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Development of appropriate packaging for shelf life extension of smoked fish in a developing economy

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Abstract
Three composite packaging materials; Paper-Polyethylene (P_aP_e,), Polyethylene-Paper **(**P_eP_a) Polyethylene-Paper-Polyethylene ($P_eP_aP_e$) were developed for packaging of dried fish samples with Polyethylene used as control. Some engineering properties (thickness, water and oil absorption rates) were determined using standard methods. Smoked dried catfish were stored in the three composite packing materials and in polyethylene for six months. The composite materials'thicknesses ranged from 0.23 to 0.31 mm while that of control was 0.27 mm. The water and oil absorption rates ranged from 1.73 to 10.00 g/cm^2/min and 2.50 to 10.86 g/cm^2/min respectively for the composite materials and 0.36 and 0.28 g/cm^2/min respectively for the control. The percentages protein of the fish stored ranged between 62.8% and 71.90%; while the moisture ranged between 8.80 and 10.50%. There was no significant decrease in protein composition ($P<0.05$) in all the samples although the control has the least value of 62.8% at the end of six months. The fat content decreases with the storage period in all the packages except for sample stored in the control with almost constant value. Polyethylene-Paper-Polyethylene packages maintained better quality attributes of stored the general acceptance of the fish on the scale of nine for the composite materials ranged between 4.78 and 6.96 while that of control was 4.6. $P_eP_aP_e$ performed better in resistance to moisture and oil migration. It also shows high protein retention and better sensory attributes. The packaging material maintained the quality attributes of stored catfish. It was effective in extending the shelf life of smoked fish.

Keywords: Spoilage, Packaging, Quality, Shelf life.

1. Introduction
Fish is one of the most important animal protein foods available in the Tropics. The Less Developed Countries (LDCs) capture 50% of the world's harvest and a large proportion of that catch are consumed internally. In Africa, 17.5% of the animal protein intake comes from fish while in Nigeria the proportion is 40%. Fish spoilage is high in the tropics due to lack of appropriate handling and processing techniques. The first obvious way to avoid spoilage and loss of quality is to keep harvested fish alive until cooking and consumption. The perishable nature of fish necessitates its proper handling and preservation to increase its shelf-life and retain its quality and nutritional attributes. Harvested fish should be processed in order to retain quality and increase shelf-life.

Smoking is one of the methods of processing fish in Nigeria. The advantages of smoking fish are manifold. It prolongs shelf-life, enhances flavour and increases utilization in soups and sauces. It reduces wastages at time of bumper catches and permits storage for the lean season. It also increases protein availability to people throughout the year and make fish easier to pack, transport and market.

A well dried fish product will go bad if it is not well packaged because of the hygroscopic nature and easy ability of fish to lose oil when exposed to the atmosphere. In Nigeria, smoked fish are not properly packaged and hence they are sold within a short period. This has made smoked fish business to remain at a small scale level in the country.

Appropriate packaging is necessary to maintain the quality of fishery products and customer satisfaction. Various types of packaging made up of different materials design and sizes are used all over the world on board vessels during processing, transportation, storage, retail and display. An effective fish packaging material should be able to reduce oxidation and dehydration, provide less bacterial and chemical spoilage, prevent odor

permeation and protect the product from physical damage [4]. The importance of effective packaging materials design should be one with water vapor barrier that will protect the stored products from gaining moisture. In most climates especially in the tropics, the transmission of water vapor will tend to be from the outside to the inside of the hold walls as the external temperature is likely to be higher than the internal temperature [18].

Packaging materials available in Nigeria for dried/smoked fish include jute bags, mat bags, baskets, sacks, paper cartons, wooden rackets, cane and baskets. These materials only serve to hold the products during handling, transportation and storage but offer little protection to the microbial, chemical, dust and insect attack [12].

The principal requirement of packaging is to deny access to insect and to prevent rehydration and consequent increase in water activity leading to microbial spoilage. However, research has shown that packaging materials used for packaging smoked fish in Nigeria offer little protection for the dried fish, as they suffer microbial infection, insect attack and nutrient loss. Furthermore, contamination from dust, the non flexibility and cost of some of these materials make them not ideal for packaging of smoked fish [8, 17].

The objective of this study was therefore to develop appropriate packaging materials produced from locally available materials that can extend the shelf life of smoked catfish.

2. Materials and Method

2.1 Selection of Materials for Packaging

A preliminary study was carried out to investigate the types of materials used for packaging of dried fish in Nigeria. Information obtained revealed that, jute bags, mat bags, cartons, baskets, wooden boxes, earthen pot, paper and polyethylene materials were prominent. These materials ranked in the order of preference as follows: Polyethylene>Paper>Carton>Jute-bags>Mat-bags>Baskets>Wooden boxes>Earthen pot [13]. Based on this, paper and polyethylene were selected and used for the production of composite packaging material.

2.2 Development of Composite Materials

Composite packaging materials were made from Polyethylene and paper. The materials were then laminated (putting layers of polyethylene on both surfaces) using Linea DH -650 laminating machine.

The packaging materials used were labeled as follows:

1. $P_eP_aP_e$ – Polyethylene Paper Polyethylene Packaging
2. P_eP_a – Polyethylene Paper Packaging
3. P_aP_e – Paper Polyethylene Packaging
4. C – Polyethylene – As control.

2.3 Determination of Engineering Properties of Packaging Materials

The two properties that were determined are the water absorption rate and oil absorption rate being important factors affecting the quality of smoked fish during storage. Other properties measured were thickness (with the aid of a micrometer screw gauge) and the opacity using visual inspection

2.3.1 Determination of Water Absorption Rate

The water absorption rates of the packaging materials were determined in accordance with BS 6504. Samples were immersed in water and the weight gain after 1 hour recorded. Water absorption was calculated from the measurement using Equation 1.

$$W_{AR} = \frac{W_f - W_i}{ATW_i} \quad (1)$$

Where, W_{AR} is the water absorption rate (g/cm^2/min)
$W_f$is the final weight (g),
W_i is the initial weight before immersion (g),
A is the surface area of the immersed material (cm^2), and
T is the time of immersion (min.)

2.3.2 Determination of Oil Absorption Rate

The oil absorption rates for the packaging materials were determined using method BS 6504. Packaging materials were immersed in oil and increase in weights was determined after one hour. The oil absorption rate was calculated using Equation 2.

$$O_{AR} = \frac{M_f - M_i}{ATM_i} \quad (2)$$

Where;
O_{AR} is the water absorption rate (g/cm^2/min),
M_f is the mass of the immersed material (g),
M_i is the mass of the material before immersion (g),
A is the surface area of the material in cm^2,
T is the time (min.)

2.4 Drying and Packaging of Fish

Catfish (*Clarias gariepinus)* of six months age harvested at Kano State Department of Fisheries, Wudil, were killed, gutted, cleaned, salted, weighed and dried in an improved smoking kiln developed by Olayemi *et al*. 2013 [14]. After drying, the smoked dried catfish were removed from the smoking kiln cooled and packed in each of the four packaging materials in three replicates. The samples were then stored in a shelf under ambient condition for six months.

2.5 Proximate Analysis

The proximate and sensory analyses were carried out for the initial quality of the dried fish before storage. The proximate analysis was determined using methods described by AOAC (2002) [1]. The Nitrogen Free Extract (NFE) was determined using equation 3.

$$NFE\ \% = 100 - X_w - X_p - X_c - X_f - X_a \quad (3)$$

where;
X_w = Moisture content %
X_p = Protein content %
X_c = Carbohydrate content %
X_f = Fat content %
X_a = Ash content %

2.6 Sensory Analysis

Sensory evaluation of the smoked dried samples of catfish in the different packaging materials were carried out using 10 man trained panels for smell, taste, color , texture and general acceptance on 9 points hedonic scale with score 9 having excellent attraction. Necessary precautions were taken to prevent carry-over flavor during the tasting by ensuring that

the panelists passed a piece of lemon fruit in their mouths after each stage of sensory evaluation. Thereafter the qualities were monitored on monthly basis for a period of six months.

2.7 Data Analysis
The measured engineering properties were carried out in triplicates as well as the quality parameters determined in the laboratory. The differences between mean values were calculated using Analysis of variances (ANOVA) and statistical differences were reported at $P < 0.05$.

3. Results and Discussion
3.1 Effect of Composite Lamination on Engineering Properties of Materials
Table 1 shows the engineering properties of the materials used. $P_eP_aP_e$ has the least value of water and oil absorption rates compared with P_eP_a and P_aP_e except for the control which has lower values. These properties enhanced the keeping qualities of the dried samples during storage.The thicknesses values ranged from 0.23 to 0.31 mm which met the standard for partial barrier of at least 0.15 mm for packaging materials as reported by Emblem and Emblem (1996) [6].

3.2 Effect of packaging on the proximate composition of the stored fish
The values of the percentage protein, NFE, crude fibre, ash and the moisture content of the smoke dried fish during the storage period are shown in Table 2.
Generally, the moisture contents of the smoke dried catfish stored in the different packaging materials increased with increase in storage period for the first four months and decreased from the fifth month of storage. This was due largely to the interaction of the environment with the packaging materials. In the first four months (June-September) being raining season the environment was humid thus causing absorption of moisture by the dried fish from the environment. However, as soon as dry season sets in (October-November) the fish lost some part of this moisture. Although P_eP_a has the highest value of moisture gained (3.5%) there was no significant difference ($p< 0.05$) in the values recorded for all the packaging materials used. This suggests that there the marginal increase in moisture is due largely to environmental effect which is in line with the findings of Daramola *et al.* 2007 [5] there is increase in moisture content of stored dried fish due to environmental effect.
The protein content of the stored fish generally decreased with storage period. However, there was no appreciable loss in protein content for all the samples. This suggests that the packaging materials were efficient in maintaining the protein content of the smoked fish. The protein content also increased with increase in NFE which confirms the findings of Kumolu-Johnson *et al*. (2010) [9].
The ash content generally decreased with storage period. This is in contrast to the findings of Cardinal *et al*.; (2001) who observed that relative and significant increases occurred in ash content of smoked fish samples during storage period. This may be due to the packaging materials used as it was observed that $P_eP_aP_e$ and the control have the least value of 5.2% and 5.1% respectively after six months of storage.

3.3 Effects of packaging on the sensory properties of the stored fish.
The sensory evaluations show that the ratings ranged between 3.83 and 7.17 on hedonic scale of 9. $P_eP_aP_e$ packaging materials ranked best and was the most accepted of all the four packaging materials. As shown in Figure 1, the values generally decreased with storage period. However, the trend shows minimal variations for the fish in $P_eP_aP_e$ with the fish stored in $P_eP_a$showing the most variation. This observation may be due to the high rate of water and oil absorption of P_eP_a which influenced the quality of the fish during storage. The observed trends also suggest that packaging of dried fish in $P_eP_aP_e$ can keep the fish in good quality over a relatively long period confirming the observation made by Masoomeh *et al*. 2010 [10]. It was also observed that the catfish stored in the control had the least means values of general acceptance. This might be due to the transparency nature of the materials used as control which enhances light interaction with the stored fish.

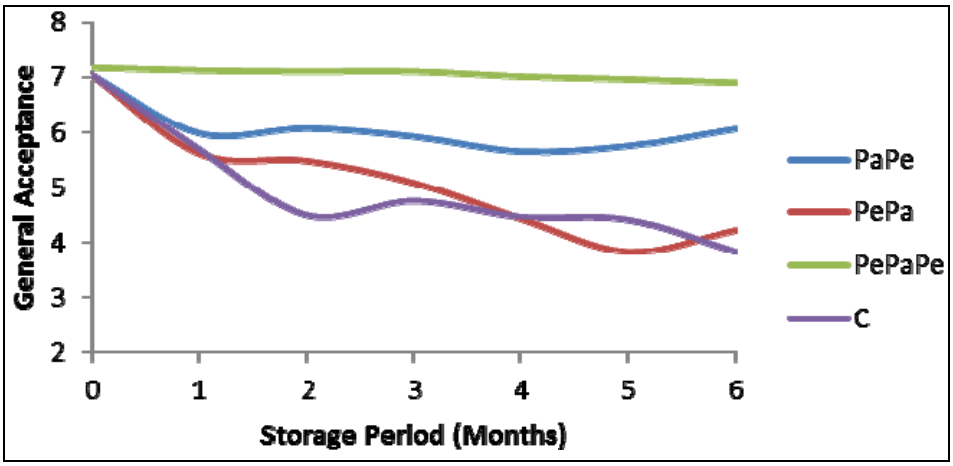

Fig 1: Variation in General Acceptance of Smoked fish during storage.

4. Conclusion
This study established that packaging materials with improved characteristics in terms of engineering and chemical properties can be developed from locally available materials in the market. Combining the materials increased the strength of the materials while limiting their weaknesses. The use of the packaging materials improved the storability of smoked dried fish by increasing the shelf life from about one month to between four and six months in good quality.
Packaging materials used in this study could be used to

package smoked catfish to improve its marketing on the shelves in super markets with proper labeling. This development will not only lead to improvement of the value chain of fish but provide additional business opportunity for investors. This will further enhance the export value of processed fish, reduce the risk of damage and guaranteed quality smoked fish to consumers.

Table 1: Engineering Properties of the Composite Packaging Materials

Packaging Material labels	Thickness (mm)	Water Absorption Rate ($g/cm^2/min$)	Oil Absorption Rate ($g/cm^2/min$)	Opacity
P_aP_e	0.23	5.168	10.857	Opaque
P_eP_a	0.23	10.000	7.418	Opaque
$P_eP_aP_e$	0.31	1.730	2.500	Opaque
C	0.27	0.360	0.280	Transparent

Table 2: Nutrient Composition of Smoked fish stored in Composite Packaging Materials

Packaging Material	Storage Period (Months)	Proximate Composition					
		Protein	NFE	Fat	Ash	Crude fibre	Moisture content (%wb)
P_aP_e	0	68.4	3.6	12.5	6.4	1.8	7.3
	1	68.5	1.9	12.3	6.1	2.1	9.1
	2	68.6	1.5	11.2	6.7	2.4	9.6
	3	68.1	0.8	11.6	6.8	3.1	9.6
	4	66.2	3.2	11.7	5.8	2.9	10.2
	5	63.9	5.2	11.4	5.8	3.1	10.6
	6	63.3	6.2	11.4	5.6	3.2	10.3
P_eP_a	0	68.4	3.6	12.5	6.4	1.8	7.3
	1	68.4	3.6	11.2	6.0	2.4	9.2
	2	68.2	2.8	11.3	6.1	2.8	9.9
	3	67.5	2.9	11.8	6.9	3.0	9.9
	4	63.8	6.8	11.6	6.4	3.1	10.3
	5	64.8	5.6	13.6	5.9	3.3	10.8
	6	64.5	6.9	13.7	5.9	3.6	9.4
$P_eP_aP_e$	0	68.4	3.6	12.5	6.4	1.8	7.3
	1	70.2	1.9	11.8	6.1	2.7	7.6
	2	71.1	1.6	10.8	5.8	2.6	9.1
	3	70.6	1.1	11.2	6.0	2.4	9.5
	4	70.4	1.4	10.4	5.2	3.4	9.2
	5	69.4	1.6	10.1	5.1	3.4	9.4
	6	69.4	1.3	11.6	5.2	3.2	9.3
Control (polyethylene)	0	68.4	3.6	12.5	6.4	1.8	7.3
	1	68.9	3.8	12.4	6.2	2.3	8.4
	2	65.3	4.2	12.3	5	2.8	9.9
	3	65.5	6.2	12.5	5.8	3.4	9.6
	4	62.1	7.0	12.5	5.0	4.6	9.9
	5	62.1	7.4	12.3	5.9	4.8	10.5
	6	62.8	8.9	12.6	5.3	3.7	9.1

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