of Giant Freshwater Prawn (macrobrachium rosenbergii) in ice storage condition collected from selected farms and depots. Progressive Agriculture 22 (1-2): 139-149
Hattula T, Elfving K, Mroueh U, Luoma T (2001) Use of liquid smoke flavouring as an alternative to traditional flue gas smoking of Rainbow Trout fillets (*Oncorhynchus mykiss*). Lebensmittel-Wissenschaft und-Technologie 34: 521-525

Huss HH (1995) Quality and quality changes in fresh fish. FAO Fisheries Technical Paper No. 348. Rome. 195pp

Kirk S, Sawyer R (1991) Pearson’s composition and analysis of foods (No. Ed 9). Longman Group Ltd. 708pp

Kumar P, Dora KC, Sarkar S, Chowdhury S, Ganguly S (2015) Vacuum packaging and quality analysis of Silver Pomfret (*Pampus argenteus*) under refrigerated condition (4±1° C). International Journal of Tropical Agriculture 33 (2 (Part I)): 177-184

Kumar P, Ganguly S (2014) Role of vacuum packaging in increasing shelf-life in fish processing technology. Asian Journal of Bio Science 9 (1): 109-112

Lannelongue M (1982) Storage characteristics of brown shrimp (*Penaeus aztecus*) stored in retail packaged containing CO2 enriched atmospheres. Journal of Food Science 47 (3): 911-923

Nirmal NP, Benjakul S (2009) Effect of ferulic acid on inhibition of polyphenoloxidase and quality changes of Pacific white shrimps (*Litopenaeus vannamei*) during iced storage. Food Chemistry 116 (1): 323-331

Okpala COR, Choo WS, Dykes GA (2014) Quality and shelf life assessment of Pacific white shrimps (*Litopenaeus vannamei*) freshly harvested and stored on ice. LWT – Food Science and Technology 55 (1): 110-116

Pagu I, Nistor C, Măgdici E, Hoha G, Albu A, Păsărin, B (2013) Research regarding the influence of age and corporal weight on efficiency of smoking and chemical composition of smoked rainbow trout. University of Agricultural Sciences and Veterinary Medicine Iasi. pp 216-220

Richardson T, Finley JW (eds) (1986) Chemical changes in food during processing. IFT Basic Symposium Series, 1st Edition. Van Nostrand Reinhold Company Inc., New York. 520 pp

Rørvik LM (2000) *Listeria monocytogenes* in the smoked salmon industry. International Journal of Food Microbiology 62: 183-190

Sandulachi E (2012) Water activity concept and its role in food preservation. Technical University of Moldova. Chemistry Journal Moldova 7 (2): 103-115

Siang NC, Kim LL (1992) Determination of trimethylamine oxide, trimethylamine and total volatile basic nitrogen by Conway’s micro-diffusion method. In: Laboratory manual on analytical methods and procedures for fish and fisheries products (Miwa and Ji eds.) Southeast Asia Fisheries Development Center. B3:1-B3:6