SHELF-LIFE AND QUALITY CHARACTERISTICS OF SMOKED CATFISH (*Clarias gariepinus*) STORED IN COMPOSITE PACKAGING MATERIALS

BY

OLAYEMI, FOLINE FOLORUNSHO
B. Eng. Agric. Engineering (Zaria), M.Sc. Agric. Engineering (Ibadan)
MATRIC NO.: 36912

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ABSTRACT

Smoking and drying are major methods of processing and preserving fish in Nigeria. However, inadequate packaging using cartons, baskets, jute and mat bags with transparent polyethylene are the most common which offer little protection against external agents and has been a major challenge. There is dearth of information on the developments of appropriate fish packaging thereby limiting fishery preservation to small scale business. The use of composite packaging materials for storage of smoked catfish were investigated. Packaging materials were laminated into six opaque composite packages: Polyethylene-Cardboard (PC), Cardboard-Polyethylene (CP), Polyethylene-Cardboard-Polyethylene (PCP), Polyethylene-Paper (PP_a), Paper-Polyethylene (P_aP) and Polyethylene-Paper-Polyethylene (PP_aP) and Polyethylene (P) as control. Thickness, weight, Impact Resistance Weight (IRW), water and oil absorption rates of the packaging materials were determined using standard methods. Catfish (*Clarias gariepinus)* of six months age harvested at Kano State Department of Fisheries, Wudil, were killed, gutted, cleaned, salted, weighed and dried in a smoking kiln. Proximate, microbial and sensory analyses (9 Hedonic scale) of dried catfish were determined at the start of the experiment and monthly for six months in storage under ambient conditions. Data were analyzed using descriptive statistics and ANOVA at $p = 0.05$.

The thicknesses of the composite materials ranged from 0.23 to 0.46 mm while control was 0.27 mm. The weights and IRW ranged from 15.0 to 34.7 g and 25.0 to 50.0 g for the composite respectively, while the corresponding results for control were 18.9 g and 35.0 g. The water and oil absorption rates for the composite were 0.8 to 10.0 $g/cm^2/min$ and 2.5 to 10.9 $g/cm^2/min$, while the control had 0.3 and 0.4 $g/cm^2/min$ respectively. The crude

protein, moisture content, fat, ash and crude fiber of the fish (332.48 ± 62.91 g) stored in the composite ranged from 65.7 to71.9 %; 8.8 to 10.5 %, 11.0 to 12.2 %; 5.3 to 6.3 % and 2.5 to 3.3 %, while their corresponding values in the control were 64.4 %, 9.6 %, 12.4 %, 5.7 %, 3.6 % respectively at six months as compared to their baseline values of 68.4 %, 7.3 %, 12.5 %, 6.4 %, 1.8 %. Total bacterial and yeast/mould counts of the stored catfish in composite were from 10.0 x 10^{-4} cfu/g to 16.0 x 10^{-4} cfu/g and 5.0 x 10^{-4} cfu/g to 19.0 x 10^{-4} cfu/g; while that in the control were 18.0 x 10^{-4} cfu/g and 17.0 x 10^{-4} cfu/g respectively at six months. The baseline values for total bacterial and yeast/mould counts were 2.0 x 10^{-4} cfu/g and 0. The overall acceptance scores for samples in composite ranged from 4.8 to 7.0, while that of control was 4.6 with baseline value of 7.0. Fish stored in PP_aP and PCP had best results in crude protein, moisture content, fat, ash, crude fiber, total bacterial, yeast/mould count and sensory evaluation for the stored catfish. PP_aP and PCP packages maintained the quality attributes of stored catfish compared to others. Their usages would not only add-value to fish business in Nigeria but improve market integrity.

Keywords: Fish processing and preservation, Smoking kiln, Charcoal, Storage, Fish quality assessment.

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CERTIFICATION

We certify that **Olayemi, Foline Folorunsho** carried out this research work in the Department of Agricultural & Environmental Engineering, Faculty of Technology, University of Ibadan, Ibadan, Nigeria.

Supervisor
Dr. A. O. Raji
B.Sc. (Hons.), M.Sc. (Ibadan), Ph. D. (Newcastle-upon-Tyne)
MNSE, MNIAE, MASABE, MNIFST, R. Engr. (COREN)
Reader
Department of Agricultural and Environmental Engineering
University of Ibadan.

Co-Supervisor
Dr. O. A. Oyelese
B.Sc., M.Sc., Ph. D (Ibadan), PGDE (Jos)
Department of Aquaculture and Fisheries Management
University of Ibadan.

DEDICATION

To my Boss and Mentor

Deacon J. S. Opadokun

That advised me to obtain my Ph. D.

To my beloved brother and friend

Pastor Femi Akande

That kept reminding me of this advice.

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INTRODUCTION

1.1 Background Information.

The importance of fish in the developing world cannot be overemphasized as it is a source of food and income to many people. In Nigeria, fish production has been increasing as a result of the expansion of the aquaculture industries brought about by various developmental programs of the government to encourage private sector participation, thereby making fish protein available to the teeming populace. With increase in fish production, there will be the need to process excess to prevent post harvest losses. Processing will not only add values to the products but also extend their shelflife.

Shelf life is defined as the period of time a product is fit for consumption; it is a relatively short period for fresh fish stored under refrigerated conditions (12 days). The limit of the shelf-life which can be determined based on sensory, chemical and microbial criteria is affected by the rate of enzymatic reactions and the number and species of microorganisms affecting the products storability. Other determining factor is the handling temperatures which must be evaluated throughout the processing stages (Leistner, 1995 and Chowdburg *et al*., 2007).

Various traditional methods had been employed to preserve and process fish for consumption and storage in an attempt to extend its shelf life. These include smoking, drying, salting, frying, fermentation and combination of these. In Nigeria, fish smoking is

the most widely practised method. Practically, all species of fish available in the country can be smoked. It has been estimated that 70 - 80 % of domestic marine and freshwater catch is consumed in smoked form. The advantages of smoking fish are manifold. Fish smoking prolongs shelf life, enhances flavour and increases utilization in soups and sauces. It reduces wastages in time of bumper catches and/or harvest and allows storage for the lean season. It also increases protein availability to people throughout the year and makes fish easier to handle (pack, transport and market) (Akinola *et al*., 2006).

Research and developments in fishery in Nigeria have been in the areas of production and processing with little or no attempt on the packaging of the processed products. The packaging materials in use are still the indigenous ones that are not attractive, prone to easy entry of insects and rodents, thereby of no international appeals. The packaging materials only serve to hold the fish products during handling, transportation and storage but offer little protection to the products from microbial, chemical, moisture intake, dusts and insect pests (Okonkwo *et al.,* 1991). Fish products are highly prone to rapid deterioration due to the permeability of the atmospheric conditions such as oxygen, nitrogen, carbon dioxide, light and water vapour, and these have exposed the fish consumers to health hazards while the marketers suffer monetary losses. According to Normall (2007) many countries producing and processing fish have tried to develop effective packaging materials using the available materials that will provide the two main functions of advertising the food at the point of sale and protecting it to a pre-determined degree for the period of the expected shelf life.

Development of fishery industries in Nigeria to ful capacity, and Nigeria having her share in the international markets entail that, all the value chains from production to consumption be fully identified and developed. Packaging which is an end and seal to

value addition must be given necessary consideration and attention for the full development of our fisheries business.

1.2 Statement of Problem

One of the major ways of adding values to fish in the Tropics is by smoking and drying. Various attempts have been developed by various researchers in this area. A well dried fish product will go bad if it is not well packaged because of its hygroscopic nature and easy ability 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 the production of smoked fish to remain at a small scale business level in the country. Though much effort have been made in the area of fish dehydration in Nigeria, there is no visible attempt made so far to address the area of fish packaging which gives a seal to dried products. The effects have been monetary, health and integrity losses in fish production to the country. Packaging plays an important role in safeguarding the health of consumers by protecting and preserving the food product in storage. The food quality can be impaired when packaged due to inadequate package integrity, poor barrier properties or lack of compatibility. Also poor design and handling of the conventional and non-conventional smoking kiln could be a problem .

Migration or transfer of residue from materials used for packing to the food product and / or from the environment through the material can cause packaged food to be unacceptable for human consumption (Galic *et al.*, 2009). Apart from the health hazard occasioned by improper packaging, most exported fish products to the United Kingdom were rejected and declared unfit for both human and animal consumptions. This study was carried out to assess the effectiveness of using different composite packaging materials for

the storage of smoke-dried catfish under ambient conditions with the aim of gaining acceptance both locally and internationally (Musa *et al*., 2010).

1.3 Research Objectives

The main objective of the study was to investigate the storage of smoked catfish as affected by different composite packaging materials with a view to improving its quality, extend the shelf life and safeguard the health status of the consumers.

The specific objectives were:

i. To determine some engineering properties of the packaging materials used for storage of smoke-dried catfish.
ii. To design, construct and evaluate the fish smoking kiln used for this study.
iii. To determine the shelf life of the smoke-dried catfish stored in some composites and known packaging material.
iv. To determine whether the use of the composite materials are much better than the usual practice of polyethylene material in the storability of smoke-dried catfish.

1.4 Justification of the Study

There is increase in the number of fish farms in the country with the private sector driven aquaculture industries. Many of these farms raise catfish as the main species. The reason for this is that catfish is widely distributed, thrives in diverse environment, hardy and widely acceptable. It feeds on a wide array of natural prey and can adapt it feeding habits depending on food availability. Recent production data shows that the aquaculture industry in Nigeria produced about 825,000 metric tonnes of fishery products in 2010 (FAO, 2012). There is the need to add value to fish produced in order to sustain

production, through various processing methods and develop appropriate packaging materials that will meet local and international market standards.

In Nigeria, a major problem in fish processing and preservation industries is poor packaging materials for finished fish products. Packaging protects, preserve and provide additional mechanism for marketing products by improving shelf life, freshness and quality. Knowledge of the kinds of deteriorative reaction that influence food quality is the first step in developing food packaging that will minimize undesirable changes in quality and maximize the development and maintenance of desirable quality. Appropriate packaging is necessary to maintain the quality of fishery products and consumer acceptance. It is therefore desirable to have adequate knowledge of the function of packaging and the environment where it has to operate so that optimization of package design and the development of cost – effective packaging can be achieved.

1.5 Scope of Study

i. Survey, selection and construction of effective packaging materials for smoke-dried catfish.
ii. Determination of some engineering properties of packaging materials.
iii. Construction of an effective fish smoking kiln for the smoking and drying of catfish.
iv. Packaging and storing of smoke-dried catfish in various packaging materials over a period of six months.
v. Determination of proximate composition (initial and final), microbial and sensory evaluations of the smoke-dried catfish stored in different packaging materials under ambient conditions.

1.6 Expected Contribution to Knowledge

i. After this study, It is expected that the outcome of this study would develop an effective process for the preservation of smoked catfish under healthy condition.

ii. This process development will involve handling from harvesting, pre-drying, drying, packaging and storage.

iii. Furthermore, the study will improve the shelf-life of smoked catfish, thereby reducing waste, improving the income for the producers and scaling up the fishery business from small scale.

iv. It is also expected that the quality standard of smoke-dried catfish to be produced will meet international standard, thereby increasing our foreign exchange earnings.

v. Development of dried fish primary packages for local and export markets.

CHAPTER TWO

LITERATURE REVIEW

2.1 Fish

The term fish is defined as all fresh or salt water finfish, mollusc, shelf fish, crustaceans and other forms of aquatic animal life. The fish trade has grown significantly over the last decade due to improvement of technology, transportation, communication and sustained demand. Fish can be classified into 3 categories of marine, fresh water and aquaculture (Eyo, 2001). 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 as reported by FAO (1985). In Africa, 17.5 % of the animal protein intake comes from fish while in Nigeria, the proportion is 40 % (William and Denis, 1988). An estimated 20 to 50 % of the fish produced in the remote coastal centres and hinterland of many tropical countries perish before they get to the consumers due to poor handling, preservation and processing practices adopted by the artisanal fisherman, fish farmers and fisheries entrepreneurs. Though much attention is being paid to fish preservation to extend its shelf life and improve fish quality, adequate interest must be shown in the technology of fish processing to meet consumers' taste and thereby enhance fish utilization and improved marketing of the catch (Eyo, 2001).

The Nigeria policy has now seen the potential in fish development through aquaculture practise, taking into cognisance the high water availability in the country. The campaign for higher fish production is not only to improve in the protein intake in the

country but also to increase employment generation and improve on the national foreign exchange earnings (Iliyasu *et al*., 2011).

Responding to the national call, many Nigerians have started serious aquaculture practices by establishment of various man-made ponds, reservoirs and cages. Majority of fish farmers' farm in catfish (*Clarias garieppinus*). The reason for this is that it is one of the most ideal aquaculture species in the world. It is widely distributed, thrives in diverse environment, and is hardy, acceptable and an ecological pioneer species. It feeds on a wide array of natural prey and can adapt its feeding habits depending on food availability. It has the ability to withstand adverse environmental conditions and has a wide tolerance for relatively poor water quality conditions in which other fresh water fishes would find it difficult to survive. The hardiness of the catfish makes it an ideal candidate for highly intensive culture, without prerequisite pond aeration or high water exchange rates (VASEP, 2005). Fish is highly susceptible to deterioration immediately after harvest. Immediately fish dies a number of physiological and microbiological deterioration sets in which reduces the quality of the fish (Okonta and Ekelemu, 2005). Because of the perishable nature of fish, it requires proper handling and preservation to increase its shelf life and retain its quality and nutritional attributes. The first obvious way to avoid spoilage and loss of quality is to keep harvested fish alive until cooking and consumption (FAO, 2005). Immediately after a catch, a complicated series of chemical and bacteria changes begin to take place within the fish and if not controlled, the fish may be spoilt within 12 hours at tropical temperature. Out of the 128.8 million tons of fish production about 20 million tons are lost due to inability to transform the freshly harvested fish into stable acceptable products and to distribute these products to the people who need them in good quality and affordable prices (FAO, 2005).

Tawari and Abowei (2011) reporteded that the time lapse between lifting of the nets and delivering to the store can vary with distance that needs to be covered. Storage of the fish is usually at the bottom of canoe exposed to warm and dirty water. Most fishing communities do not have ice-storage facilities, hence the daily catch is either sold fresh or smoke-dried before spoilage sets in. Traditional ovens and kilns with low batch capacities and long smoke-drying times are no match for the heavy fish that are harvested during the peak season.

Harvested fish should be processed in order to reduce wastage, retain quality and increase shelf life (Wongwichan *et al*., 2009). A number of methods are used to preserve fish. Some of these techniques are based on temperature control using ice, refrigeration, freezer and others which involve the control of water activities which include drying, salting, smoking, freeze-drying and combination of different techniques (FAO, 2001). Some of the infrastructural challenges in Nigeria include erratic power supply and poor road network particularly in the fishing areas; hence, control measures in the form of dehydration, salting and smoking are most practiced. Abolagba and Enofe (2003) examined the various indigenous technologies in postharvest fishery operations in Edo and Delta States. It was reported that the commonest method of fish preservation and processing practiced was smoking using Chorkor smoking kiln and drum smokers with firewood as the energy source. They observed that a lot of fish is still being lost due to lack of proper storage and unhygienic handling and packaging during and after smoking.

Kolawole *et al.* (2010) investigated indigenous fish preservation practices among women at Epe division in Lagos State. About 52.5 % of the women solely engaged in fish processing and preservation while 47.5 % combined it with other income generating businesses. Salting, sun-drying, smoke-drying and frying were the most popular

processing and preservation techniques utilized by the women, while 55 % utilized 3 to 4 of these methods. The study identified lack of storage facilities, inadequate capital, smoke pollution, transportation problems and low sales of products as the major constraints.

Davies and Davies (2009) evaluated the status of fish storage technologies in Niger Delta area of Nigeria. They observed that traditional fish storage were predominant (97.7 %) while the modern fish storage techniques in use were 2.1 %. The modern fish storage facilities used were freezer (57 %), cold room (32 %) and refridgerator (11 %). The fish storage technologies adopted by the traditional fish storage operators were generally inadequate with resultant losses. The cost of maintenance and services of the modern technologies were very high compared to traditional storage technologies. Majority of the traditional fish storage operators used thatched houses (61 %), hanging of processed fish on roofs huts (3 %), eaves of houses (1.5 %), kitchen roof (3 %), smoke houses (8 %) and rack (5 %). It was also discovered that fish were packaged in woven bags, jute bags, wooden trays, raffia baskets, plastic bags, sturdy boxes, wooden crates and boxes. Abolagba and Nuntah (2011) carried out a survey on cured fish processing, packaging, distribution and marketing in Edo and Delta States. It was revealed that processors were mainly married women with education not beyond secondary school. Smoking was the main curing method used and storage materials for the cured fish were baskets, jute bags, paper bags and plastic drums. Cases of losses of cured fish include insect infestation, rodent attacks, mould attacks and breakage due to packing material and compression.

The investigation carried out by Ibrahim *et al.* (2011) accessed the productive resources among women fish processors in Lake Feferewa fishing community of Nasarawa State, Nigeria. The reason for their involvement in fish processing is to generate income for payment of children's school or medical fees. Results revealed that 62 % of the

women had access to fish processing facilities, 28 % had access to extension services and training, 12 % had access to capital, only 4 % had access to modern technologies while 6 % of them had access to rural institutions. Their major constraints were lack of collateral to obtain bank loan, lack of fish processing facilities, inadequate extension services and inadequate fish storage facilities. The occupational hazards were redness and swelling of eyes.

The processing pattern of fish in the North Western Nigeria is in contrast to other zones as men are the main processors (89 %) as reported by Bolorunduro *et al.* (2005). It was also observed that 43.1 % were aware of improved fish smoking kiln disseminated in the zone with about 32 % adopting one kiln or the other. Improved smoking kiln disseminated include Chorkor, Altona, Burkinabe and Watanabe. The major constraints were scarcity of improved kilns, high cost of kilns when available, difficult technical feature of the kilns and insufficient awareness creation by the ADPs. Akinola *et al.* (2006) and Ojutiku *et al.* (2009) evaluated the traditional methods of fish smoking, solar drying and drying using Chorkor. Solar dryer and Chorkor gave better product quality in terms of dryness and dust free products. However, traditional methods still remain the predominant fish processing and drying methods in the country.

Akpabio and Ekanem (2008) focused on the extension needs of fish marketers in Akwa Ibom State, Nigeria. Four significant dimension of extension needs identified from their study include; information on value – added management of fish marketing activities, scientific processing method, improved fish handling techniques and innovative fish procurement/selection strategies for both fresh and dried fish marketers. It was observed that the market was dominated by women with the ratio of women to men being 4 to 1. Smoked fish constituted 65 % of fish sold in the market while fresh and live fish

was 35 %. The major problems faced by the marketers were erratic power supply of electricity, inadequate storage facilities and stall to display the fish products.

Eyo (2001) examined the traditional approach to fish handling preservation and processing technology in inland fishery in Nigeria. It was observed that the methods adopted by the artisanal fishermen lead to wastage through spoilage during handling and poor quality products during preservation. It was suggested that efforts should be made by the fisheries researchers and extension workers to improve on the current traditional methods.

The review of the current trend in fish processing and preservation in Nigeria showed that fish smoking is the most prominent method of fish preservation which is carried out mainly by women folks with exception of Northwestern zone of the country. The reason for the disparity might be due to the cultural / religious beliefs which do not allow the women folk exposure to the public. Majority of the fish smoking kilns and ovens are operated in the open air due to heavy density of smoke; hence, the adoption is not in line with their culture and religious beliefs (Flowra, *et al*. 2010). The different fish processing methods have various challenges as highlighted above. However, the processing method to be delivered in this study will not only improve the effectiveness of the smoking operation but return the business to the women folks in all the zones of Nigeria.

2.2 Shelf Life of Agricultural Products

Shelf life of food can be defined as the length of time a food product may be stored without becoming unsuitable for use or consumption. Also shelf life can be defined as the length of time that food, medicine and other perishable items are given before they are considered unsuitable for sale or consumption. In some regions, a 'best before', 'use by' or freshness date is required on packaged foods. Shelf life study are used by food and consumer products industry to determine and validate the length of time a product will retain its quality under a certain set of storage conditions. The shelf life of a food product is used to ensure the safety and quality of products prior to consumer release. During the shelf life of a food, it should be safe to use, retain anticipated quality traits that are known of the product and contain the nutritional compositions that are indicated on the labels (Gyesley, 1991; Gould, 1996; Vongsawashi *et al*., 2008). The maintenance of food's quality depend on a number of factors which include the quality of the raw product, the way the food was processed, storage method and conditions (packaging, temperature and humidity). Also factors that influenced shelf life are initial microbiological quality, season and handling which vary from fish species to species (Abba *et al*., 2009). Therefore, to ensure that product meets high standard, one should use highest quality raw material, establish and pursue good processing techniques and maintain an appropriate product environment after processing. The recommended storage time in the form of shelf life is determined using these considerations as reported by Patterson and Ranjitha (2009).

The principal mechanism involved in the determination of processed food quality is to give the microbiological spoilage sometimes accompanied by pathogen development, chemical and enzymatic activities causing lipid breakdown, colour, flavour and texture changes and moisture and/or other vapour migration producing changes in texture, water

activity and flavour. The storage conditions necessary for shelf life of agricultural products are as follows:

a) Temperature - Excessive temperature is damaging to food storage. With increase in temperature, protein breakdown and some vitamins will be destroyed. The colour, flavour and odour of some products may also be affected. It was recommended that food should be stored at room temperature or below and not at attic or garage to enhance its shelf life.

b) Moisture - Excessive moisture can result in product deterioration and spoilage by creating an environment in which microorganisms may grow and chemical reactions can take place.

c) Oxygen - The oxygen in air can have deteriorative effects on food colours, vitamins, flavour and other food constituents. It can cause the conditions that will enhance the growth of microorganisms.

d) Light - The exposure of food products to light can result in deterioration of specific food constituents such as fats, proteins and vitamins resulting in discolouration, off-flavour and vitamin loss.

Labuza and Breene (1989) observed that food products packaged in transparent films can deteriorate during retail light display due to change in sensitive pigments or lipids. Oxidation of the constituents leads to fading or discolouration and off-flavour development. They observed that foods are diverse, complex and active systems in which microbiological, chemical, enzymatic and physiochemical reactions can simultaneously take place, evaluating shelf life is thus an arduous task. Maintenance of quality and safety is dependent on the understanding of these reactions, the influence of the environment and

successful limitation of the ones most responsible for spoilage or loss of desirable characteristics (Prakash *et al*., 2011).

Konstantino (2001) developed mathematical model for shelf life prediction based on the knowledge of the product spoilage mechanisms. It was discovered that for fish and fish products, spoilage is caused by a fraction of the total fish micro flora, the specific spoilage organisms. Temperature is one of the most important factor influencing microbial growth, modelling the growth which is a function of temperature is essential in shelf life prediction.

A shelf life study is an objective methodical means to determine how long a food can reasonably be expected to keep for without any appreciable change in quality. New Zealand Food Standard (2005) developed two methods for determining shelf life of agricultural products. These are direct and indirect methods. The direct method which is the most commonly used involved storing the product under pre-selected conditions for a period of time longer than the expected shelf life and checking the product at regular interval to see when it begins to spoil. The steps in direct method are as presented in Figure 2.1.

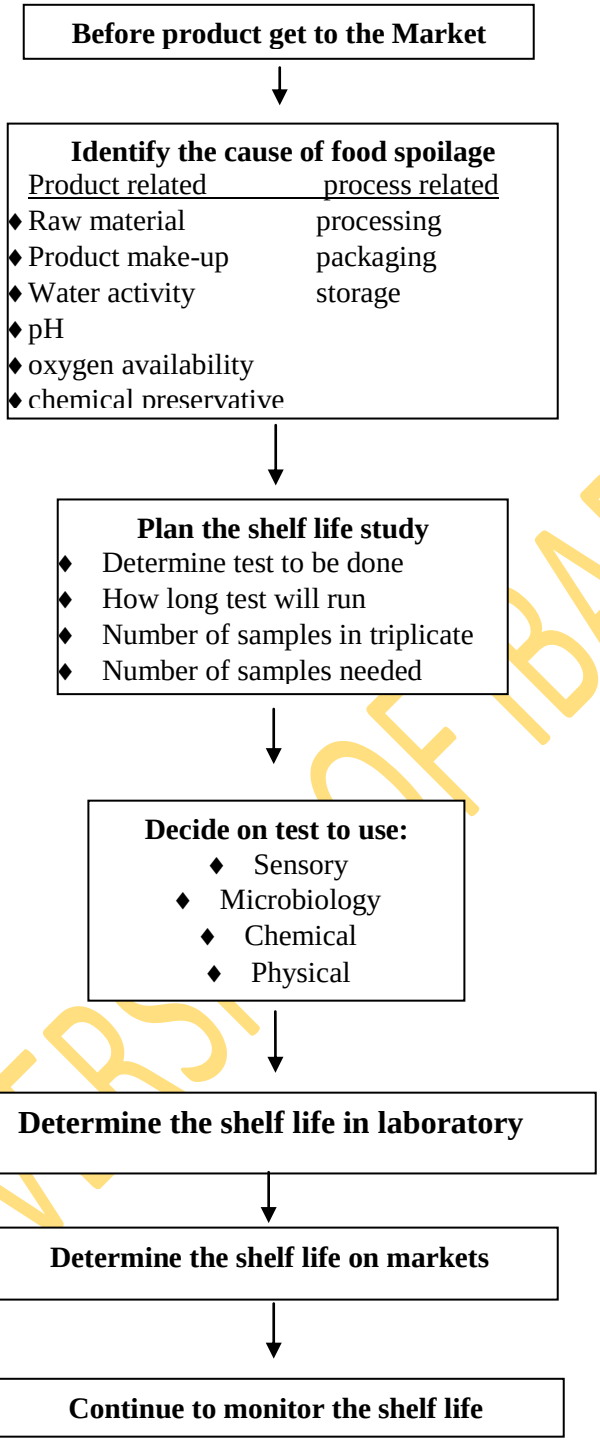

Figure 2.1: Direct Method of Determination of Shelf Life of Agricultural Products.

(Source: New Zealand Food Standard, 2005**)**

Shelf life studies are used by the food and consumer products industry to determine and validate the length of time a product will retain its quality under a given handling condition. Majority of the packaged food in the country are assigned shelf life dates without any studies to justify these assertions. Shelf life study even though are complex are essential to determine if a packaged product is safe for consumption, retain the anticipated quality traits and meet the nutritional claims (Smith and Stratton, 2007). Until this is achieved on all our food products we may not be able to meet international standards and product acceptance. This is one of the objectives this study is designed to achieve.

2.3 Food Dehydration

Drying is a mass transfer process consisting of the removal of water or another solvent by evaporation from a solid, semi-solid or liquid. This process is often used as a final production step before selling or packaging of products. It is the process of reducing the amount of water contained in a product in order to considerably reduce the reactions which lead to product's deteroration. This will result in reduction of the water activity of the food product to an extent that will inhibit the growth and development of pathogenic and spoilage microorganisms significantly, thereby reducing enzyme activity and the rate at which undesirable chemical reactions occur. The water is evaporated into the surrounding air by activated energy.

Food drying which is the oldest method of food preservation had been for thousands of years but airtificial dehydration of food dated back only to about two centuries. The removal of most of the water present in a product can extend the shelf life without the need for refrigeration. Drying also reduces the weight and volume of product

to be carried per unit food value, which leads to substantial savings in the costs of handling, transportation and storage of the dried product as compared to the fresh material. However, drying can bring undesirable changes in foods. The shape and size of solid food process changes during drying due to shrinkage. The nutritional quality, color, texture and flavour also change after drying. The extent of these changes depends on the drying methods and techniques used in drying (Chen *et al*., 2008).

Dehydration is a process where some artificial source of heat is provided to take the place of direct exposure to the sun. It is a simultaneous heat and mass transfer operation where the sensible and latent heat of evaporation or sublimation is supplied to the food and water or water vapour move within the food to the evaporating surface and the water vapour is transferred from the surface to the surrounding atmosphere. The mechanism of this transfer is a way of classification of the drying methods which have three distinct categories. The first known as the convective or convention drying method occurred when food is placed in a current of heated air. The second category known as conductive or conduction drying method is when food is placed in contact with the heated surface usually a metal surface. The third category known as radiative drying method occurs when food is exposed to radiant heat and radiation is the main mechanism of heat transfer. Furthermore, the use of microwave, freeze drying and dielectric energy are other new emergence drying methods (Schubert and Regier, 2005).

Various equipment have been developed for dehydration of food products. Such equipment which removes the moisture of products are ususally called dryers, ovens or kiln (Rohm, 2010). Some dryers are intended for solid materials; in these, the material may be loaded into a shelf, tray or moving belt. Another classification is Atmosphere pressure or Vacuum drying. In atomsphere - pressure drying, heat is brought to the

material by circulating air stream, which also carries away the moisture, while in vacuum drying, the material is placed inside a closed chamber, and heat is provided by radiation or conduction from a hot surface. Finally, some are continuous, while others are batch dryers. Continuous drying is desirable for economy in high-volume operations. For small-scale or some limited seasonal operations, batch drying can be appropriate.

The three fundamental parameters required for drying are; the introduction of thermal energy which heat the product, sets the water migrating towards its surface and turning the liquid water into water vapour (Olayemi *et al.*, 2011a). The capacity of the surrounding air to absorb the driving water vapour from the product is dependent on the moisture present in the air before it enters the dryer and on the air temperature. The velocity of the air going over the product's surface must be high; especially at the beginning of the drying process, so as to take away the moisture rapidly.

Drying of food stuff has to occur rapidly to avoid the product going mouldy. But not too rapid to form a crust at the product's surface (if the temperature is too high) which can result in product blackers. In order to dry product properly, the characteristics of the fresh product must be taken into account as well as the expected final product's quality such as texture, colour, and taste.

Whatever the type of dryer used for foodstuffs; it undergoes three phases which vary in time according to the characteristics of both air and product. The drying velocity, product temperature and air humidity content have a distinct effect on these different stages. The first phase is short to non-existent and corresponds to the rise in temperature of the product until it reaches an equilibrium with the air. This is the phase where the product temperature is brought to the drying air temperature. The second phase known as the constant drying air velocity period is the evaporation of the free water on the surface

of the product, which is permanently renewed by the moisture coming from inside the product. The product's temperature is contant. The third phase corresponds to the evaporation of bond water. The free water which migrated from the inside to the outside of the product to be transformed into water vapour has completely disappeared by the end of the second phase; only bound water is left in the product, tightly attached to it. Water no longer evaporate at the surface of the product but inside it. An evaporation front progresses towards the heart of the product. The water vapour is then picked up by the air on the surface of the product. The deeper the front (the thicker product is) the more difficult the water transfer is. In the phase the soluble compounds, brought up to the surface of the product by the movement of the water clog the pores of the product sometimes forms a crust which stops the water transfer towards the ambient air.

2.4 Fish Smoking

Food has been preserved by smoke-curing before the dawn of recorded history. People in all cultures in the world have relied on the smoke curing of fish and meat products for long term storage. Smoking also impacts a desirable flavour, appearance and texture to the products. The process of smoking occur through the use of fire wood containing three major components that are broken down in the burning process known as pyrolysis which is a chemical decomposition by heat into cellulose, hermicellullose and lignin (Brownell, 1983). A preliminary drying period at 30 ^{o}C during which the skin is toughened to prevent subsequent breakage, a smoking and partial cooking period at 50 ^{o}C and final cooking period at 80 ^{o}C. The total time and the proportion spent at each stage will depend on the species, its size, fat content and the kind of product required.

In developed countries where refrigeration and an integrated infrastructure for efficient transportation of perishables are in place, smoking is not a means of fish preservation but used to enhance the flavour of the fish through cold smoking. But in developing countries, hot smoking is still a very important method of fish preservation. In this process, drying is of paramount importance for preservation because it is the high moisture in the flesh of the fish that allows bacterial activity and spoilage (FDA, 1998). Fish smoking has two basic procedures of cold and hot smoking. The hot smoking which is common in developing countries cooks the fish product by the application of heat and smoke. The fish product centre is subjected to a temperature of 176 ^{o}F (80 ^{o}C) for a long period which will enable the protein to coagulate. The cold smoking used in the developed countries only applies smoke to the product at temperature less than 90 ^{o}F (32.5 ^{o}C). The protein constituent in this fish will not coagulate at this condition (Clucas, 1982).

The smoking process requires five basic steps:

a) Preparation of the fish (small and medium fish may be smoked whole) while splitting, filleting, nobbing, or chunking are associated with large fish.

b) Salting or brining

c) Equilibration and drying

d) Smoking and cooling (hot or cold smoking)

e) Product packaging and storage.

The cleaning process is the first operation after the fish is harvested. This involves scaling of the fish and removal of the viscera including the kidney, gills and head of large

fish where necessary. The fish is then cured in salt following an effective procedure to obtain uniformly salted product. A combination of smoke, salt and drying is one of the earliest recorded methods of food preservation. These procedures loosely known as smoking or smoke preservation are successful because they kill food poisoning and spoilage bacteria or render them harmless by altering the chemistry of the environment these storage organisms needs to grow (Hilderbrand, 2000). According to the guidelines suggested by Sankat and Mujaffar (2006), vacuum or modified atmosphere packaged (MAP) hot smoked fish should have at least 3.5 % of Water Phase Salt (WPS) and reach a centre temperature of at least 145 ^{o}F for at least 30 minutes to enable it destroy the harmful pathogen. Traditional methods of smoked fish preservation typically produced high salt and low moisture content products that are not desirable to most modern consumers as reported to Ikenweiwe *et al*. (2010). Commercial processors have therefore adjusted processing conditions to produce the lower salt and moist products. The processing conditions has been standardized, controlled, monitored and documented to disallow the formation of toxic products (Dekker, 2003).

Various mathematical models have been developed to predict salt absorption rate but practical determination by testing has been found to be very effective. The salt absorption rate depends on brine strength, brining time, product thickness, fat content, and species (Gudlaugsson, 1998). Drying of fish requires that moisture be removed from the flesh. Factors which affect the rate of drying are heat, humidity, air velocity, air exchange, flesh characteristics and flesh thickness (Hilderbrand *et al.*, 1992). Drying means that the water is extracted from a substance usually by heating. There are two factors of primary importance during drying; the heat transfer that causes the evaporation of water and the mass transfer of the evaporated water through the substance and subsequently the removal

of moisture away from the surface of the substance itself. The main purpose of drying is to prolong the preservation time of the product. Deterioration of food is caused either by microorganisms or chemical processes. In drying, both of these processes are slowed down or finally stopped altogether depending on how far the drying is carried out with one exception which is oxidation (Hilderbrand, 1999).

The drying time is divided into periods of constant drying rate and falling drying rate. The former period is characterized by the surface of the substance being entirely saturated with moisture at the wet-bulb temperature of the air. The air velocity, temperature and the level of humidity controls the constant drying rate period. During the period of falling drying rate, the surface of the substance is already dry but the evaporation occurs within the fish flesh. The air velocity at this point has less effect and the speed of the drying process is mainly dependent upon the resistance against the water vapour flow to the surface of the substance. At the end, the drying process stops entirely and the moisture content of the fish at that point is called equilibrium humidity and to some extent the temperature (Horner, 1997).

Various heat sources had been developed for fish smoking using force conventional devices like direct gas flame, indirect steam heaters and electronic resistance coil. According to Doe *et al*. (1998), the rate of heat transfer from air to the fish for cooking or drying is directly related to air velocity, air temperature and relative humidity. The rate at which smoke is deposited on fish surface depends on smoke density, air circulation, humidity, temperature, and nature of the fish surface (texture and oil content). Wood smoke composes of millions of microscopic particles which rise like a fog and by vapour. The fog is mostly water, carbon and trace solids. The vapour also contains volatile oil which are released from the wood and furnish the characteristics flavours and

preservative qualities on the product been dried. The choice of wood for smoking varies a great deal with geography and wood types. Experience has shown that hardwood is better than the soft ones (Hilderbrand, 1992).

2.5 Development of Fish Smoking Ovens and Kilns

Improving the effectiveness of traditional methods of fish smoking, different models of improved ovens and kilns were developed in various parts of Africa (Anon, 1996; Bala and Mondol, 2001). Serious development in fish smoking kiln started early 1950s due to the awareness of the shortcomings in traditional oven which stimulated development work in new and improved kilns. Until the end of 1960, the oven most used for smoking fish was cylindrical or rectangular and made of mud or metal. These ovens had considerable disadvantages of low capacity, inefficient fuel usage (firewood), thereby contributing more to forest depletion, the health of the women was at risk because of the effect of the smoke on their eyes and lungs, burnt fingers and exposure to direct heat. The fish smoking procedure was very laborious and poor quality smoked fish was produced. Some of the types used are:

1. Chorkor kiln

This is a rectangular kiln made of mud, cement and block wall of internal dimension of 0.7 m x 0.7 m x 0.7 m. The top is flat to enable the wood frame trays to sit singly against them. This version has two chambers, and each chamber has a centrally placed stoked hole, 38 cm high and 38 cm wide (Plate 2.1). Chorkor kiln originated from Ghana.

Plate 2.1: Improved Chorkor Kiln

Source: Davies *et al.* (2008)

Advantage:

(a) It is fuel efficient.

(b) It is easy to operate and maintain.

(c) Produces evenly smoked fish which fetches a high price in the market.

(d) High batch processing capacity.

(e) Durable if protected from rain.

Disadvantage:

(a) Cost of construction is relatively high

(b) Construction require a little 'technical – know - how'

2. Improved Banda (IMB)

This is a modified traditional rectangular mud type smoking kiln. It has a dimension of 120 cm x 70 cm. The fire box is reduced to 30 cm x 30 cm. It has a damper perforated covered with framed Zinc with chimney. It has 3 trays for fish.

Advantage:

(a) Using this kiln, wood fuel consumption is reduced to 52 % compared with the traditional smoking kiln.

(b) The quality of the smoked fish is also high and acceptable to consumer.

(c) It is less labour intensive.

(d) It is cheaper to construct than most improved kilns.

Disadvantages:

(a) It requires the use of firewood, hence it may not be useful for industrial purpose especially for processing industry.

(b) It requires high technical-know-how and relatively high capital when compared with the traditional kiln.

3. Modified Drum Kiln (MDK)

The kiln is made from a 200 litre capacity metal drum with a length of 90 cm and diameter of 58 cm. The drum is cut open midway (side) using a welding nozzle. The base of the drum is used as the combustion chamber with the fire box measuring 22 x 22 cm cut out from the base. The smoking chamber is separated into 3 compartments 10 cm above the damper. Above the smoking chamber, the kiln cover is attached (Plate 2.2). A metal pipe of 4 cm is incorporated to serve as the chimney at an angle of 40^{o} above the cover.

Advantages:

(a) It is fuel efficient compared with the traditional drum kiln.

(b) Produces good quality fish that command high price and is acceptable to consumers.

(c) It is less labour intensive

(d) It is very simple to construct

(e) It is portable and can be carried on fishing boats

(f) It is cheaper to construct than most improved smoking kilns.

Disadvantages:

(a) Health risks for the processors

(b) Low batch processing capacity

Plate 2.2: Modified Drum Kiln

Source: Davies *et al.* (2008)

4. Altona Kiln

This type of kiln is made up of cement blocks with the top sealed with a slab of concrete, perforated at the centre to serve as a chimney. It has 3 trays of wire gauze placed 1 m apart under which the heat is generated. A metal door flushed over the smoking chamber and fire place. The source of heat can be coal.

Advantages:

(a) It is less labour intensive

(b) High batch processing capacity.

(c) Produces evenly smoked fish which fetches a high price in the market.

(d) It is fuel efficient.

(e) It can be used for industrial purpose

(f) Faster processing time.

(g) Reduction of health risk for the processors.

Disadvantages:

(a) High cost of construction

(b) It requires technical-know-how (Figure 2.2)

(c) It is not portable

5. Multiple Drum Oven

Advantages:

(a) It is less labour intensive

(b) High batch processing capacity

(c) Produces evenly smoked fish

(d) Faster processing time

(e) Reduction in health risks for the processors (Figure 2.3).

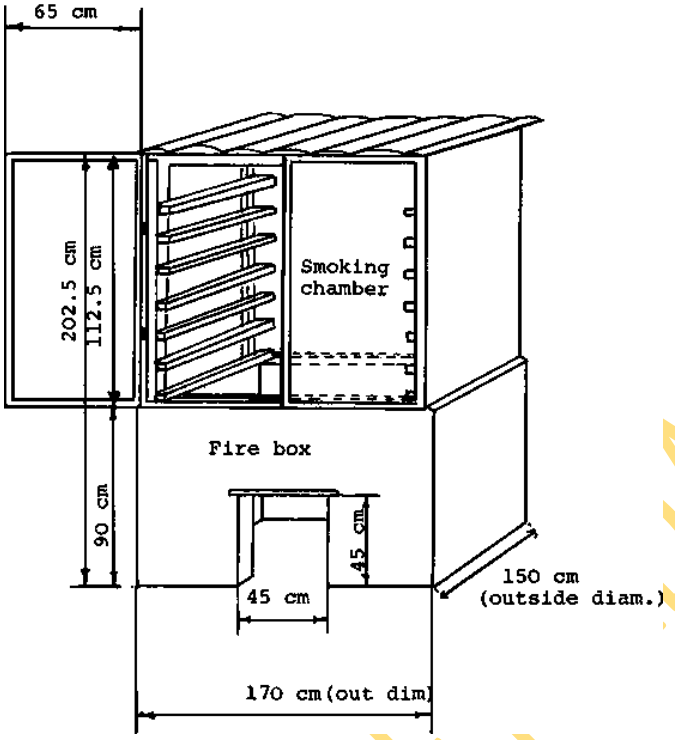

Figure 2.2: Altona kiln

Source: Davies and Davies (2009)

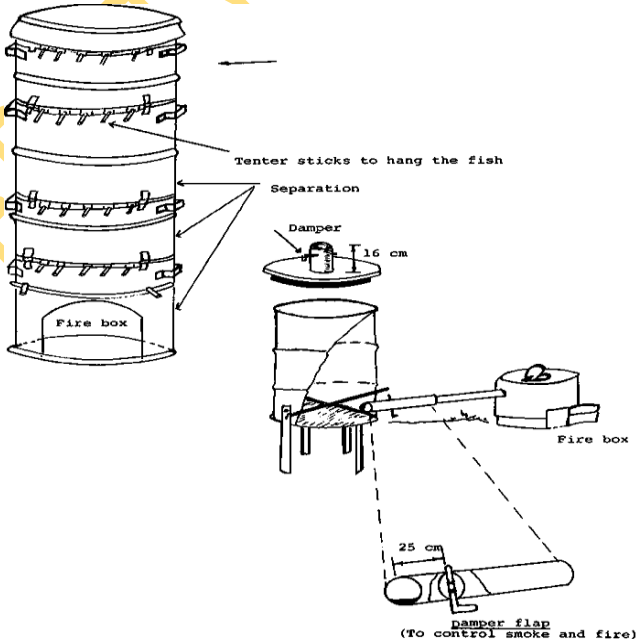

Figure 2.3: Multiple Drum Oven

Source: Davies and Davies (2009)

Disadvantages:

(a) High cost of construction.

(b) It requires high technical skills

(c) High cost of maintenance and operation.

Many of these improved ovens and kilns were found with one disadvantage or the other. Some were expensive and therefore unaffordable with a lot of inconveniences associated with their operations. Others had high labour requirements without adequate returns on labour input. They were also found to be technically ineffective with uneven heat and smoke distribution as well as poor product quality. There were no devices for control of temperature and smoke density during drying. Therefore, this necessitates the development of improved fish smoking kilns that is efficient, affordable and easy to use by fish processors irrespective of gender.

2.6 Packaging

Packaging is the science, art and technology of enclosing or protecting products for distribution, storage, sale and use. Packaging also refers to the process of design, evaluation and production of packages. Packaging can also be defined as a coordinated system of preparing and transportation, warehouse, logistic, sale and end use (Soroka, 2007). Packaging contains, protects, preserves and transports food, providing an additional mechanism for information and marketing products by improving shelf-life, convenience, freshness and quality (Seung and Burgess, 2007). The earliest recorded use of package dated back to 1035A.D when a Persian traveler visiting Cairo noted that vegetables, spices and hardware were wrapped in paper for the customers after they were sold. The first packages (natural materials) available at that time were baskets of reeds, wineskins,

wooden boxes, pottery vases, wooden barrels and woven bags (Tweed, 2005 and John, 2006). In the 20th century, bottles, transparent cellophane, overwraps and panel on carton. Aluminum and several types of plastic had been developed as advancement in packaging technologies. Ten years back packaging accounted for about 2 % of gross national product in development of which half is related to food packaging (Brody and Marsh, 1997). Knowledge of the kinds of deteriorative reactions that influence food quality is the first step in developing food packaging that will minimize undesirable changes in quality and maximize the development and maintenance of desirable properties. Once the nature of the reaction is understood, knowledge of the factors that control the rate of these reactions are necessary in order to fully control the changes in food during storage.

Appropriate packaging is necessary to maintain the quality of fishery products and customer satisfaction. In general, packaging requirement for fishery products vary according to the type of product whether fresh, frozen or processed, type of market, mode of storage and transportation. 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 (Stammen *et al*., 1990). An effective fish packaging material should be able to reduce oxidation and dehydration, provide less bacterial and chemical spoilage, prevent odour permeation and protect the product from physical damage (Byett, 2006). There is no packaging material that is perfect but knowledge of the functions of packaging and the environments where it has to operate will lead to the optimization of package design and the development of real and cost-effective packaging. The purpose of food packaging is to preserve the quality and safety of the food it contains from the time of manufacture to the time it is used by the consumer (Dallyn

and Shorten, 1989). An equally important function of packaging is to protect the product from physical, chemical and biological damages. Packaging acts as an insulating barrier between environment and product. Different methods can be applied in order to estimate the influence of dynamic environmental conditions (temperature, humidity, air velocity) on product quality. One way to estimate the effectiveness of packaging materials is to perform experiments under well controlled conditions. Another way, which is less expensive, is the use of numerical simulation and computational fluid dynamics (CFD) for analysis of the heat transfer (Hoang *et al.*, 2000).

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 (Yam, 2009). This requires an impervious moisture proof layer on the outside of the insulation as well as a water proof barrier of the lining to prevent liquid melt water entering the insulation. The vapour barrier can be achieved either through watertight surface or pre-fabricated insulation panels, reinforced plastic materials, polythene sheets, plastic film of minimum thickness of 0.02 mm, laminated with bitumen membrane. The minimum thickness of aluminum or galvanized sheets should be 0.3 mm (ASHRAE, 2007). Severin (2007) gave the material properties for effective packaging as follows;

- The best insulating material should have the lowest thermal conductivity in order to reduce the total coefficient of heat transmission.
- Also, it should have very low moisture vapour permeability thereby having negligible water absorption with minimal condensation and corrosion.

- Furthermore, the material should be resistant to water, solvents and chemicals. It should be durable and not lose insulating efficiency quickly.
- It should allow a wide choice of adhesiveness for its installation.
- It should be easy to install and of light weight and easy to handle. Ordinary tools can be used for its installation.
- It should be economical with significant saving on initial cost as well as saving on long-term performance.
- It should not generate or absorb odour and not be attacked by fungus and mildew

The local packaging materials in Nigeria used for packaging smoked and dried fish include jute bags, mat bags, cartons, baskets etc. The packaging materials only serve to hold the products during handling, transportation and storage. The packaging materials offer little protection to products from microbial, chemical, dust and insect attack because of their properties (Okonkwo *et al.*, 1991). Paper used in making cartons is not resistant to penetrating insects and mats, bags, jute bags and baskets with their numerous holes are worse. Highland (1981) listed the packaging containers and means of transportation for smoke-dried fish from harvest through the post-harvest chain. These packaging materials include sacks, paper cartons, wooden rackets, cane and bamboo baskets while transportation means used ranges from wheelbarrows, motorcycles, pick-up vans, lorries and trucks. None of these local packaging materials are rigid and rough to prevent physical damage to the fish during transportation and storage (Enenwaji, 1997).

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. Though the Center for Innovative Food Technology (CIFT) recommendation is to line

gummy or boxes with polythene and store container in dry well ventilated premises the cost of these materials may not be within the reach of an average artisanal in the country. There is a need for the country to develop one that is not only acceptable to our need but international communities and at reasonable cost. If dried fish is allowed to absorb moisture to give a water activity of 0.75 or higher during storage, bacteria and moulds are likely to cause spoilage (ICMSF, 2002).

2.7 Fish Quality Assessment

Quality is the measure of the degree of goodness of any product under consideration. Fish quality involves all the attributes which the consumers and marketers considered important and necessary. Such consideration includes intrinsic and extrinsic qualities (Hass, 1988). The intrinsic quality that comes naturally with fish includes species, size and degree of contamination from handling, nutritive value, sex, age and presence of parasites. Quality assessments in fish include sensory evaluation, chemical tests and microbiological test. These assessments are further broken down into objective and subjective methods as reported by Eyo (2001). The objective methods include chemical, biochemical, microbial and physical tests while the subjective test is the organoleptic or sensory test.

There is a need to carry out the microbial analysis of fish products so as to know the qualitative and quantitative microbial flora of the products, particularly microorganisms that are of public health significance. Trimethylamine (TMA), Total Volatile Bases (TVB) and Hypoxanthine (HX) are the major tests that had stood the test of time in analyzing the fish quality. Other methods such as Peroxide Value (PV), Thiobarbiperic Acid (TBA), Iodine Value (IV) and Histidine level could also be used to

determine the quality of fish but the one of interest in this study is the proximate analysis. When the spoilage is due to changes in texture or the development of off-flavor, caused by physicochemical and biochemical or microbial reactions, the underlying mechanism might be difficult to identify. Therefore, the evaluation of spoilage will always directly or indirectly be related to sensory assessment. Sensory evaluation by a trained panel usually gives a good estimate of the overall quality state of a food. One approach in sensory testing is to try to determine, at a certain level of probability, whether a product has changed (difference tests). Hence, this approach gives "endpoint" information and does not allow for modeling quality loss with time. Hedonic testing is a somewhat different approach that attempts to model the progressive loss of overall quality characteristics, using a graded hedonic scale.

Studies on the fungal infestation of five traditional smoke-dried fresh water fish in Ago-Iwoye, Nigeria were carried out by Fafioye *et al.* (2002). The species of fungi isolated and identified were *Mucor spp.*, *Aspergillus spp.*, *Fussarim spp* and *Rhizopus spp*. It was observed that though smoking fish provides longer shelf life than other preservative methods, the smoking will only be effective if it was properly done. Adebayo-Tayo *et al*. (2008) identified twelve different fungi and aflatoxin B_1 and G_1 in three main markets in Nigeria; on smoke–dried fish with moisture content ranging from 22.7 –to 27.6 %. The level of infestation might be due to high percentage of moisture content of the smoked fish. Abolagba and Uwagbai (2011) carried out a comparative analysis of the microbial load of smoke-dried fish sold in Oba and Koko markets in Edo and Delta States, Nigeria respectively at different seasons. The study revealed that smoke-dried fish sold in Koko and Oba markets in both rainy and dry seasons are highly contaminated with microorganisms. This implies that caution

should be exercised in consumption of smoke-dried fish unless reheated as to inactivate the microbial cell.

The fungal infestation and nutrient quality of eight smoke-dried fish were studied by Oyebamiji *et al*. (2008). It was observed that all the eight species were good sources of high quality protein, minerals and amino acid but they were highly infested with fungi because of improper drying and packaging. Wogu and Iyayi (2011) studied the mycoflora of some smoked fish varieties in Benin City, Nigeria. It was discovered that improper smoking and drying might have led to insect infestation, fungal attack, fragmentation and degradation of the product. The moulds isolated from the study were contaminants rather than originating from the fish samples. This also suggested that better preservation and handling which includes drying, packaging and storage might reduce mycoflora proliferation.

The microbial quality of six sun dried seafood species were analyzed by Prakash *et al*. (2011). It was discovered that the microbial load varied with different seafood in different season and the counts increased with increase in relative humidity and moisture content of the dried seafood. It was also discovered that poor quality of dried fishes might be due to unhygienic processing, inadequate salting and lack of air-tight packaging of the dried fishes. In a study to determine the microbial load analysis of some raw fish samples carried out by Das *et al*. (2007), it was discovered that microbial load in the raw fishes samples was high which indicates that raw fish would decompose very quickly at ambient temperature while the presence of coliforms and salmonella indicates that the raw fishes were handled in an unsafe manner.

Abidemi-Iromini *et al*. (2011) determined the effects of different smoking methods on microbial load of freshly collected freshwater mud catfish in Ibadan, Nigeria. The microbial load for cold smoked products were 72, 66, 38 %, hot smoke products had 61, 32, 81 % while oven dried had 12, 0, 0 % for samples dried for 24, 48 and 72 hours respectively. There was

positive correlation between the microbial load and processing method. Furthermore, the consumers preference for cold smoked, oven dried and hot smoked products were 25, 35 and 40 % respectively.

Chukwu and Shaba (2009) evaluated the effects of drying methods on proximate composition of catfish using smoking kiln and electric oven. It was observed that the changes in proximate composition were significant for the two drying methods with electric oven given better results. Silva *et al*. (2011) investigated the concentration of the polycyclic aromatic hydrocarbon (PAH) in smoked fish samples processed using sawdust, charcoal and firewood. The results showed that smoked fish samples that were processed using charcoal gave lowest level of the total PAH, followed by the firewood method while the sawdust method gave the highest level of total PAH.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Survey and Selection of Available Packaging Materials for Fish in Nigeria

A survey of the packaging materials available for smoked and dried fish in Nigeria was carried out. This was conducted by administering questionnaires in two Agricultural Development Project zones in two states each of the six geopolitical zones of the country. The outcome of the survey was used for selection of the materials used in this study. This being the most commonly used materials found out. Composite materials were then developed from these commonly used materials. The selection was based on the analysis of field report obtained from the questionnaires administered using the criteria of flexibility, availability and cost of the materials. Those that ranked high were selected for this study.

3.2 Production and Cost of the Selected Packaging Materials.

The result of the survey in section 3.1 was the basis for selection of Paper, Cardboard, Polyethylene and thick Polyethylene materials of thickness 0.18 mm, 0.35 mm, 0.05 mm and 0.27 mm respectively as the packaging materials for the study. Paper, Cardboard and Polyethylene materials were laminated in six composite ways using Linea DH -650 laminating machine (Plate 3.1) and having various thicknesses.

Plate 3.1: Linea DH-650 – Laminating Machine

The six types of composite packaging materials were produced from the three selected materials - Polyethylene, Paper and Cardboard. The Polyethylene–cardboard-Polyethylene (PCP) packaging material is a three layered structure laminated from Polyethylene thickness 0.05 mm, Cardboard of thickness 0.35 mm and Polyethylene of thickness 0.05 mm. The Polyethylene-Paper-Polyethylene (PPaP) packaging material is also a three layered structure laminated from Polyethylene of thickness 0.05 mm, Paper of 0.18 mm and Polyethylene of 0.05 mm thickness. The Polyethylene-Cardboard (PC) packaging material is a double layered structure laminated from Polyethylene (outward) and Cardboard (inward) of thickness 0.05 mm and 0.35 mm respectively.

The Cardboard-Polyethylene (CP) packaging material is a double layered structure laminated from Cardboard (outward) and Polyethylene (inward) of thickness 0.35 mm and 0.05 mm respectively. The Polyethylene-Paper (PPa) packaging material is also a double layered structure laminated from Polyethylene (outward) and Paper (inward) of 0.05 mm and 0.18 mm thickness respectively; while the Paper-Polyethylene (PaP) packaging material is a double layered structure laminated from Paper (outward) and Polyethylene (inward) of thickness 0.18 mm and 0.05 mm respectively. The control used for the packaging material is the Polyethylene bag used by the traders and has thickness of 0.27 mm. Each of the samples was formed into an A4 envelope size of 21 cm X 30 cm manually with proper sealed edges (Plate 3.2). The cost for the unit production of each packaging material is presented in Appendix I.

The composite materials produced are:

(i) Cardboard lined with Polyethylene materials (CP)

(ii) Polyethylene lined with Cardboard materials (PC)

(iii) Polyethylene–Cardboard-Polyethylene materials (PCP)

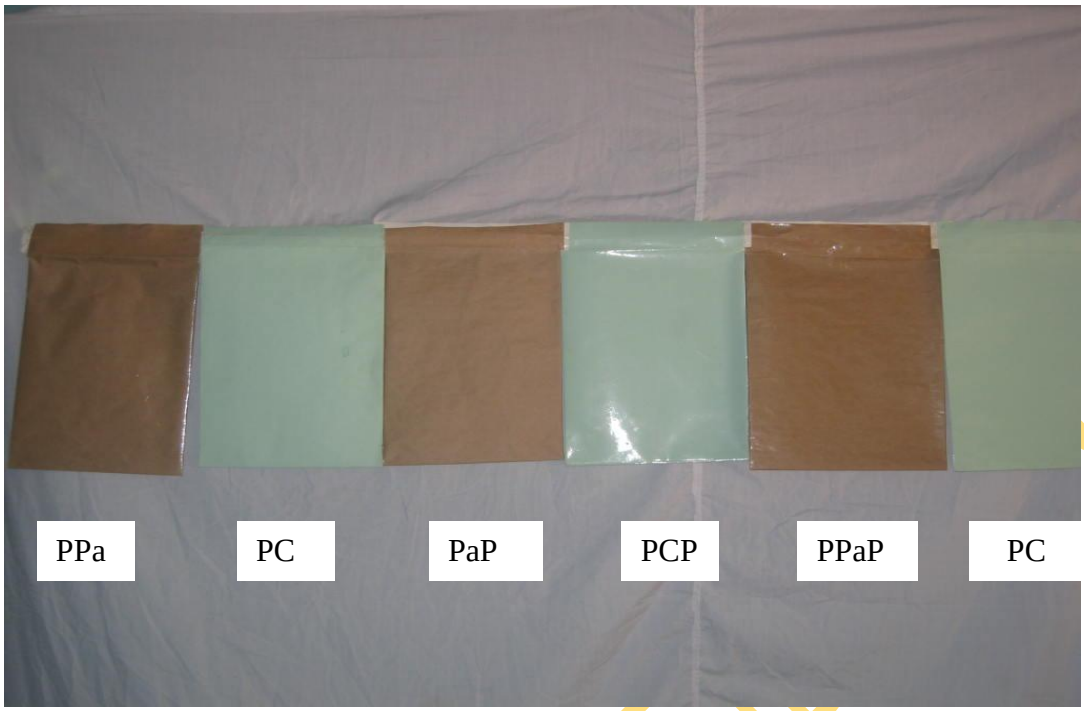

Plate 3.2: Composite Packaging Materials Developed for the Study

(iv) Paper lined with Polyethylene (PaP)

(v) Polyethylene lined with Paper materials (PPa)

(vi) Polyethylene-Paper-Polyethylene materials (PPaP)

(vii) Polyethylene material (farmers' practice) as Control (C)

3.3 Determination of Some Engineering Properties of the Packaging Materials.

Some physical properties (thickness, impact test, weight, water absorption rate, oil absorption rate and opacity) of the packaging materials were determined as follows. The thickness of the materials used for the packaging materials were measured with a micrometer screw gauge. Each of the packaging materials was inserted into the frame between the spindle and the anvil situated in the opposite ends of the frame. The screw was rotated until the object was fixed between the spindle and the anvil. The reading was taken from the thimble and the body over which the thimble rotates. Ten random measurements were taken from each of the packaging materials to determine the mean thickness.

The impact tests were conducted on each of the packaging materials according to ASTM D 882-95 A, using method B. A dart with 51.0 mm diameter hemispherical head was dropped from a height of 1.50 m. A uniform missile weight increment was employed during the test until failure was achieved. The total missile weight that achieved 50 % deformation of the test sample was recorded. Those treatments were replicated on twenty samples of each of the packaging materials.

Ten of test pieces of the packaging materials measuring 20 x 20 cm were immersed in water and the increase in weight after one hour was determined in accordance with BS

6504 for the water absorption rate determination. Water absorption was calculated from the measurement using Equation 3.1.

$$W_{AR} = \frac{W_f - W_i}{ATW_i} \quad 3.1$$

Where, W_f is the final weight in g of the immersed packaging material, W_i is the initial weight in g of the packaging materials before immersion, A is the surface area of the immersed packaging material in cm^2, T is the time of immersion in minute and W_{AR} is the water absorption rate

The oil absorption rates for the packaging materials were determined using method BS 6504. 20 x 20 cm pieces of packaging materials were immersed in oil and increase in weight were measured after one hour. The oil absorption rate was calculated using Equation 3.2.

$$O_{AR} = \frac{M_f - M_i}{ATM_i} \quad 3.2$$

Where; M_f is the mass in gram of the immersed packaging material in oil, M_i is the mass in gram of the packaging material before immersion in oil, A is the surface area of the packaging material in cm^2, T is the time in minute to immersed the packaging material and O_{AR} is the water absorption rate

The opacity test on the packaging materials was determined by physical observation and classified to transparent and non-transparent. While the weight of the packaging materials were measured using weighing balance (Snowrex counting scale SRC 5001, Saint Engineering Ltd., Saint House, London).

3.4 Construction and Performance Evaluation of Fish Smoking Kiln

The smoking kiln was designed and constructed based on the available materials. The design considerations and calculations are presented in Appendix II. The kiln is

rectangular in shape with internal dimension of 600 x 600 x 1200 mm (Figures 3.1 and 3.2). It has an inner lining made of galvanized iron sheet. The galvanized iron sheet was lagged with 25.4 mm asbestos particles and covered with 12.7 mm thick plywood. The double walls structure with the insulating material was provided to conserve the heat energy by reducing heat loss and also to keep the working environment conductive. The kiln has 4 tray shelves made of wire gauge of dimension 580 x 580 mm. The trays were constructed of durable and light weight frame and smooth edge fine wire mesh which can prevent the dried fish products from falling through. The trays were placed on 25.4 mm pipe which allow them to be pulled out without tipping and can easily be slide in and out. The total surface area available for drying was 1.44 m^2. The drying capacity varies with species and thickness of fish. The kiln has double wing doors which can be opened and closed easily (Figure 3.3). The doors fit smoothly when in a closed position. The kiln was incorporated with three (3) axial fans connected in series and powered by five (5) pairs of 1.5 volt batteries with an ON and OFF switch control. This helps to improve the air and heat circulation within the kiln chamber and removal of moisture out of the product. It also has six air-inlets at the base made of 25.4 mm pipe to permit fresh airflow for combustion and drying of the fish product and air-outlets at the top made of 25.4 mm pipe to serve as the exhaust for water and water vapour escape. The kiln was powered with saw dust for smoking and charcoal for heating/drying operations. The saw dust and charcoal were placed inside a combustion pot of dimension of 400 x 400 x 220 mm dimension. A forklike hanger was made for combustion pot to remove or place it inside the kiln during operation. Plate 3.3 shows the pictorial view of the smoking kiln.

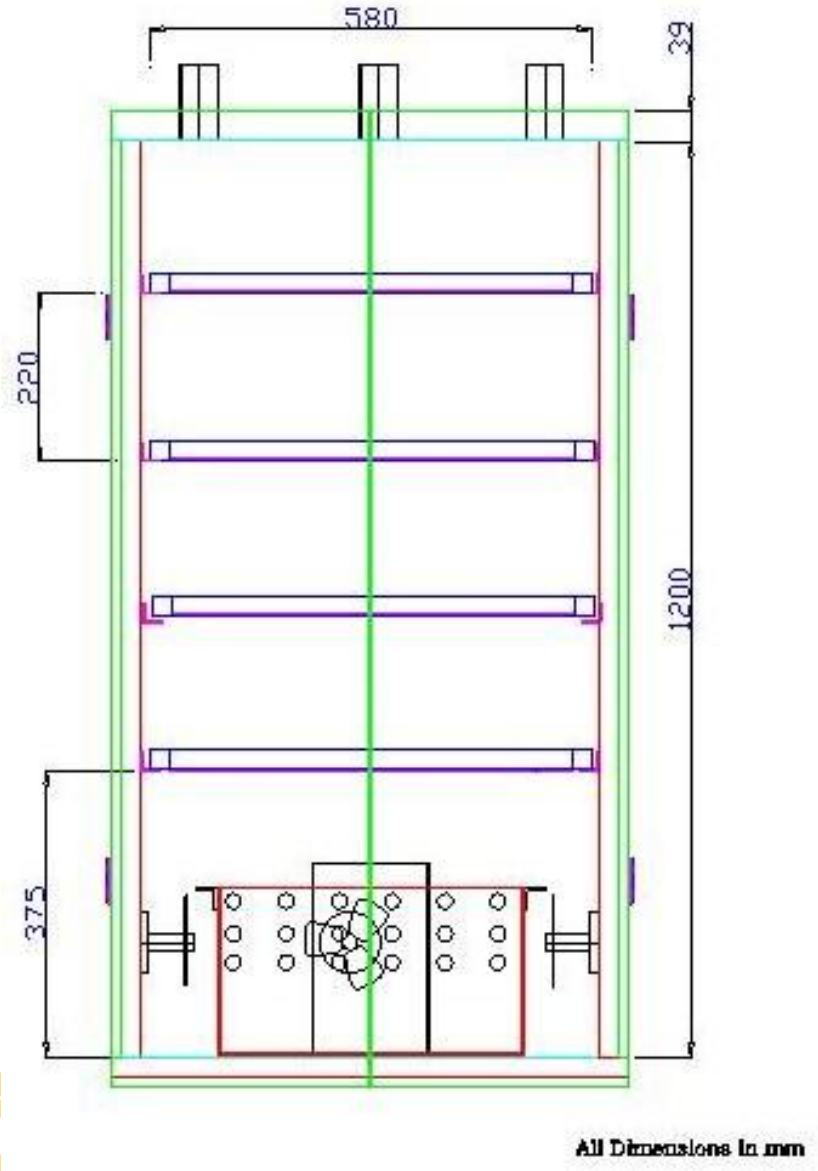

Figure 3.1: Front View of the Smoking Kiln

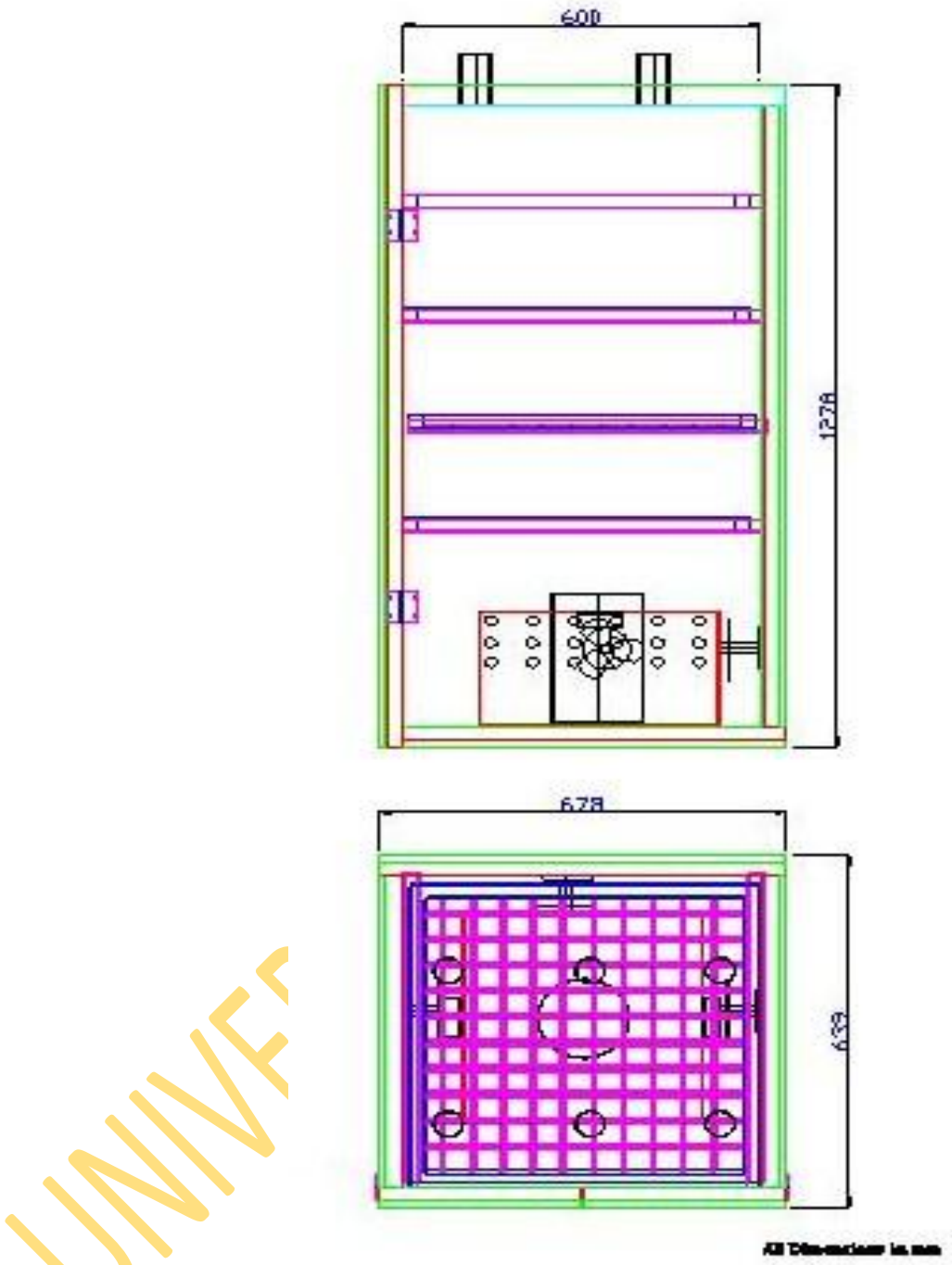

Figure 3.2: Side and Plan Views of the Smoking Kiln

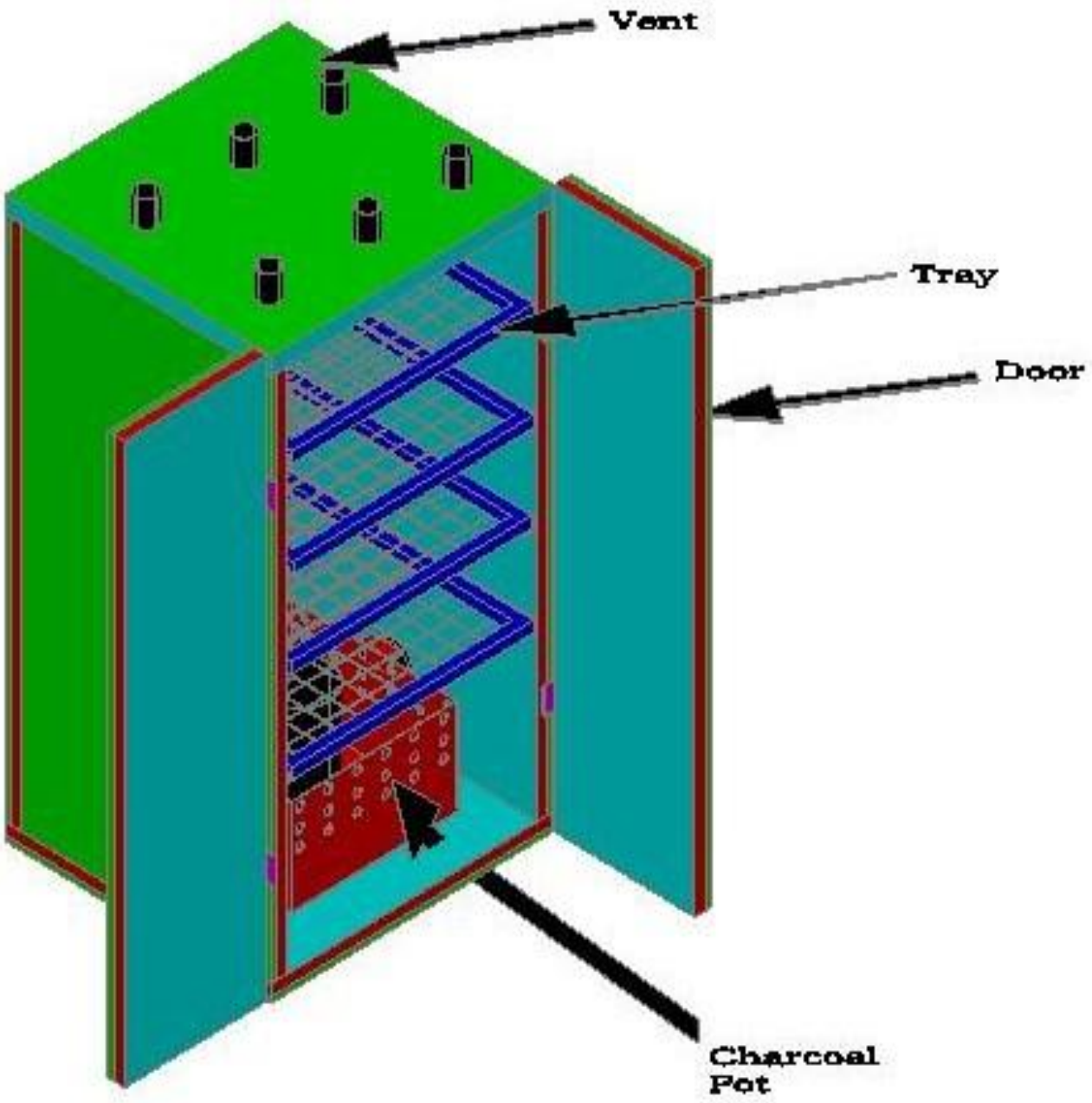

Figure 3.3: Internal Features of the Smoking Kiln

Plate 3.3: Close and Open Views of Fish Kiln Constructed for the Study

The performance testing of the kiln at no load was performed using saw dust at constant weight of 0.5 kg and varying weight of charcoal at 0.5, 1.0 and 1.5 kg with fan and without fan, and the temperature attained by the kiln at an interval of 15 minutes were taken using mercury in glass thermometer. The reading was terminated when the saw dust and charcoal were fully burnt. This was done to determine the ideal operating condition of saw dust and charcoal to be used for drying. Also the temperature used for the smoking operation was obtained from the ideal operating condition at no-load condition.

3.5 Harvesting and Handling of Catfish

Six months old catfish of average weight of 350 g were purchased from the Kano State Department of Fisheries farm (Plate 3.4) at Mariri, in Wudil Local Government of Kano State. The catfish were killed by stunning and they were gutted. The fish were then thoroughly washed to remove the blood stain and other impurities and allowed to drain. The fish were placed inside iced fish box (Plate 3.5) and transported from the farm to the Nigerian Stored Products Research Institute, Kano, for smoking and drying.

3.6 Smoking and Drying of Catfish

Saw dust (0.5 kg) was introduced into the saw dust chamber to give the smoking condition and charcoal container was loaded with 1 kg charcoal, properly fired and placed inside the fish smoking kiln to attain a temperature of 120 ^{o}C. The fish were then arranged on the shelves on which palm oil has initially been rubbed. The palm oil was applied to avoid drying fresh catfish getting stucked to the rack. The fish were then placed on the shelves. The fish was cooked until dryness was achieved and the axial fans were put on for proper air circulation.

Plate 3.4: Fish Harvested For Experiment in the Wudil LGA of Kano State.

Plate 3.5: Iced Fish Box Developed for Transportation of Fresh Fish

One kilogramme charcoal was added continuously every two hours during the smoking process and the temperature of the drying chamber was continuously monitored using mercury in glass thermometer (^{o}C) installed in the top, middle and bottom parts of the chamber. The smoking/drying was stopped when the fish were properly dried to safe moisture content. When the heating elements were removed the fans were still in on position to cool the dried fish (Plate 3.6). The smoked dried catfish were removed when they were cooled to the ambient temperature.

3.7 Packaging and Storage of Smoke-Dried Catfish

After removal of the cooled smoke-dried catfish from the smoking kiln, they were packed in ten samples each and packaged in the packaging materials and labelled as follows:

i. PPaP – Polyethylene-Paper-Polyethylene Packaging
ii. PPa – Polyethylene-Paper Packaging
iii. PaP – Paper-Polyethylene Packaging
iv. PCP – Polyethylene-Cardboard-Polyethylene Packaging
v. PC – Polyethylene-Cardboard Packaging
vi. CP – Cardboard-Polyethylene Packaging
vii. C – Polyethylene – As control.

The packaged samples were kept in a shelf (Plate 3.7) inside a laboratory and stored at ambient temperature and relative humidity of 25 - 41^{o}C and 75 – 87 % respectively. Initial sample of the fresh and smoke-dried catfish were drawn for proximate analysis, sensory evaluation and microbial analyses. The analyses were carried out at the Abuja Stock Commodity Exchange laboratory in Kano. Monthly samples of the smoke-dried catfish were drawn for six months and subjected to same analysis in the same laboratory.

Plate 3.6: Smoking and Drying of Catfish Used for Trial

Plate 3.7: Ambient Storage of Packaged Catfish under Laboratory Condition in NSPRI, Kano.

3.8 Microbial Analyses

Fresh and dried samples of the catfish were analyzed initially for the presence of pathogens and monthly samples of each of the catfish packaged in the different materials were analyzed for a period of six months. The analyses were conducted at Abuja Securities Commodities Exchange laboratory in Kano. 10 g representative sample was obtained from the muscle of the fish (the thickest part of muscle) to prepare serial dilutions (10^{-1} – 10^{-3}) using sterile water as a diluent. The Plates used were Equitron autoclave (Plate 3.8).

The samples were homogenized for 60 seconds using a Sweard Stomacher Lab Blender 400C (Weber Science, Hamilton, NJ). Total plate count, E. *coli*, *Staphylococcus*, *Salmonella*, yeast and mould counts were determined by the Grid-Membrane Filtration method (GMFM). Homogenized sample (10 ml) was passed through a 0.45 mm grid membrane filter. After that, the filter was placed on a plate with media and incubated. *Listeria spp*. was determined by a qualitative method. The enrichment step was done with 10 g of the sample added to 100 ml of Demi Fraser broth, and the solution was incubated at 30 ^{o}C for 24 hr, followed by plating 0.1 ml in selective and differential media ALOA (Agar Listeria Ottaviani & Agosti) at 37 ^{o}C for 24 hr. ALOA is a prepared selective and differential medium for the isolation of *Listeria spp*. from foods for presumptive identification of *L. monocytogenes*.

The selectivity of the medium is due to lithium chloride and the addition of an antimicrobial mixture. The differential activity is due to the presence in the medium of the chromogenic compound X-glucoside as a substrate for the detection of betaglucosidase enzyme, common to all *Listeria* species.

Plate 3.8: Equitron Autoclave

The specificity is obtained by detecting the metabolism of a substrate by an enzyme (phospholipase) that is only present in the *L. monocytogenes* species. The combination of both subtracts allows the differentiation of *Listeria spp*. "non monocytogenes", which develops blue colonies, from *Listeria monocytogenes,* and surrounded by an opaque halo. ALOA allows differentiation *L. monocytogenes* even in the presence of competitive flora. Presumptive *Listeria* colonies from ALOA agar were identified using a Gram staining technique followed by API Listeria test (bioMerieux Industry, Hazelwood, MO). API Listeria is a system for the identification of *Listeria*. It uses standardized and miniature tests with a specially adapted database. The API Listeria strip consists of 10 microtubes containing dehydrated substrates, which enable the performance of enzymatic tests or sugar fermentation. The API test was done using the kit containing 10 API Listeria strips, 20 ampoules of suspension medium, 10 incubation boxes and 10 results sheets. The inoculum was prepared by suspending few well-isolated colonies in 2 ml suspension medium and the strips were placed in the Genlab incubation boxes (Plate 3.9) with 3 ml of distilled water. After that, 50µl of bacterial suspension was distributed into the tubes and the incubation box was closed and incubated at 35 ^{o}C for 24 hours. The result was read and identification was obtained in the list of profile or with identification software (bioMerieux Industry, Hazelwood, MO).

Plate 3.9: Genlab Incubator

3.9 Proximate Analysis

3.9.1 Fat Determination

The fat content of raw and smoked catfish was determined by a solvent extraction (Submersion) method for fat (Crude) in Meat and Meat Products (AOAC, 2002). Soluble material was extracted from dried samples by a 2-step treatment with petroleum ether solvent. Solvent was recovered by condensation, leaving extracted soluble material, which was determined by weight after drying. Three grams of homogenized fish samples were mixed with sand and dried for 1 hr in a Genlab oven (Plate 3.10) at 125 ^{o}C. Samples were extracted with 40 ml of petroleum ether at boiling temperature for 25 min, and rinsed for 30 min. The fat deposited from the sample was recovered with the extraction cups. The cup and contents were dried for 30 minutes at 125 ^{o}C, then cooled and weighed. Percent of fat in the sample was calculated by subtracting the weight of the extraction cup after drying from the weight of the extraction cup before extraction times 100, then divided by the sample weight (AOAC, 2002).

3.9.2 Protein Determination

The protein content was determined by a Block Digestion method (AOAC, 2002). 2 g of well-ground and mixed catfish samples were weighed and transferred to a 250 ml digestion tube. H_2SO_4 (15 ml) was added to each tube, and 3 ml of 30 – 35 % H_2O_2 was slowly added. After the reaction subsided, the tubes were placed in the Digester Foss Tecator 8 (Plate 3.11) and the mixture was digested at 400 ^{o}C until it became clear in 45 minutes. The tubes were removed and cooled for 10 minutes. 50 - 75 ml of H_2O was carefully added. The NaOH-$Na_2S_2O_3$ solution was placed in an alkali tank of the steam distillation unit (kjeltec Tm 8200) (Plate 3.12). A distillation tube containing diluted digest was attached to the distillation unit (Olayemi *et al*., 2011a).

Plate 3.10: Genlab oven

Plate 3.11: Digester Foss Tecator 8

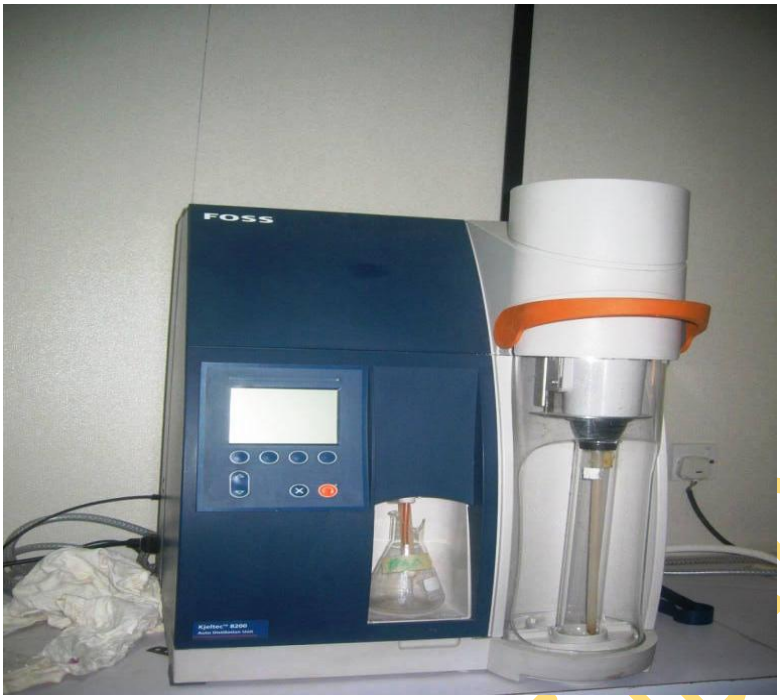

Plate 3.12: Distillation Unit (Kjeltec ^{Tm} 8200)

A receiving flask, containing 25 ml H_3BO_3 solution with mixed indicator, was placed on the receiving platform. The mixture was steam distilled and 100 - 125 ml was collected (absorbing solution turns green from liberated NH_3). Digestion tubes and receiving flasks from the unit were removed. The absorbing solution and reagent blank were titrated using Tittrettre (07G0IS73) (Plate 3.13) with 0.2 NHCl to a neutral gray end point. The protein content was calculated using the following formula (Equation 3.3).

$$\% \text{ Protein} = (V_A - V_B) \times 1.4007 \times N \qquad 3.3$$

Where; V_A and V_B = volume standard acid required for sample and blank respectively; 1.4007= miliequivalent weight N × 100 (%); and *N* = normality of standard acid.

3.9.3 Moisture Determination

The moisture content was determined by a mechanical moisture analyzer IND ML50 (Plate 3.14). The samples were milled with a blender to increase the surface area. The lid was removed and a 2 g sample was loaded into the analyzer. The moisture content of the sample was determined automatically.

3.9.4 Ash Determination

Ash content was determined by measuring the mass of a dried sample before and after it had been heated in a muffle furnace NYC-12 (Plate 3.15). A 2 g of catfish sample was weighed into crucibles and placed in a temperature-controlled furnace preheated to 600 ^{o}C. The crucible was held at this temperature for 2 hr; then it was directly transferred to a desiccator, cooled, and weighed. The percent of ash was reported to the first decimal place (AOAC, 2002).

Plate 3.13: Tittrettre (07GOIS73

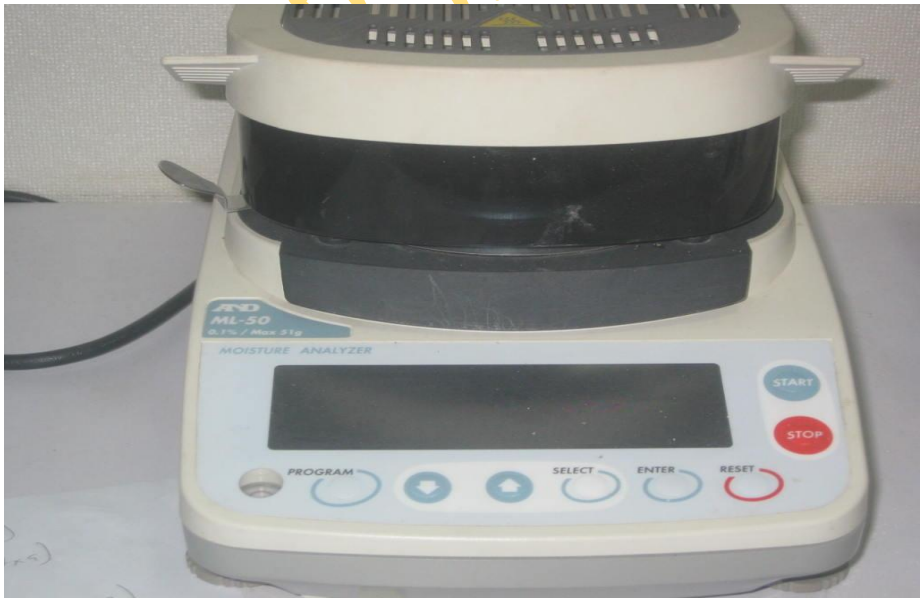

Plate 3.14: Moisture analyzer IND ML50

Plate 3.15: Murffle furnance NYC-12

3.9.5 Nitrogen Free Extract Determination (NFE)

NFE was determined by the use of Equation 3.4

$$NFE\ \% = 100 - Xw - Xp - Xc - Xf - Xa \quad 3.4$$

Where

Xw = Moisture content %

Xp = Protein content %

Xc = Carbohydrate content %

Xf = Fat content %

Xa = Ash content %

3.10 Sensory Evaluation

Organoleptic / Sensory evaluation was carried out on the smoke-dried samples of the catfish stored in the seven packaging materials using 10-man semi trained panels for smell, taste, color, texture and general acceptance on 9 points hedonic scale with score 9 having excellent attraction. The sensory evaluations were conducted initially and monthly during the time of experimental sampling. Necessary precautions were taken to prevent carry-over flavour during the tasting by ensuring that the panelists passed a piece of lemon fruit in their mouths after each stage of sensory evaluation.

3.11 Statistical Analysis

Data were analysed using ANOVA and descriptive statistics. The correlations were done using the Pearson Correlation Procedure of SAS.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Selection of Materials for Use as Packaging Materials

The preliminary studies carried out on the survey of materials used for packaging of dried fish in Nigeria revealed that, jute bags, mat bags, cartons, baskets, wooden boxes, earthen pot, paper and polyethylene materials ranked high. The survey result is a confirmation of earlier studies carried out by Enenwaji (1997) and Okonkwo *et al.* (1991). The observation in this survey showed that these materials 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 them make them not ideal for use.

4.2 Development of Composite Materials

Based on the observations from the survey, composite packaging materials made from Polyethylene (nylon), paper and cardboard were selected for use in making laminated packaging for this study. The choice of these materials was in line with earlier packaging development by other researchers using either lamination or liners of different materials for packaging of dried fish (Normall *et al*., 2007). The choice of these materials was based on their flexibility, lightweight, availability, cost effectiveness and insulating properties.

Furthermore, none of the available materials have all the required functional properties. The composite laminations were done to improve the functional properties of the resultant packaging materials, as the properties of one will be imposed on the other. With these composite packaging materials, the insulating and opacity properties of the paper and cardboard will be called to bear in the resultant materials while the better barrier property and printability of the Polyethylene will be visible. Hence, the deficiencies or limitations of one material used in the composite were complimented by the other; in addition to their inherited functional properties. The properties of the composite materials obtained are presented in Table 4.1.

4.3 Costs of Packaging Materials

The unit costs of the seven types of packaging materials used in this study are as presented in Table 4.2. The least cost material was Polyethylene (control) at ₦ 10.00 per unit for an A4 sized pack (current rate is ₦164 to 1 USD); while the Polyethylene-Paper-Polyethylene packaging material had the highest cost of ₦ 32.00. It is closely followed by Polyethylene-Cardboard-Polyethylene which cost ₦25.80; Polyethylene-Paper and Paper-Polyethylene cost ₦ 20.00 respectively. The Cardboard-Polyethylene and Polyethylene-Cardboard cost ₦16.80 per unit. However, the costs of each of these packaging materials are still minimal and affordable. These costs are less than ₦50.00 per unit (Table 4.2) and each pack can take up to three (3) to four (4) smoke dried medium size fishes with market value of between ₦ 600.00 and ₦ 800.00. The calculations for the cost of the packaging materials are presented in Appendix I. The costs of production of these packaging materials are economical and the materials are also available; thereby meeting one of the requirements of functional packaging materials with a low production costs (Tice, 2003).

Table 4.1: Lamination Arrangement and Thickness of the Packaging Materials

Composite Materials	Number of Layer	Layer Arrangement	Layer Thickness (mm)
		Polyethylene	0.05
	3	Cardboard	0.35
PCP		Polyethylene	0.05
		Polyethylene	0.05
	3	Paper	0.18
PPaP		Polyethylene	0.05
PC	2	Polyethylene	0.05
		Cardboard	0.35
CP	2	Cardboard	0.35
		Polyethylene	0.05
		Polyethylene	0.05
PPa	2	Paper	0.18
PaP	2	Paper	0.18
		Polyethylene	0.05
C	1	Thick Polyethylene	0.27

Table 4.2: Costs of Production of the Packaging Materials.

S/No.	Type of Packaging Material	Unit Cost (₦. K)
1	Polyethylene -cardboard- Polyethylene	25.80
2	Polyethylene -paper- Polyethylene	32.00
3	Polyethylene –cardboard	16.80
4	Cardboard-Polyethylene	16.80
5	Polyethylene -paper	20.00
6	Paper-Polyethylene	20.00
7	Thick Polyethylene alone (control)	10.00

Furthermore, the cost can be further reduced if the production processes were fully mechanized and with high volume of production. The reduction of energy usage by eliminating the need for refrigerator and freezing in the use of these packaging materials and the job opportunities are other advantages in their use.

4.4 Engineering Properties of the Packaging Materials

The results of the engineering properties (thickness, weight, water absorption rate, oil absorption rate, opacity and impact resistance weight) are as presented for the six composite packaging materials and the control in Table 4.3. PCP was not transparent with three layers of thickness 0.40 mm, impact resistance weight of 40 g and weight of 34.70 g. It has water and oil absorption rates of 0.769 and 4.123 g/cm^2/min respectively. The PPaP was not transparent with 3 layers of thickness 0.31 mm with impact resistance weight of 50 g and unit weight of 17.68 g. It has water and oil absorption rates of 1.73 and 2.50 g/cm^2/min respectively. Also the CP was not transparent with double layers of thickness 0.40 mm with impact resistance weight of 30 g and unit weight of 32.57 g. The water and oil absorption rates of 5.628 and 8.799 g/cm^2/min. Likewise, the PC is a non-transparent material with double layers of thickness 0.40 mm, impact resistance weight of 25 g and unit weight of 32.17 g. It has water and oil absorption rates of 6.574 and 10.230 g/cm^2/min respectively. Furthermore, the PPa is a non-transparent material with double layers of thickness 0.23 mm, impact resistance weight of 30 g and unit weight of 15.15 g. Its water and oil absorption rate were 10.00 and 10.857 g/cm^2/min respectively. Also the PaP is a double material of thickness 0.23 mm, impact resistance weight of 40 g and unit weight of 15.03 g. It has water and oil absorption rate of 5.168 and 7.418 g/cm^2/min respectively. While the control is a single layer transparent material of thickness 0.27 mm, with impact

resistance weight of 35 g and unit weight of 18.06 g. Its water and oil absorption rate were 0.36 and 0.280 g/cm^2/min respectively.

The thickness of the packaging materials as presented in Table 4.3 ranges from 0.23 to 0.46 mm. PaP and PPa had the least thickness of 0.23 mm, followed by the control, C, of 0.27 mm; PPaP had 0.31 mm, while CP and PC had 0.40 mm and PCP had the highest thickness of 0.46 mm. These values met the standard for partial barrier of at least 0.15 mm for packaging materials as reported by Emblem and Emblem (1996). Size, geometry and thickness are some of the factors that affect the performance of packaging material. Paine and Paine (1983) reported that for a given packaging material of the same shape and geometry, the thicker the material the lower the permeation to environmental pressure especially moisture intake; as permeation is inversely proportional to thickness. For PCP, CP, PC with the same geometry and size, the PCP with highest thickness is expected to have lowest permeation compared with CP and PC; and likewise PPaP is expected to have lowest permeation compared with PPa and PaP. Hence it is expected that the packaging materials PCP and PPaP will offer better barrier properties than other packaging materials (Olayemi *et al*., 2011b). Therefore the effect of the ambient conditions especially the relative humidity might be minimal on these packaging materials in comparison to others.

The values of the water absorption rates in (g/cm^2/min) were 0.230, 0.790, 1.623, 5.168, 5.628, 6.579 and 10.0 for C, PCP, PPaP, PaP, CP, PC and PPa respectively. Packaging materials C, PCP and PPaP show lower water absorption rate than the other packaging materials and this, might be due to their microstructure composition.

Table 4.3: Engineering Properties of the Packaging Materials

Packaging Materials	Thickness (mm)	Water Absorption Rate ($g/cm^2/min$)	Oil Absorption Rate ($g/cm^2/min$)	Opacity	Impact Resistance (g)	Package Unit Weight (g)	Cost (₦)
CP	0.40	5.628	8.799	Opaque	30	32.57	16.80
PC	0.40	6.574	10.230	Opaque	25	32.17	16.80
PCP	0.46	0.769	4.123	Opaque	40	34.70	25.80
PaP	0.23	5.168	7.418	Opaque	40	15.03	20.00
PPa	0.23	10.000	10.857	Opaque	30	15.15	20.00
PPaP	0.31	1.730	2.500	Opaque	50	17.68	32.00
C	0.27	0.360	0.280	Transparent	35	18.86	10.00

The PCP and PPaP packaging materials were laminated with nylon material in the inner and outer covers, while C is entirely nylon. It is well known fact that Polyethylene has better barrier properties than paper and cardboard which were used as either inner or outer layer of the other packaging materials with higher water absorption rate. Materials with lower water absorption rates are expected to offer better barrier properties than those with higher values. Hence it is expected that packaging materials C, PCP and PPaP would have lower moisture contents for the stored catfish.

The oil absorption rate measurement for all the packaging materials are shown in Table 4.3. The values of oil absorption rates in $g/cm^2/min$ for the packaging materials were 0.280, 2.50, 4.123, 7.418, 8.799, 10.23 and 10.857 for C, PPaP, PCP, PaP, CP, PC and PPa respectively. Paine and Paine (1983) and Yam (2009), discovered that the oil absorption rate is affected by the microstructure composition of the packaging materials and there exists a positive correlation between the oil absorption rate and the fat content of stored products. Packaging materials with internal surface of cardboard and paper like PC and PPa have higher oil absorption rate than others. It is expected that packaging materials with higher oil absorption rates might have higher values of fat content.

The opacity assessment were carried out by visual observation and classified into transparent and non-transparent. All the six composite packaging materials were non-transparent while the control C was transparent. It has been discovered that storing food in colored or opaque containers will prevent light from passing through to the food and thereby extending the shelf life. Brown and Forel (2008) observed that UV light catalyzes the oxidation of food causing photo-oxidative rancidity, vitamin loss and fading of natural

color. The transparency of the control C might therefore affect the fat content due to oxidation even though the oil absorption rate is low.

The Impact Resistance Weight (IRW) for the packaging materials ranges from 25 to 50 g. From the result obtained in this study the impact resistances of the packaging materials used are affected by the material composition, thickness, layer numbers and position the load were applied. For packaging materials made from nylon and cardboard, the PCP of three layers and 0.46 mm thickness has 40 g impact resistance weight compared with CP and PC of 0.40 mm having 30 and 25 g impact resistance weight respectively. This trend was also observed in the PPaP 0.31 mm, PPa and PaP 0.26 mm with 50, 40 and 30 g respectively.

These composite packaging materials were designed to be used as primary packaging materials with carton as the secondary. The export specifications for cartons were given by Groenewald and Bester (2010) as

51 x 47 x 47 cm	standard size
61 x 47 x 47 cm	medium size
76 x 52 x 53 cm	large size

It is obvious that the size of the carton (30 x 21 cm) used for each of the packaging design in this study is a medium sized carton and it is an ideal secondary packaging material for export; with the number of pack per carton to be 40 (4 x10). It can be deduced from this information that for a pack of three dried fish with average weight of 87.52 g, the maximum force per unit area applied on the stored fish in the secondary carton will be 201 N/cm^2, while the force for the least impact resistance for the packaging material was 438.87 N/cm^2. Hence since the packaging materials with the least impact resistance has a higher force than the maximum force applied on the packaging materials used to store the

catfish, one can reasonably assume that all the packaging materials have enough strength to withstand the subjected load during packaging**.**

The unit weight of the packaging materials range from 15.03 to 34.70 g. The packaging materials are light and flexible, being functional properties of good packaging materials. Even though there is no perfect packaging materials, the six composite packaging materials developed for this study with the control exhibited good functional properties. They are light in weight, flexible, available with adequate strength and thickness. Their varying barrier properties due to their thickness, water and oil absorption rates might be the critical factors for their performance and evaluation in the storage trial.

4.5 Evaluation of the Fish Smoking Kiln

4.5.1 No-Load Conditions

The smoking kiln was evaluated at no-load condition to know whether it is capable of providing the minimum requirements for smoke-drying of fish.

4.5.1.1 Themal Evaluation of the Smoking Kiln at No-load

The temperatures obtained in the smoking kiln at six different conditions of operation at No-Load with fan and without fan were shown in Figure 4.1 and Appendix III a, b, c. The initial temperatures of the kiln at no-load at charcoal loadings of 0.5 kg without fan and with fan were 104 and 110 ^{o}C and the temperatures declined to 34 and 41.33 ^{o}C after 165 and 225 minutes respectively. The charcoal loadings of 1.0 kg without fan and with fan recorded initial temperatures of 150 and 164 ^{o}C and the temperatures declined to 39 and 52 ^{o}C after 300 and 315 minutes respectively. Loading of 1.5 kg of charcoal without fan and with fan had initial temperatures of 152.17 and 168.67 ^{o}C and later reduced to 39.33 and 40.67 ^{o}C respectively after 435 minutes.

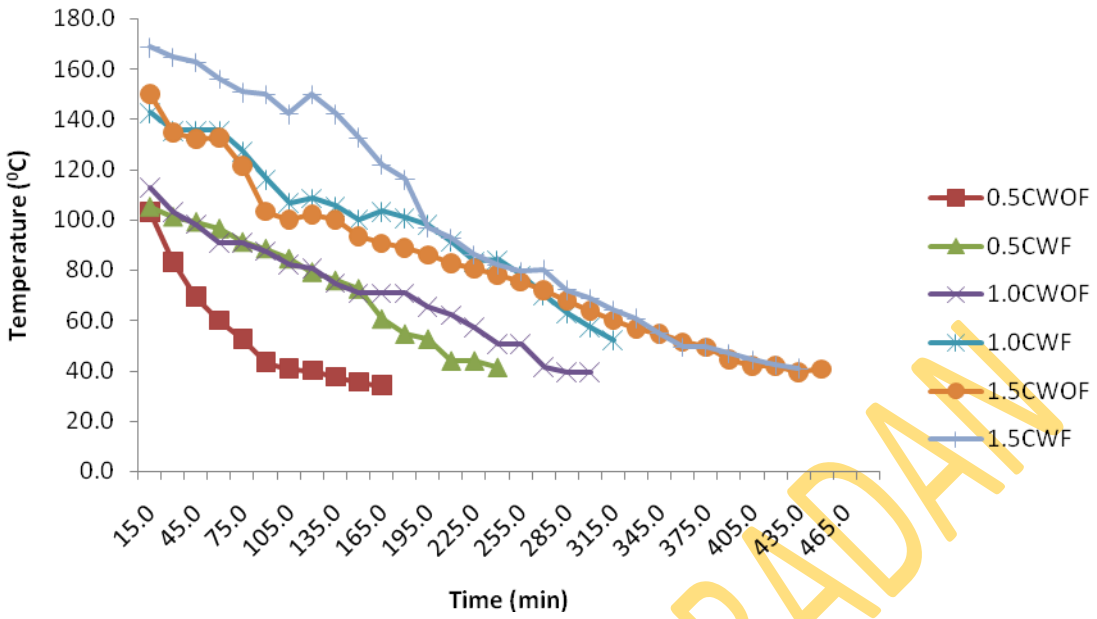

Figure 4.1: Temperature Distribution in Smoking Kiln at No Load

(CWOF – Charcoal without fan , CWF – Charcoal with fan)

The temperature deviations in the different conditions were 6.05 and 1.12 ^{o}C for charcoal of 0.5 kg without fan and with fan respectively (Appendix III d). The charcoal weight of 1.0 kg had temperature deviations of 3.21 and 1.4 ^{o}C for without fan and with fan conditions respectively. The temperature deviations for charcoal loading of 1.5 kg were 4.15 and 1.65 ^{o}C for without fan and with fan conditions respectively. Furthermore, the costs of running the kiln at these conditions were ₦ 240.00 and ₦ 280.00 for 0.5 kg charcoal loading without fan and with fan respectively. The 1 kg charcoal loading had ₦ 460.00 and ₦ 550.00 as costs of running the kiln for without fan and with fan conditions respectively. The running costs for 1.5 kg charcoal loading for without fan and with fan conditions were ₦ 680.00 and ₦ 720.00 respectively (Table 4.4).

The evaluation was necessary to know if the designed kiln would be able to meet the required drying conditions for fish as demanded by Federal Department Agriculture (2001). Fish are require to be heated to an internal temperature of 70 ^{o}C for 3 hours so as to eliminate the harmful pathogens; while the smoking kiln must be able to provide temperature between 95 – 110 ^{o}C so as to give the fish the internal temperature without denaturing the fish products (FDA, 2001). It was observed from the results obtained that charcoal did not supply steady power to the kiln but at decreasing level with increase in time. Hence the charcoal needed to be loaded regularly to achieve the power requirement for fish smoking.

Table 4.4: Temperature Deviation and Cost of Power for Operating the Smoking Kiln

Operation Condition	Temperature Deviation (^{o}C)	Cost (₦:K)
1.5 kg charcoal with fan	1.65	720:00
1.5 kg charcoal without fan	4.15	680:00
1.0 kg charcoal with fan	1.4	550:00
1.0 kg charcoal without fan	3.21	460:00
0.5 kg charcoal with fan	1.12	280:00
0.5 kg charcoal without fan	6.05	240:00

The kiln when operated with 1.0 kg charcoal with fan (WF), 1.5 kg without fan (WOF) and 1.5 kg with fan(WF) met the required standard of 70 ^{o}C for 3 hours in the six operations examined (FAO, 2005). Furthermore, the temperature attained by 1.5 kg with fan (WF) was too high and could cause denaturation of the fish, but the operations of the charcoal at 1.0 kg with fan (WF) and 1.5 kg without fan (WOF) were ideal for the fish smoke-drying conditions. Nevertheless, the temperature deviation of 4.15 ^{o}C within the kiln chamber at 1.5 kg charcoal loading without fan (WOF) and the cost (₦ 680.00) of operation, as compared to 1.0 kg charcoal loading with fan (WF) of temperature deviation of 1.4 ^{o}C and operation cost of ₦ 460.00 make it a better choice over 1.5 kg charcoal loading WOF and the best operating condition out of the six. Operating the smoking kiln with 1.0 kg charcoal gave the required energy for 4 hours, temperature fluctuation of 1.4 ^{o}C and cost of operation of ₦ 460.00 as compared to 4.5 hours for 1.5 kg without fan (WOF) with temperature fluctuation of 4.15 ^{o}C and operating cost of ₦ 680.00. Based on this analysis, it is proposed that the operating condition for the developed kiln should be 1.0 kg charcoal with fan (WF) which is able to give the required drying requirement, low temperature fluctuation within the drying chamber, thereby guaranteeing uniform drying and low cost of operation.

4.5.1.2 Heat Energy Distribution in the Kiln Chamber

The effectiveness of the use of the fan was seen not only in the increase of heat energy obtained by temperature increase with respect to time but in the uniformity of the heat distribution within the drying chamber. The operation of charcoal at 1.0 kg with and without fan showed that the useful heat energy was produced for 4 hours with fan as compared to 3 hours 10 minutes obtained without fan. Likewise, the temperature

fluctuation within the chamber at these conditions was 1.4 ^{o}C when operated with fan as compared to 3.21 ^{o}C when operated without fan. Hence, a fast and uniform drying of the fish was expected because of the higher and steady supply of energy. This, in the long term might transform into better and hygienic smoke dried catfish. Furthermore, it was observed that the higher the weight of the charcoal used as the power source the higher the heat energy generated in the drying chamber and the operation with fan produced more uniform energy within the kiln chamber.

4.5.1.3 Cost of Operation of Kiln With and Without Fan

It was observed that the cost of operating the kiln with fan is higher than when fan was not in operation, but this cost is not significant as compared to the benefit obtained. A packet of the battery containing 24 units cost ₦300.00 (2 USD) and can last for 40 hours in operation. Comparing this with the cost of the utilization of the battery (fan) with respect to power supply and the uniformity of heat distribution, the use of the fan is highly beneficial.

4.5.2 Fish Drying

4.5.2.1 Heat generated in the kiln under load

The thermal performance of saw dust of 0.5 kg and charcoal of 1.0 kg with fan in operation when loaded is shown in Figure 4.2. Comparing the same operation at no load, it was observed that there was a temperature drop from 130 to 70 ^{o}C at the start of operation. This sharp drop in the kiln temperature might be due to the wetness of the fresh catfish which pick-up the heat energy to equilibrate with smoking kiln. Hence there is heat transfer between the fresh catfish and the air within the smoking kiln. The catfish was

gaining heat energy, from the drying air which resulted in decrease in the temperature of the smoking kiln.

Furthermore, it was also observed from Figure 4.2, that the drying process of the catfish followed three phases. Phase I from time 0 to 110 minutes corresponds to the rise in temperature of the catfish until it reaches equilibrium with the kiln temperature. What happened at this phase was that the heat energy was used to raise the temperature of the catfish to attain the high temperature of the smoking kiln. The phase II took place between time 110 to 340 minutes of the drying process which corresponds to the evaporation of the free moisture on the surface of the catfish which are permanently renewed by the moisture coming from the inside of the catfish. This phase is the stage for proper drying of the catfish where moisture were removed from the catfish and transported to the atmosphere through the chimney. The uneven stability of the Phase II might be due to the non-uniformity of the heat energy from the charcoal which is not able to give constant air temperature and velocity during operation. The Phase III is from time 340 to 570 minutes of the drying which corresponds to the stage where the free water in the catfish has been fully evaporated and transformed to water vapor. Here the water evaporated at the surface is not seen at this point but inside as only the bound water are affected.

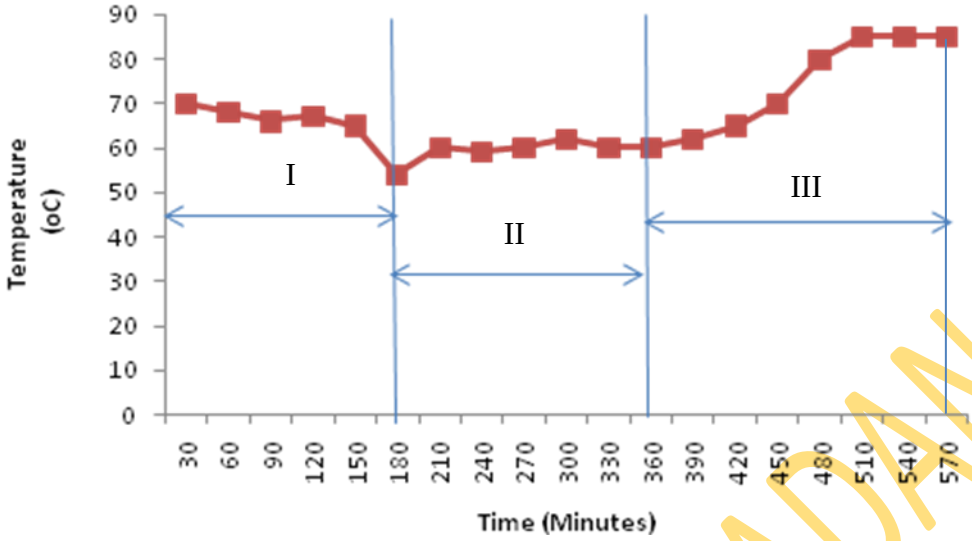

Figure 4.2: Temperature of the Smoking Kiln at Loading Condition with 1.0 kg Charcoal.

4.5.2.2 Effect of Drying on Health Status of Operators

Some of the limitations of many of the smoking kilns are the adverse effects on the health status of the operator. In the African Union Against Tuberculosis and Lung Diseases (AUATLD) conference held in Abuja in March, 2011, preliminary findings of the study conducted in Lome, Togo showed that women who are constantly exposed to smoke, heat and burnt, during the process of smoking fish are at high risk of developing chronic chest and respiratory infections (Guardian, 2011).

The smoking kiln developed for this study was able to eliminate these three problems. The provision of the chimney at the top of the combustion chamber and the operation of the kiln in close condition make the smoke not to be dispersed and hence the inhaling of smoke by the lung and eyes were eliminated. Furthermore heat and burns of the operators are reduced due to effective insulation of the kiln and its close operation. These make the use of the kiln not laborious and improve the health status of the operators which may lead to higher productivity level. The effective insulation of the kiln reduces heat losses to convention, conduction and radiation thereby conserving more energy for productive purposes.

4.5.2.3 Quality and Proximate Composition of Smoke-Dried Catfish

The initial proximate compositions of the fresh and dried catfish, which were Protein (16.3 and 68.4 %), Crude fiber (0.9 and 1.8 %), moisture content (78.0 and 7.3 %), Fat (0.5 and 12.5 %), Ash (1.3 and 6.4 %) and NFE (2.3 and 3.6 %) respectively are as presented in Figure 4.3. Furthermore, the total weight of fresh catfish of 19.284 kg was reduced to 5.076 kg of dried weight after 9 hours 30 minutes of drying as seen in the pie chart (Figure 4.4).

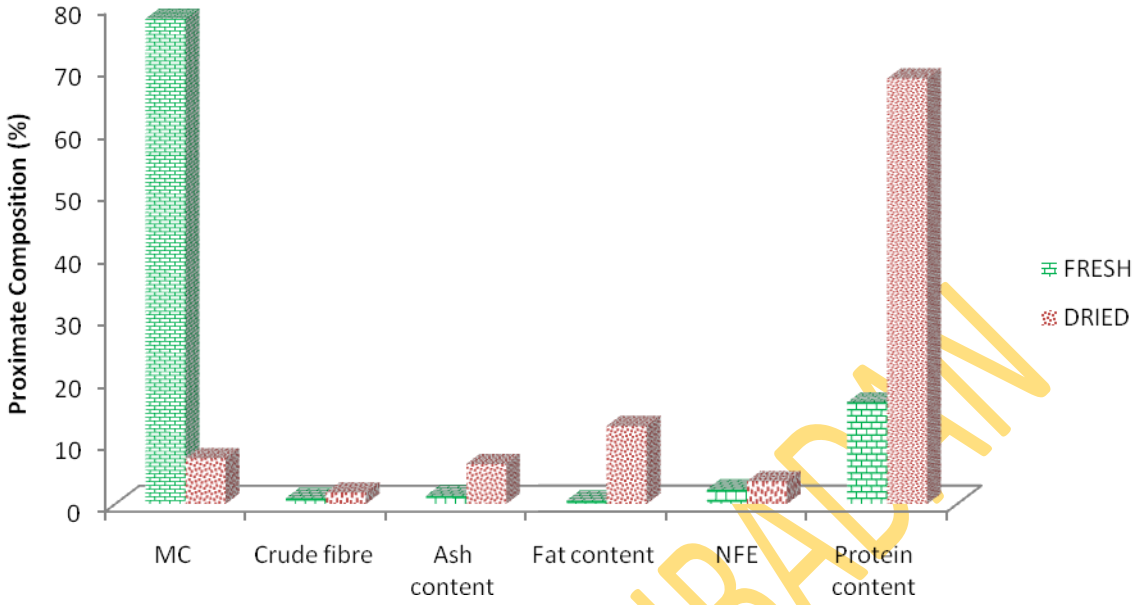

Figure 4.3: Initial Proximate Compositions of the Fresh and Dried Catfish

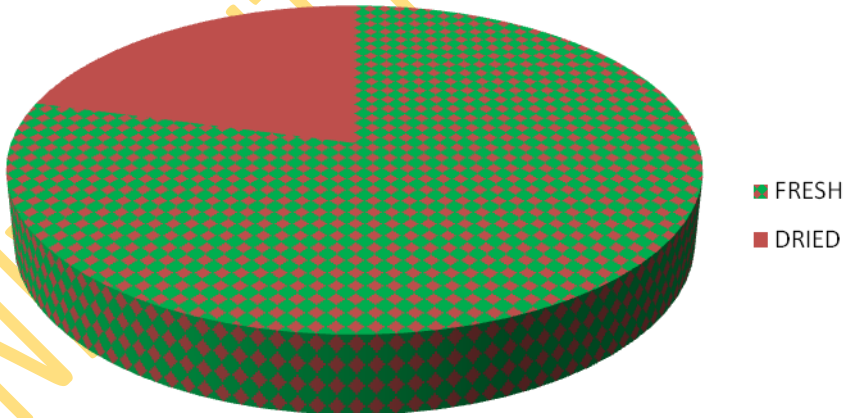

Figure 4.4: Fresh and Dried Weight of Catfish

It is evident from Figure 4.4 that fresh catfish is constituted of 75 % water and there is a need to cold treat or dehydrate immediately after harvest so as not to expose it to microbial attack and chemical decomposition.

It is evident that the smoking and drying of the catfish brought about changes in its proximate composition (Huda *et al.*, 2010, Ansari, 2004 and Akinneye *et al*., 2010). The proximate composition of the Smoked dried catfish during storage is presented in Appendix IV. There is an inverse relationship between the protein content of the fresh and dried smoked catfish on one hand and the moisture content, and fat on the other hand. The protein content of dried catfish is 68.4 % compared to 16.24 % in initial fresh catfish. This clearly shows that drying of catfish condenses the protein after the removal of water from the fish tissles. As such, the 68.4 % protein content corresponded to 7.3 % of moisture content in the dried fish; and vice versa. The 16.24 % of protein content of the fresh catfish corresponds to 78.7 % moisture. In like manner the 12.5 % fat in the dried fish corresponds to 7.3 % moisture content of dried fish and vice versa. Moisture content of 78.7 % corresponds to 0.5 % of fat. Ash content and carbohydrates 6.4 % and 1.8 % respectively for dried fish and 1.33 % and 0.92 % for fresh fish was much higher in the dried fish because of the loss of moisture through drying. The result shown in Figure 4.3, depicts that the catfish species used in this study belonged to high – protein (15 – 20 %), low – oil (≤ 5 %) category. The significant increase in protein levels ($P \leq 0.05$) in dried catfish, when compared with the raw fish, suggests that protein nitrogen was not lost during drying. This is in accordance with the findings of Puwastien *et al.* (1999); Gokoglu *et al.* (2004); Tao and Linchan (2008) and Effiong and Mohammed (2008).

The low ash, carbohydrate, fat, NFE, high protein and moisture content values obtained from the proximate analysis agreed with other analysis carried out by earlier

researchers like Olayemi *et al*. (2011b); Marnba and Jose (2005); and Abdulahi (2001). The moisture of the smoked fish which was 7.3 % falls within the allowable limit (6 - 12 %) for smoked dried fish as this is of paramount importance in preventing spoilage during storage. This observation is in agreement with the findings of Kumolu-Johnson *et al*. (2009), Salan *et al*. (2006), Adu-gyamfi (2006) and Eyabi *et al*. (2001). They reported that spoilage of fish resulting from the action of enzymes and bacteria can be slowed down by the addition of salt as well as reduction in moisture through sun drying or smoking

The initial microbial analysis of the smoked dried catfish were shown in Table 4.5. The total bacteria count of 2.0 cfn x 10^{-4}, *E.coli* 0.0 cfu x 10^{-4}, *Salmonella spp* 0.0 cfu x 10^{-4}, *Pseudomona spp* 0.0 cfu x 10^{-4} and yeast/mould 0.7 cfu x 10^{-4}. The total mean bacteria count was 2.0 x 10^{-4} colony forming unit per gram of the fish sample. This value falls within the maximum recommended value of bacteria count for good quality fish products which is 5 x 10^{-5} colony forming unit per gram according to ICMSF (2002) and the CFS (2007) which is < 10^{-6}. The result also indicated that there was no contamination with enteric organisms by handlers during smoking as there was no coliform found after smoking. The absence of *E. coli* and *Salmonella species* which are indicative organism of contamination by microorganisms from enteric origin further confirms the effectiveness of the smoking kiln in reducing microbial contamination. According to Eyo (2001) and Cutter (2002) microbial action plays a large part in the spoilage of fish and fish products. Fish smoking in the developed kiln has been able to effectively reduce this main source of spoilage. It was also noticed that *Pseudomonas*, an opportunistic bacteria in food spoilage and infection was not found (Talaro, 2009). The value of yeast/ mould recorded after smoking was also found to be within the acceptable limit. (Table 4.5). The microbial analysis of the smoke dried fish during storage is presented in Appendix V.

The sensory evaluation which was conducted on a 9 point hedonic scale of smell, texture, colour, taste and general acceptance were 6.63, 6.90, 7.78, 6.75 and 7.02 respectively (Table 4.6). The results show that the dried catfish were of good quality and can be widely accepted. Apart from the good proximate, microbial and sensory qualities, the bright brownish colour of the dried catfish in Plate 4.1 attest to the high quality product produced. This is a measure of the effectiveness of the smoking kiln which was operated under close environment with uniform heat supply due to the incorporation of the fans. This in effect leads to reduction in microbial attack which usually results in discolouration and uniformity in drying of the catfish. The variations in the sensory properties of the dried catfish during storage are presented in Appendix VI.

Table 4.5: Initial Microbial Analysis of Smoke Dried Catfish (Cfu×10^{-4})

Total Bacteria Count	E.Coli	Salmonella Spp	Psuedomonas Spp	Yeast/M
2	0	0	0	0

Table 4.6: Initial Sensory Evaluation of Smoke Dried Catfish

Parameter	Scores
Smell	6.63
Texture	6.9
Colour	7.78
Taste	6.75
General Acceptance	7.02

Plate 4.1: Smoke-Dried Catfish Product of the Study

4.6 Proximate Composition of Smoke-Dried Catfish in Storage

4.6.1 Effect of moisture content on the quality of catfish during storage

The moisture contents of smoked dried catfish stored in seven (7) different packaging materials for a period of six months are presented in Table 4.7. The initial moisture content of the dried catfish was 7.3 % before storage. However, the value of the moisture contents of the smoke-dried catfish samples in all the packaging materials increased at the first month of storage (in June); as follows: CP (9.9 %), PC (9.5 %), PaP (9.1 %), C (8.9 %), PCP (8.7 %), PPaP (7.6 %). The mean values of moisture contents for the packaging materials were 10.5, 9.7, 8.8, 9.9, 9.9, 9.2 and 9.6 for CP, PC, PCP, PaP , PPa, PPaP and C respectively. Generally, the moisture contents of the smoke dried catfish stored in the different packaging materials increases with increase in storage period for the first four months (June to September); and decreases from the fifth month of storage. The reason for this trend might be due to the water activities on the stored products. June to September was the raining season while October onward constitute dried season in Kano.

The water activity which is a function of the relative humidity is expected to be high during the raining season and low during the dry season. The implication is that the packaged catfish absorbed more moisture from the humid environment during the first four month of storage(June to September) while the products begins to loss moisture to the surrounding atmosphere as the dry season sets in. The analysis of variance of the moisture content of the smoked dried catfish stored in the different packaging materials were significantly different from each other at ($\leq$0.05) with the Cardboard–Polyethylene packaging material having the highest 10.5% moisture content followed by Paper – Polyethylene and Polyethylene – Paper Packaging Material at both 9.9% moisture content.

Table 4.7: Moisture Content (%) of Stored Catfish

Month	CP	PC	PCP	PaP	PPa	PPaP	C
0	7.3	7.3	7.3	7.3	7.3	7.3	7.3
1	9.4	9.5	8.7	9.1	9.2	7.6	8.4
2	10.1	9.7	8.1	9.6	9.9	9.1	9.9
3	11.3	9.8	8.4	9.6	9.9	9.5	9.6
4	11.1	10.1	9.5	10.2	10.3	9.2	9.9
5	10.5	9.5	9.1	10.6	10.8	10.4	10.5
6	10.4	9.8	10.0	10.3	9.4	9.3	9.1

Polyethylene – Cardboard, control (Thick Polyethylene material), Polyethylene – Paper – Polyethylene; and Polyethylene – Cardboard – Polyethylene recorded 9.7, 9.6, 9.2 and 8.8 percent respectively.

The result of the Duncan's New Mutiple Range Test(DNMRT) on the moisture content, indicates that CP differ in value from other packaging materials, while PPa and PaP were not significantly different; C, PPaP and PCP were also not significantly different from each other but are significantly different from othe packaging materials. However, it should be noted that the mean value of moisture content of fish samples stored in the different packaging materials are within the safe limit for smoke dried fish. The least moisture content of 8.8 % was recorded in Polyethylene–Cardboard–Polyethylene packaging material. The range is from 8.8 to 10.5 % for all the packaging materials. This shows that all the packaging materials have water absorbent properties which are functions of the prevailing relative humidity and water activity during the six months of storage. The resultant effect is that fish stored in the different packaging materials have tendency to absorb water which predisposes the stored fish to spoilage with time. The implication is that the packaging material with the least water absorbent property will have the tendency to prolong the shelf life of the stored fish than other materials. This is because the amount of water available for microbial activities in each pack will determine the time at which spoilage starts and the rate or extent of spoilage (Canha and Gislaine, 2008). Since the moisture content of the stored catfish for each packaging material is different it implies that the barrier properties which determine quality of fish are not the same.

Variation of the moisture content in the different pack may be due to the water activity and the effectiveness of the barrier properties of each of the packaging material;

which in turn determines the shelf life of the stored fish. Since the moisture content of the catfish stored in the different packaging materials were below the safe moisture level of 12 % (Daramola *et al.*, 2007), it means that all the packaging materials are effective but have varying barrier properties to withstand the water activities for different period of time. Also the results show that the moisture content of the stored catfish is related to the thickness and water absorption rate of the packaging materials. It is observed that the packaging materials with lower moisture contents of the stored catfish have lower water absorption rates and higher thickness. It can be established in this study that the moisture content of the stored catfish is directly proportional to the water absorption rate and inversely proportional to thickness of the packaging material. Hence packaging materials with low water absorption rate and higher thickness will offer better barrier to the environmental pressure caused by water activity as a result of prevailing relative humidity. This implies that PCP, PPaP and C packaging materials offer better barrier properties than other ones used in this study as shown by their low moisture content.

Furthermore, the variation in the moisture content of the stored catfish in different packaging material is a measure of permeability of the packaging materials. The lower the moisture content, the lower the permeation. From this study it was observed that the fish stored in thicker packaging materials have lower moisture content, after six months of storage. Hence, it can be established that as the thickness of the packaging materials (of the same size and geometry) increases the moisture content of the products strored in them decreases. Therefore, thickness of packaging material improves the barrier property. Hence, the lower water absorption rates and high thicknesses for PCP and PPaP might be the principal factors responsible for lower moisture contents in the catfish stored in these packaging materials (Masoomeh *et al*., 2010).

4.6.2 Crude Fiber Content of the Smoke-Dried Catfish in Storage.

The initial crude fiber of the catfish before storage was 1.8 %. At the first month of storage the crude fiber increased for all the samples stored in the packaging materials, as follow: CP (2.4 %), PC (2.2 %), PCP (2.0 %, PaP (2.1 %), PPa (2.4 %), PPaP (2.7 %) and C (2.3 %). At the second month of storage the crude fiber were CP (2.8 %), PC (2.5 %), PCP (2.5 %), PaP (2.4 %), PPa (2.8 %), PPaP (2.6 %) and C (2.8 %). At the third month of storage the values were CP (2.8 %), PC (2.5 %), PCP (2.3 %), PaP (3.1 %), PPa (3.0 %), PPaP(2.4 %) and C (3.4 %). At the fourth month of storage the crude fiber were CP (2.6 %), PC (2.4 %), PCP (2.6 %), PaP (2.9 %), PPa (3.4 %), PPaP (3.4 %), and C (4.6 %). At the fifth month of storage the values were CP (2.9 %), PC (2.6 %), PCP (2.5 %), PaP (3.1 %), PPa (3.3 %), PPaP(3.4 %) and C (4.8 %). At the sixth month of storage the crude fiber were CP (3.4 %), PC (3.1 %), PCP (3.0 %), PaP (3.2 %), PPa (3.6 %), PPaP (3.2 %) and C (3.7 %) with mean values of CP (2.8 %), PC (2.6 %), PCP (2.5 %), PaP (2.8 %), PPa (3.3 %), PPaP (3.0 %) and C (3.6 %).

The crude fiber content of the smoke-dried catfish is generally low with the control having the highest mean value of 3.6 %, followed by Polyethylene – Paper 3.3 %, Polyethylene – Paper–Polyethylene 3.0 %, Polyethylene – Cardboard – Polyethylene, Polyethylene – Cardboard, Cardboard – Polyethylene and Paper – Polyethylene following a narrow ranges of 2.5 to 2.8 % as shown in Table 4.8. The initial crude fiber of the smoke-dried fish is 1.8 % which is much lower than any of the fish stored in the packaging materials; which range from 2.5 to 3.6 %. The slight increase in crude fiber is likely due to the absorbent nature of the packaging materials which is also a function of relative humidity and water activities.

Table 4.8: Crude Fibre (%) of Stored Catfish

Month	CP	PC	PCP	PaP	PPa	PPaP	C
0	1.8	1.8	1.8	1.8	1.8	1.8	1.8
1	2.4	2.2	2	2.1	2.4	2.7	2.3
2	2.5	2.5	2.5	2.4	2.8	2.6	2.8
3	2.8	2.5	2.3	3.1	3	2.4	3.4
4	2.6	2.4	2.6	2.9	3.1	3.4	4.6
5	2.9	2.6	2.5	3.1	3.3	3.4	4.8
6	3.4	3.1	3	3.2	3.6	3.2	3.7

4.6.3 Ash Content of the Stored Smoke-Dried Catfish.

The initial ash content of the smoke-dried catfish before storage was 6.4 %. At one month of storage the ash content for each packaging materials were CP (6.3 %), PC (6.1 %), PCP (6.3 %), PaP (6.1 %), PPa (6.0 %), PPaP (6.1 %) and C (6.2 %). At the end of the sixth month of storage, the ash contents were CP (6.0 %), PC (5.8 %), PCP (5.8 %), PaP (5.6 %), PPa(5.9 %), PPaP (5.2 %) and C (5.3 %). All the samples stored in all the packaging materials experienced fall in mineral content. PPaP and C experienced the greatest mineral depletion, from 6.1and 6.2 % at first month to 5.2 and 5.3 % at the end of the sixth month of storage respectively. This result is in line with the finding of Fawole *et al.* (2007).

The quality of the catfish dried can be noticed in the ash content measured which has no significant difference between initial value and when in storage as seen in Table 4.9. This implies that the smoked dried catfish did not increase in ash content which could have been caused by added soot due to charring of the fish if the smoking was not properly done.

There is no significant change in the ash content may be due to the proper handling process of the catfish and the drying method and techniques used. The use of 0.5 kg of sawdust and 1.0 kg of charcoal with the fans in operation might be one of the main factors in the quality of the catfish produced. The catfish were properly harvested, cleaned and transported in iced fish boxes for smoking and drying under conducive environment that eliminate contamination by extraneous matters both at fresh and drying stages, Owaga *et al.*(2009) reported that increase in ash content in fish processing are mainly attributed to poor and improper handling.

Table 4.9: Ash Content (%) of Stored Catfish

Month	CP	PC	PCP	PaP	PPa	PPaP	C
0	*6.4*	*6.4*	*6.4*	*6.4*	*6.4*	*6.4*	*6.4*
1	6.3	6.1	6.3	6.1	6.0	6.1	6.2
2	6.4	6.4	6.6	6.7	6.1	5.8	5.0
3	6.1	6.5	6.3	6.8	6.9	6.0	5.8
4	6.5	6.3	5.4	5.8	6.4	5.2	5.0
5	6.3	6.2	6.0	5.8	5.9	5.1	5.9
6	6.0	5.8	5.8	5.6	5.9	5.2	5.3

4.6.4 Fat Content of the Stored Smoke-Dried Catfish

The initial fat content of the fresh dried catfish before storage was 12.5 %. At first month of storage the fat contents of the smoke dried catfish stored in the dirrerent packaging materials used were CP (12.1 %), PC (11.2 %), PCP (11.7 %), PaP (12.3 %), PPa (11.2 %, PPaP (11.8 %) and C (12.4 %) as shown in Table 4.10. Generally, the fat content of the smoke dried fish decreases with increase in storage period. However the highest reduction was observed in the fish samples stored in PCP cartons in which the fat content reduces from 12.5 % at the initial time to 10.6 % after the sixth month. Fish samples stored in the control do not show appreciable reduction in fat content. From the analysis of variance, there is a significant difference ($P \leq 0.05$) in the fat contents of the catfish stored in the different packaging materials.

The results show that the oil absorption rate and opacity have significant effect on the fat content of the stored catfish this because the fat content of the stored catfish is directly proportional to the oil absorption rate and transparency of the packaging materials. The control packaging material C with low oil absorption rate has higher fat content as well as the least reduction in fat content value during storage. This might be due to the transparency nature of the packaging material which allows the penetration of UV light into the stored catfish.

This observation is also confirmed by Brown and Forel (2008) and Huaixia *et al*. (2010) that UV light causes oxidation through photo-oxidative rancidity leading to fat conservation, lost of vitamins and fading of food. Furthermore, the higher fat contents in PC and PPa packaging materials as seen in the fifth month of storage might be due to their high oil absorption rate caused by the macrostructures nature of the packaging materials which has higher tendency for oil absorbent.

Table 4.10: Fat Content (%) of Stored Catfish

Month	CP	PC	PCP	PaP	PPa	PPaP	C
0	*12.5*	12.5	12.5	12.5	12.5	12.5	12.5
1	12.1	11.2	11.7	12.3	11.2	11.8	12.4
2	12	11.6	10.8	11.2	11.3	10.8	12.3
3	10.3	11.4	10.9	11.6	11.8	11.2	12.5
4	11.9	11.7	10.5	11.7	11.6	10.4	12.5
5	11.5	13.5	10.5	11.4	13.6	10.1	12.3
6	11.3	13.8	10.6	11.4	13.7	11.6	12.6

4.6.5 Protein Content of the Stored Smoke-Dried Catfish

The protein contents of the catfish stored in the different packaging materials for six months are presented in Table 4.11. The initial protein of the fresh dried catfish before storage was 68.4 %. After a month of storage the protein contents in the packaging materials were CP (69.6 %), PC (68.6 %), PCP (70.1 %), PaP (68.5 %), PPa (68.4 %), PPaP (70.2 %) and C (68.9 %) while at the end of the sixth month the protein contents were CP (61.1 %), PC (62.3 %), PCP (69.5 %, PaP (63.3 %), PPa (64.5 %), PPaP (70.2 %) and C (62.8 %). The protein content of the fish samples stored in PCP and PPaP did not reduce with increase in storage period on the other hand there were rather a little increase in the values. However, the fish samples taking from other packaging materials shows a reduction of 11.9 %, 9.8 % and 6.1 % for CP, PC and PPa respectively.

The initial fish protein content of 68.4 % was higher than the means in the control (64.4 %). Cardboard–Polyethylene (65.7 %), Polyethylene–Cardboard (66.1 %), Polyethylene - Paper (66.2 %) while Polyethylene–Cardboard–Polyethylene (71.9 %) and Polyethylene–Paper–Polyethylene, (70.2 %) were slightly higher than the initial value of 68.4 % (Figure 4.5). In the mean proximate composition (Figure 4.5), the crude protein formed the largest quantity of the dry matter in the catfish samples. This is in line with the report that protein forms the largest quantity of dry matter in fish (Pannevis, 1993). The quality reduction is in conformity with the submission of Marit *et al.* (1989) and further suggested that it might be due to combination of autolysis and rancidity in the storage.

Nevertheless, the fish stored in all the packaging materials still had good protein nutritional quality at 6 months of storage. This is in confirmation with Made *et al.* (1994) who reported the stability of crude protein in stored catfish for about six months.

Table 4.11: Protein Content (%) of Stored Catfish

Month	CP	PC	PCP	PaP	PPa	PPaP	C
0	*68.4*	*68.4*	*68.4*	*68.4*	*68.4*	*68.4*	*68.4*
1	69.6	68.6	70.1	68.5	68.4	70.2	68.9
2	68.4	68.5	78.8	68.6	68.2	71.1	65.3
3	68.2	68.0	70.9	68.1	67.5	70.6	65.5
4	66.4	63.4	71.0	66.2	63.8	70.4	62.1
5	62.8	63.4	70.9	63.9	64.8	69.4	62.1
6	61.1	62.3	69.5	63.3	64.5	69.4	62.8

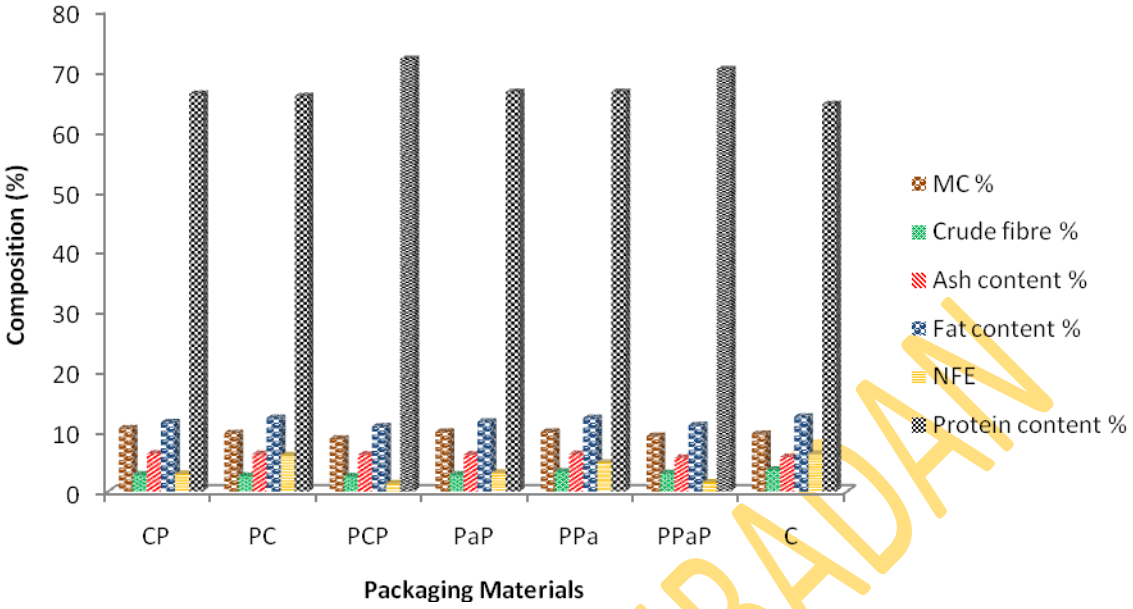

Figure 4.5: Mean Proximate Composition of Stored Catfish

The analysis of variance at ($P \leq 0.05$) shows that there is a significant difference in the protein content of the smoked dried catfish stored in different packaging materials. From the DMRT, the PCP (71.9 %) and PPaP (70.2 %) packaging materials were in the same range and conserved the crude protein intact; as compared to others which shows slight decreases; possibly due to slight fungal growth; which likely reduces the quality of the fish in term of crude protein.

4.6.6 Nitrogen Free Extract (NFE) Contents of Smoke Dried Catfish

Table 4.12 shows the values of the NFE for the catfish stored in different packaging materials for six months. The initial value of the NFE of the fresh catfish before storage was 3.6 %. At the end of first month in storage, the NFE values for the different packaging materials were CP (0.2 %), PC (3.3 %), PCP (1.2 %), PaP (1.9 %), PPa (3.6 %), PPaP (1.9 %), and C (3.8 %) while at the end of six month of storage the NFE values were CP (7.8 %), PC (9.2 %), PCP (2.1 %), PaP (6.2 %), PPa (6.9 %), PPaP (1.3 %) and C (8.9 %). The NFE content reduces for the first three months of storage in all the packaging materials except for the fish samples stored in the control which shows increase in NFE values from 3.6 % after smoking to 8.9 % after six months of storage. It is also worthy of note that the NFE content of the fish samples was not stable in all the packaging materials as the values obtained increased after the third month.

The NFE means values of smoked catfish for C (6.2 %), PC (6.0 %), PPa (4.8 %) were much higher than the initial value of 3.6 %; while PaP (3.1 %), CP (2.9 %), PPaP (1.5 %) and PCP (1.3 %) recorded much lower values than the initial. The packaging materials with higher values had a higher tendency for spoilage as indicated in PC (6.0 %), C (6.2 %); and PPa (4.8 %).

Table 4.12: NFE of Stored Catfish

Month	CP	PC	PCP	PaP	PPa	PPaP	C
0	*3.6*	*3.6*	*3.6*	*3.6*	*3.6*	*3.6*	*3.6*
1	0.2	3.3	1.2	1.9	3.6	1.9	3.8
2	0.6	3.4	1.2	1.5	2.8	1.6	4.2
3	1.4	3.6	1.2	0.8	2.9	1.1	6.2
4	1.5	8.1	1.0	3.2	6.8	1.4	7.0
5	6.0	8.7	1.2	5.2	5.6	1.6	7.4
6	7.8	9.2	2.1	6.2	6.9	1.3	8.9

This result is in line with the report of Olayemi *et al.* (2011b), that increase in protein composition showed weight gain to a negative correlation with the nitrogen free extra. This suggests that the food value of the catfish in the PPaP, PCP, PaP, and CP may be improved by the reduction of the Nitrogen Free Extra content and by increase in their protein content.

4.7 Microbial Load of Smoke Dried Catfish in Storage

The total bacteria count of the dried catfish before storage was 2 x CFU x 10^{-4}. At the end of the first month in storage the total bacteria count (TBC) of the catfish in the packaging materials were CP (9), PC (7), PCP (4), PaP (5), PPa (8), PPaP (3) and C (10) x CFU x 10-4 while in the sixth month the TBC for CP (10), PC (15), PCP (14), PaP (10), PPa (12), PPaP (10) and C (12) CFU x 10^{-4} (Table 4.13).

From the result it was observed that in all the packaging materials the total bacteria count increased from the 2nd to the 4th month of storage (July to September, 2011 which corresponds to the raining season at Kano. Hence the environment's relative humidity might be a factor for the increase of total bacteria count in stored catfish during storage. The least values recorded in PPaP and PCP might be due to their good barrier properties which have been exhibited by their low water absorption rates and higher thicknesses. Nevertheless, the increased in the total bacteria counts in the various packaging materials were still within the acceptable limit ICMSF (2002). The means total bacterial count for the packaging materials PPaP, PCP, PPa, CP, PC, PaP and C were 10, 13, 15, 16, 16, 16, and 18 CFU x 10^{-4} respectively (Appendix IV). The PPaP has the least total bacteria counts of 10 followed by PCP (13) and the control C has the highest (18).

Table 4.13: Total Bacteria Count (CFU x 10^{-4}) of Stored Catfish

Month	CP	PC	PCP	PaP	PPa	PPaP	C
0	2	2	2	2	2	2	2
1	9	7	4	5	8	3	10
2	15	15	15	15	12	10	23
3	20	22	10	16	20	15	25
4	25	23	20	25	20	10	20
5	15	15	15	25	18	12	18
6	10	10	14	10	12	10	12

The total bacterial counts which is the total number of the bacterial found on the fish sample can occur from the water, gut of the fish, equipment used, fish handlers and environment. From the results obtained it can be deduced that the moisture content and opacity have influence on the total bacterial count and there are directly related. Catfish packaged in opaque materials with low moisture content have lower bacterial count than others. This can be seen in PCP and PPaP of moisture contents of 8.8 and 9.2 % with TBC of 13 and 10 respectively while PC and PaP with moisture contents of 9.7 and 9.9 % had TBC of 15 and 16 respectively. Even though there is significant difference ($P < 0.05$) in the total bacteria count among the packaging materials, the values are all within the acceptable level.

Salmonella spp. count in all the fish samples stored in different packaging materials during the six months of storage period is shown in Table 4.14. The *Salmonella spp.* count for the dried catfish before storage was 0 CFU x 10-4. This trend was maintained in PCP and PPaP throughout the six months of storage. The PaP materials recorded 3 x CFU x 10-4 in the first and 3rd months of storage and zero values for other months. For the CP, it recorded zero count for first and 3rd months while 3, 2, 3 and 4 CFU x10-4 were recorded for 2nd, 4th, 5th and 6th months respectively. For PC packaging material it recorded zero count for 1st, 3rd, and 5th, months while 10, 10, and 4 CFU x 10-4 were recorded for 2nd, 4th, and 6th month respectively. The PPa recorded zero count for 1st month and 2, 1, 7, 1 and 1 for the subsequent months respectively. The control C recorded zero count for 1st, 3rd, and 5th month but 2 counts each for 2nd, 4th and 6th month. The mean values for PPaP and PCP were 0 each, while, CP, PPa and C had 2 respectively and PC had 4. *Salmonella species* are essentially from water contaminant with human faeces which can lead to food poisoning and thyphoid fever (Talaro, 2009).

Table 4.14: *Salmonella* Count (CFU x 10^{-4}) of Stored Catfish

Month	CP	PC	PCP	PaP	PPa	PPaP	C
0	0	0	0	0	0	0	0
1	0	0	0	3	O	0	0
2	3	10	0	0	2	0	2
3	0	0	0	3	1	0	0
4	2	10	0	0	7	0	2
5	3	0	0	0	1	0	0
6	4	4	0	0	1	0	2

All these values are still within the acceptable limit and those few packages that had some values might be due to contamination during experimental analysis since majority of the samples had zero values.

The *E.coli* count for the dried catfish before storage was 0.7 CFU x $10^{-4.}$ But during storage, no *E.coli* was present in CP. PC recorded *E.coli* count of 4 CFU x 10^{-4} each in month 2^{nd}, 3^{rd}, and 4^{th}, but no count for the other months Table 4.15. The *E.coli* level is an indication of the sanitation level of the products. Even thought there are significant different in the *E.coli* at P (≤0.05) in the packaged stored catfish the values are within acceptable limit with CN having 0, NP, 1; NC, 1; PCP; PaP and PPaP having 3 and C with 6 as their means values. The acceptable level of E.coli is an indication that the sanitation level of the production is not only good but the packaging materials were able to maintaine good sanitation during the period of storage.

The *Pseudomonas spp.* count of the dried catfish was 0.0 CFU x 10-4 before storage and this value was maintain throughout the storage in all the packaging materials (Table 4.16). There is no presence of the *Pseudomonas* in all the catfish stored in these packaging materials over the period of six months. The absence of this harmful pathogen might be due to the fact that the packaging materials does not create favourable environment for their growth during storage.

Table 4.15: *E. coli* Count (CFU x 10^{-4}) of Stored Catfish

Month	CP	PC	PCP	PaP	PPa	PPaP	C
0	0.7	0.7	0.7	0.7	0.7	0.7	0.7
1	0	0	1	2	0	0	0
2	0	4	3	2	3	3	3
3	0	4	3	3	0	2	3
4	0	0	3	4	3	3	4
5	0	0	4	3	0	1	4
6	0	4	2	4	0	3	4

Table 4.16: Psuedomonas Count (CFU x 10^{-4}) of Stored Catfish

Month	CP	PC	PCP	PaP	PPa	PPaP	C
0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0

The values of yeast/mould count for thed fish sample stored in the different packaging materials are shown in Table 4.17. The yeast/mould count for the dried catfish before storage was 0.7 CFU x 10^{-4}. The yeast/molds growth which were usually caused by equipment used in handling, handling process and environment with resultant effect of increase in mycotoxin in food leading to poisoning and gastrointestinal disorder (Hogg, 2005). The increase of the yeast/molds from the second to fifth month of storage might be due to environmental issue of higher water activities caused by high ambient relative humility during the period.

While the proximate analysis guarantees that food will be a supplement to the body it is the microbial analysis that guarantees its safety to life. Hence the presence and absence of the target food borne pathogen such as *Salmonella*, *Staphylococus* and *E.coli* are required to evaluate the safety of the smoke dried catfish which were stored. The range of specified microbiological limits recommended by ICMSF (2002) for fish and fishery products is as follows: for the TBC, the maximum recommended bacterial counts for good quality products (m) is $5x10^{-5}$ (5.7 $\log_{10}$ CFU/g) and the maximum recommended bacterial counts for marginally acceptable quality products (M) is 10 (7 $\log_{10}$ CFU/g). For *E. coli*, the m value is 11 (1.0 $\log_{10}$ CFU/g) and the M value is 500 (2.7 $\log_{10}$ CFU/g), and for *Staphylococcus*, m value is 10^3 (3 $\log_{10}$ CFU/g) (ICMSF, 2002).

The FDA and EPA safety levels relating to safety attributes of fish and fishery products published in regulations and guidance are the following: for ready-to-eat fishery products (minimal cooking by consumer), the Enterotoxigenic *Escherichia coli* (ETEC) level is $1x10^3$ ETEC/g (for *L. Monocytogenes* and *Salmonella*, the level is the presence of the organism (zero tolerance). For all fish, the *Staphylococcus aureus* safety level is equal to or greater than 10^4 /g.

Table 4.17: Yeast Count (CFU x 10^{-4}) of Stored Catfish

Month	CP	PC	PCP	PaP	PPa	PPaP	C
0	0.7	0.7	0.7	0.7	0.7	0.7	0.7
1	4	2	3	3	7	2	5
2	21	20	10	2	5	10	16
3	6	24	3	15	5	3	26
4	10	25	15	20	5	8	30
5	13	30	2	2	10	0	18
6	12	13	3	0	4	7	7

In many cases, these levels represent the point at or above which the agency will take legal action to remove products from the market (FDA, 2001). From all the pathogen analyses in the catfish stored in the packaging materials it was observed that these were found to be within the acceptable limits. Hence the packaging materials were able to preserve the microbial quality of the stored catfish for six months at the safe limits. FDA (2001) observed that Pathogen entrance to food products can occur at every process from the raw material and during processing from the air, unclean hands, unsanitary utensils and equipment, unsafe water, sewage and through cross contamination between raw and cooked product. Any pathogen introduce at any of this stage has the capacity to develop and grow during storage.

The mean microbial load with respect to the packaging materials during the storage are presented in Figure 4.6 . The initial microbial loads for the dried sample were 2 x cfn x 10^{-4} for TBC (Total bacteria count) and 0.7 cfu x 10^{-4} for yeast/mould while *E.coli*, *Salmonella* spp. and *Pseudomona* had no microbial load. This suggests that the catfish handling, processing and smoking and drying were done properly as this fall within acceptable limits. It is evident that bacteria and yeast/mould were the main problematic microbial organisms associated with the storage of the catfish. If the packages were subjected to the prevailing condition more than six months the products in some of the packaging materials might fail microbiologically. This might render the products unsafe for human consumption even though the products have acceptable proximate values. Also packaging PCP and PPaP have no microbial load and therefore more stable microbiologically.

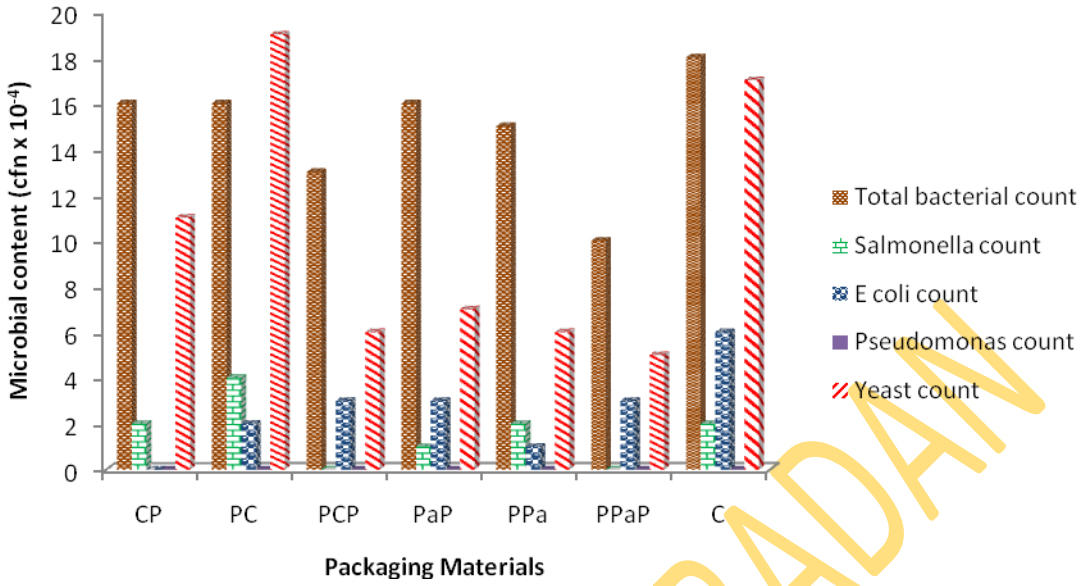

Figure 4.6: Mean Microbial Analysis of Stored Catfish

4.8 Sensory Evaluation of the Stored Smoke-Dried Catfish

Spoilage in fish products might be caused by biochemical or microbial reactions of which analysis takes time and expertise. This mechanism might be difficult to identify but sensory evaluation is always a direct or indirect way to access the quality of food products especially at the point of purchase. The initial sensory evaluation of the initial sample which gave the rating for smell, texture, colour, taste and general acceptance as 6.63, 6.90, 7.78, 6.75 and 7.02 respectively in the hedonic scale of 9 were satisfactory going by the assessment of the panellists.

4.8.1 Taste of Stored Smoke-Dried Catfish

Table 4.18 shows the values of the sensory evaluation for the taste of the catfish stored in different packaging materials for six months. The initial value for the sensory evaluation for taste before storage was 6.75. At the first month of storage the taste sensory evaluation for the packaging materials were CP (5.30), PC (5.62), PCP (7.05), PaP (5.10), PPa (5.79), PPaP (7.09) and C (5.95 while at the end of six month of storage the values were CP (6.21), PC (4.05), PCP (7.13), PaP (5.61), PPa (4.02), PPaP (6.94) and C (3.98). The mean values for taste sensory evaluations were, CP (5.78), PC (4.57), PCP (6.63), PaP (5.74), PPa (4.74), PPaP (7.06) and C (4.54), all at the scale of 9.

There are significant differences in the taste of the catfish within the packaging materials at the end of the study. Packaging materials PCP, PPaP and CP which scored 7.21, 6.90 and 6.02 respectively rank well with the initial reading of 6.63 as shown in Appendix V. The taste of the catfish in storage has inverse relationship with fat content. It has been established in this study that the fat content of the stored catfish is related to the oil absorption rate and opacity of the packaging materials. It is obvious from Figure 4.7 that the taste of fish samples stored in PCP and PPaP are better than the other ones because of their low fat content and oil absorption rate. Likewise, the lower ranking for PaP, PC, PPa and C might be due to the same factors. Oil stain was observed in packaging materials from the stored fish which ooze out of PC and PPa after 5 months of storage. The transparency of the control may also increase the oxidation as the fat content of the control is higher than all the packaging (Lagaron *et al*., 2005).

Table 4.18: Sensory Evaluation (Taste) of Stored Catfish

Month	CP	PC	PCP	PaP	PPa	PPaP	C
0	6.75	6.75	6.75	6.75	6.75	6.75	6.75
1	5.3	5.62	7.05	5.1	5.79	7.09	5.95
2	6.73	4.94	6.95	6.02	4.88	7.13	4.55
3	5.68	4.49	4.64	5.91	5.83	6.99	4.63
4	5.36	4.31	7	5.73	4.18	7	4.13
5	5.39	4	7.01	6.05	3.76	7.21	4.01
6	6.21	4.05	7.13	5.61	4.02	6.94	3.98

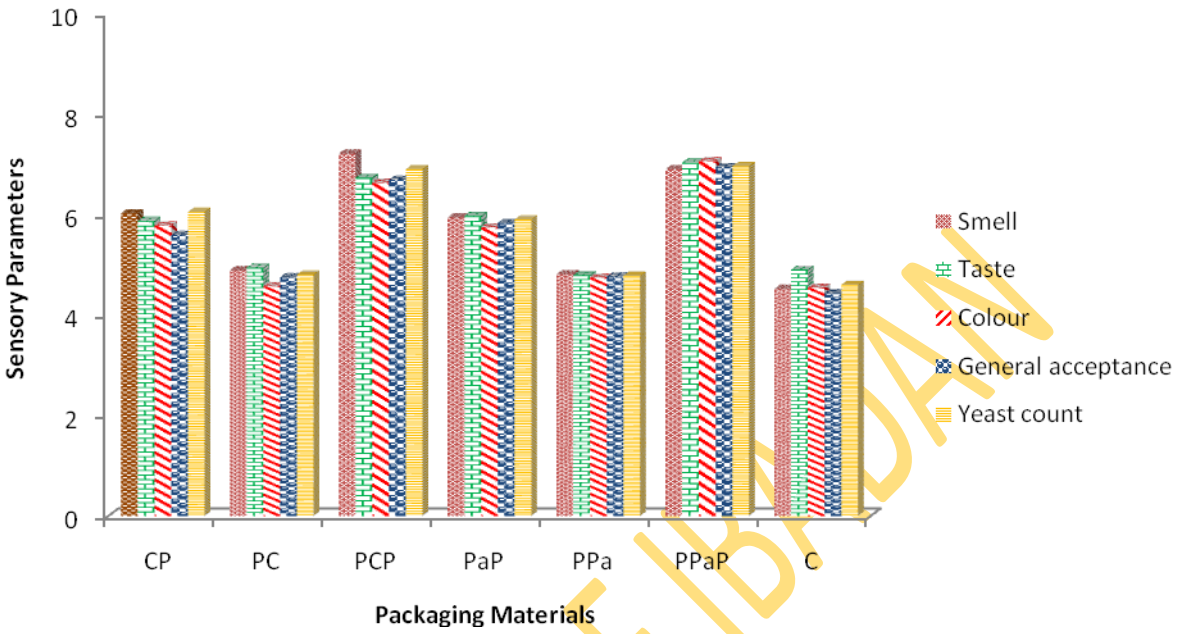

Figure 4.7: Mean Sensory Evaluation of Stored Catfish

4.8.2 Texture of the Stored Smoked-Dried Catfish

At the end of the first month of storage the sensory evaluation of texture were CP (6.10), PC (5.33), PCP (7.10), PaP (6.60), PPa (5.4), PPaP (6.87) and C (6.33) while For the sixth month the values were CP (5.73), PC (4.71), PCP (7.48), PaP (6.67), PPa (4.51), PPaP (7.11) and C (4.61). The mean values were CP (5.87) PC (4.94), PCP (6.73), PaP (5.97), PPa (4.79), PPaP (7.03) and C (4.90), all in the scale of 9 (Table 4.19).

The texture of the smoke dried catfish stored in PPaP and PCP ranked well with the initial quality sample. Significant difference exists in the texture of the catfish stored in the different packaging materials over the storage period. This result shows that the texture of the stored catfish is closely related to the moisture content. It has also been established in this study that the water absorption rate and the thickness of the packaging materials affect the moisture content of the stored catfish. This is expected as the water activity of the fish which is a function of its moisture content will create equilibrium with the environment inside the packaging material (Kok *et al.*, 2009). Hence a low moisture product will produce a dried environment and firm texture for the product; likewise a high moisture product will produce a wet environment and wet texture for the product. The better performance of PPaP and PCP in texture might be due to their low moisture content brought about through their properties of higher thickness and lower water absorption rate as compared to the other packaging materials.

Table 4.19: Sensory Evaluation (Texture) of Stored Catfish

Month	CP	PC	PCP	PaP	PPa	PPaP	C
0	6.9	6.9	6.9	6.9	6.9	6.9	6.9
1	6.1	5.33	7.1	6.6	5.24	6.87	6.33
2	6.01	5.69	6.92	5.59	4.93	7.21	4.65
3	5.62	5.03	6.1	6.2	5.69	6.93	5.03
4	5.43	4.49	6.21	5.65	4.35	6.75	4.73
5	6.34	4.41	6.59	5.12	3.99	7.33	4.02
6	5.73	4.71	7.48	6.67	4.51	7.11	4.61

4.8.3 Smell of the Stored Catfish.

The results of the sensory evaluation of smell in all the packaging for the period of storage were shown in Table 4.20. The initial smell evaluation before storage was 6.63. In the first month of storage the smell evaluation for all the fish samples stored in the packaging materials were CP (5.98), PC (5.03) PCP (6.99), PaP (5.73), PPa (5.21), PPaP (6.43) and C (5.02) while the values for the six month were CP (6.54), PC (5.00), PCP(7.27), PaP (5.94), PPa (4.22), PPaP (6.93) and C (4.33). The mean values of smell sensory evaluation for the packaging materials were CP (6.02), PC (4.89), PCP (7.21), PaP (5.94), PPa (4.81), PPaP (6.90) and C (4.42), all values on the scale of 9.

The smell of the catfish in storage is closely related to the moisture in take, bacterial activity and fat content. From this study it has been established that these are attribute of the thickness, water and oil absorption rates of the packaging materials. The higher the thickness and the lower the water and oil absorption rates the better the smell of the stored catfish.

Table 4.20: Sensory Evaluation (Smell) of Stored Catfish

Month	CP	PC	PCP	PaP	PPa	PPaP	C
0	6.63	6.63	6.63	6.63	6.63	6.63	6.63
1	5.98	5.03	6.99	5.73	5.21	6.43	5.02
2	6.5	5.56	7.41	6.42	5.36	7.02	4.63
3	5.61	4.69	6.92	6.03	6.02	7.61	4.99
4	5.94	5.02	6.99	5.31	4.34	6.75	4.48
5	5.52	4.03	7.66	6.22	3.69	6.67	3.67
6	6.54	5.00	7.27	5.94	4.22	6.93	4.33

4.8.4 Colour of the Stored Smoke-Dried Catfish

After one month of storage the values for the sensory evaluation of colour were CP (6.33), PC (5.66), PCP (7.36), PaP (6.48), PPa (5.66), PPaP (7.21) and C (5.42) while at the six month of storage the values were CP (5.04), PC (4.21), PCP (6.03), PaP (6.01), PPa (4.12), PPaP (7.04) and C (4.92). The mean values for the colour sensory evaluation were CP (5.59), PC (4.75), PCP (6.69), PaP (5.83), PPa (4.76), PPaP (6.94) and C (4.43); all at the scale of 9 as shown in Table 4.21.

The colour of the stored catfish shows that the PCP and PPaP had bright colours. The bright colour might be related to the microbial load of the catfish. Catfish stored in packaging materials with low microbial loads have better colours as seen in PCP and PPaP materials.

Table 4.21: Sensory Evaluation (Colour) of Stored Catfish

Month	CP	PC	PCP	PaP	PPa	PPaP	C
0	7.78	7.78	7.78	7.78	7.78	7.78	7.78
1	6.33	5.66	7.36	6.48	5.66	7.21	5.42
2	5.62	4.97	7.09	6.23	5.15	6.63	4.03
3	5.99	5.22	5.91	5.53	4.89	7.15	4.33
4	5.2	4.36	6.33	5.12	4.85	7.23	4.28
5	5.37	4.09	6.43	5.62	3.9	6.38	3.6
6	5.04	4.21	6.03	6.01	4.12	7.04	4.92

4.8.5 General Acceptance of the Stored Smoke-Dried Catfish

The values of general acceptance of the fish samples at the end of the first month of storage were CP (5.93), PC (5.41), PCP (7.13), PaP (5.98), PPa (5.48), PPaP (6.90) and C (5.68) while after the sixth month the values were CP (5.88), PC (4.50), PCP (6.98), PaP (6.06) PPa (4.22), PPaP (7.01) and C (4.46). The mean values for the sensory evaluation for general acceptance were CP (6.05), PC (4.80), PCP (6.90), PaP (5.90), PPa (4.78), PPaP(6.96) and C (4.60) all values at the scale of 9 as shown in Table 4.22.

In all parameters of sensory evaluations, it was observed that the PCP and PPaP packaging materials ranked best and the most accepted of all the seven packaging materials. This was also confirmed in the panellists rating of the general acceptance evaluation. It was also observed that the catfish stored in the control has the least means values of all the sensory attributes. The only implicative tendency might be due to the transparency nature of the materials used as control. The result in this study shows that not only engineering properties alone that affects the keeping qualities of stored catfish but the opacity property.

Table 4.22: Sensory Evaluation (General Acceptance) of Stored Catfish

Month	CP	PC	PCP	PaP	PPa	PPaP	C
0	7.02	7.02	7.02	7.02	7.02	7.02	7.02
1	5.93	5.41	7.13	5.98	5.48	6.90	5.68
2	6.21	5.29	7.10	6.07	5.08	7.00	4.49
3	7.16	4.89	6.64	5.92	5.61	7.17	4.75
4	5.48	4.55	6.65	5.65	4.43	6.93	4.41
5	5.66	4.13	6.92	5.75	3.83	6.90	3.83
6	5.88	4.50	6.98	6.06	4.22	7.01	4.46

4.9 Final Evaluation of Packaging Materials

Six composite packaging materials were evaluated with the traders' practice of Polyethylene material in this study. These packaging materials were able to keep the quality of the smoked catfish effectively for different period ranging from four to six months. The use of the PCP and PPaP packaging materials were found most effective with at least six month of storage. All the packaging materials used in this study are available and cheap with adequate impact resistance weight(IRW). The better performance of PCP and PPaP packaging materials might be attributed to their enhanced physical properties over the other packaging materials. Apart from their non transparent advantage over the control they have higher thickness and lower water and oil absorption rates than all the other composite packaging materials. These enhanced physical properties increased their barriers properties and enable them to withstand the dynamic environmental conditions such as temperature, light, humidity and gases. The resultant effect were the attainment of good quality factors like lower moisture content, high protein content, low microbial loads and good sensory evaluations as shown in the presented results. The performance of both packaging materials ranked close in term of quality preservation but the lower cost of the PCP to PPaP gave it an edge.

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

This study has established that packaging materials with improved characteristics in terms of engineering and chemical properties can be developed from the available materials in the market. For optimum result, the combination of available materials resulting into composite packaging materials will enhance the quality of the materials for better results. This is because a material that is for instance lacking in strength may have high barrier to moisture permeability. Combining the materials thus increase the strength of the materials while limiting their weaknesses. These composite packaging materials can be produced at a relatively low cost which can be afforded by 'would be' users. The use of composite packaging materials have shown that dried fish can be stored for between four to six months in good quality. With the drying of fish carried out in an hygienic way using appropriate drying techniques as used in the study, the risk of insect attack and microbial contamination can be completely removed in storage of dried fish in as much as a composite packaging material made of either polythene – paper - polythene or polythene – cardboard - polythene is used.

Furthermore the packaging materials developed from this study can be used as retail container to improve marketing of dried fish. This can be displayed on shelves in super markets if proper labeling is done. This will go a long way in providing good quality dried fish for people especially the elites who like the bite of smoked fish but are avoiding it due to the bad quality of available ones sold in the open market.

This development will not only lead to availability of good quality dried fish but will also lead to increase market as entrepreneurs can invest in the production of composite packaging materials for fish processors, while the exportation of smoked fish will then become a business with less risk as the quality of the smoked fish can be guaranteed for the period between processing and shipment and also maintain the quality during marketing abroad. This will give a major boost to our non-oil export market which is one of the ways of achieving the diversification of Nigerian economy.

The implication from the results of this study is that more jobs can be generated from the fishing industry. While some investors can invest in the production of composite packaging materials, others can develop market outlet (super market sales) for good quality dried fish within the country with some other ones engaging in the fabrication of improved smoking kilns for fish processors.

However, it must be noted that since the quality of smoked fish cannot be improved upon during storage irrespective of the quality of packaging materials used, there is need to commercialize the use of improved smoking kilns. This will go a long way in ensuring that evenly dried smoked fish is achievable. The quality of smoked fish can then be maintained during storage if they are stored in composite packaging materials.

5.2 Recommendations

For the needed change which this study aimed at achieving in the academic circle as well as among fish processors, farmers should be made to have access to the results of this study. Although the smoking kiln used for this study performed optimally under the conditions investigated, there is the need to experiment with another form of energy source. This is because with the direct impact of global warming looming on the country

we can no longer afford the continous cutting of trees for firewood or charcoal in the name of providing fuel. For better quality smoke dried fish, controlled smoking should be encouraged among fish processors. This will improve the quality of smoked fish in the country as well as reducing wood usage which has been the trend in other parts of the world.

Investors should be encouraged to invest in the commercialization of the two packaging materials that have proven to guarantee better quality of smoked fish during storage. When this is done, marketers and processors will willingly accept the use of the materials as long as the availability can be sustained. In this regard farmers' cooperatives should take the idea of investing in this area instead of everybody doing the same thing. This will remove glut in the market and open up the value chain.

The analysis of Polycyclic Aromatic Hydrocarbons (PAH) (which have been proven to be carcinogenic) present in smoked fish should be studied further. This is necessary to determine the permissible level of these substances in smoked fish when this is done processors can be trained on the level of smoke that should be used during fish smoking. This will help in reducing the health hazards that can be associated with the consumption of smoked fish.

For further studies the thickness of materials used in the development of the composite packaging materials should be varied. This will provide further results that will be useful in making the production of composite materials a profitable venture.

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APPENDICES

APPENDIX I: UNIT COST OF PACKAGING MATERIALS

Cost of packaging material is broken into the summation of

(i.) Cost of the materials =cm

(ii.) Cost of lamination = cl

(iii.) Labour cost= Lc

PCP = cm + cl + Lc

= 12 + 8+5.80

= ₦ 25.80

PC = 6 + 8+ 2.80

= ₦ 16.80

CP =6 + 8+ 2.80

= ₦ 16.80

PPaP = 12 + 10 +10

= ₦ 32.00

PPa = 6 + 10 + 4

= ₦ 20

PaPa = 6 + 10 + 4

= ₦ 20

C = 7 + 0 + 3

= ₦10.00

APPENDIX II: DESIGN CONSIDERATIONS AND CALCULATIONS FOR THE CONSTRUCTION OF THE SMOKIN KILN

Design considerations

Quantity of Fish to be dried: 25 kg

Duration of drying : 9 hrs

Local climate conditions : Temperature 28^{o}C and 70% rh.

Initial moisture content of fresh fish: 78%

Expected Final moisture content : 10%

Drying temperature : 85^{o}C

Mass of water to be removed

Mass of water to removed:

$M_w = mi \frac{(Mo-Mf)}{100-Mf}$

$= 25 \frac{(78-10)}{100-10}$

$= 25 \frac{(68)}{90}$

$= 18.89$ kg

Quantity of air required for drying

Using the relationship;

$Ma\ Cpa\ (T_B - T_C) = MwL$

Where Ma = mass of drying air

Cpa = Specific heat capacity of air at constant pressure.

T_B = Initial temperature of air ^{o}C

T_C= Final air temperature ^{o}C

Mw = mass of moisture to be removed.

L = Latent heat of evaporation of water.

From the relationship:

$Ma = \frac{MwL}{Cpa\ (TB-TC)}$

Mw = 18.90 kg

L=2257 kJ/kg

Cpa = 1.009 kJ/kg.k

T_B= 28^{o}C

T_c = 85^{o}C

$Ma = \frac{2257 \times 18.90}{1.009 \times 57}$

=782.90 kg;

Duration of drying = 9hrs;

Ma= mass flow rate

$= \frac{782.90}{9}$ =86.99kg/hr

$= \frac{86.99}{3600}$ =0.0242 kg/s.

Quantity of heat = Q

Q= Ma (h_2-h_1)

Where (h_2-h_1) = change in Enthalpy

h_2 = Enthalpy at 85^{o}C

h_1=Enthalpy at 28^{o}C

h=1.007 × t – 0.026

h_2 = 1.007 × 85 – 0.026 = 85.568

h_1 = 1.007 × 28 -0.026 = 28.17

h_2 -h_1 = 85.568-28.17

= 57.398 kJ/kg

$Q = Ma\ (h_2-h_1)$

= 0.0242 kg/s × 57.398 kJ/kg

= 1.389 kJ/s

= 1.4 kJ /s $\equiv 1.4\ kW$

Charcoal will supply this energy. Calorific value of charcoal = 7000kcal/kg = 29307.6 kJ

Dimensionning the drying cabinet

Mass per Tray ; 6.25 kg

Average size of fish = 350g

Average No. of fish /Tray = 18

Thickness of fish = 30 mm

Average length of fish =300 mm (with the head cut off)

Average clearance btw fish =10 mm

Arrangement 2 rows:

Tray Dimension 580 mm × 580 mm

No. of fish per row $=\frac{580}{5} = 9$

Average = 9

Space to be occupied = (9×5 cm) + 10 cm

= 45+10= 550 mm

Length = 26+26+2 = 540 mm

Required area of tray = 550 mm × 550 m m

Tray dimension = 580 mm x 580 mm

Total height of the dryer:

Combust chamber= 400 × 400 × 220 mm

Space between combustion chamber and the first tray = 200 mm

Thickness of the tray frame; 25mm

Total space occupied by trays 25 x 4 = 100 mm

Interspacing between the trays = 200 mm

Drying chamber = 580 × 580 × 900mm

The internal dimension of the dryer is 600 x 600 x 1200 mm.

APPENDIX III: TEMPERATURE AND TIME MEASUREMENT OF SMOKING KILN ON NO LOAD

Appendix IIIa: Temperature in the fish smoking kiln using 0.5kg of sawdust and 0.5kg charcoal with and without fan operations

Time (min)	Temperature without Fan (^{O}C)	Temperature with Fan (^{O}C)
0	104 ± 11.43	110.00 ± 1.31
15	103.33± 8.08	105.33 ± 1.62
30	83.33 ± 7.57	101.33 ± 1.15
45	69.33 ± 5.03	99.33 ± 1.15
60	60.00 ± 2.00	96.67 ± 1.15
75	52.67 ± 12.7	91.33 ± 1.15
90	43.33 ± 3.05	88.67 ± 1.15
105	40.67 ± 2.31	84.67 ± 1.31
120	40.00 ± 2.00	79.33 ± 1.15
135	37.33 ± 2.15	76.00 ± 1.00
150	35.33 ± 2.15	72.67 ± 1.05
165	34.00 ± 2.00	60.67 ± 1.15
180		54.67 ± 1.05
195		52.67 ± 1.15
210		44.00 ± 2
225		44.00 ± 2.46
240		41.33 ± 2.31

Appendix IIIb: Temperature obtained in the fish smoking kiln using 0.5 kg of sawdust and 1.0 kg charcoal with and without fan operations

Time (min)	Temperature without Fan (^{O}C)	Temperature with Fan (^{O}C)
0	150.00 ± 17.32	164.00 ± 2.50
15	112.67 ± 4.16	142.67 ± 2.43
30	103. ± 4.16	137.33 ± 2.32
45	98.00 ± 4.00	135.33 ± 2.03
60	90.67 ± 4.15	135.33 ± 1.76
75	90.67 ± 3.56	127.33 ± 1.15
90	87.33 ± 3.26	116.00 ± 1.29
105	82.00 ± 3.00	106.67 ± 1.11
120	80.67 ± 2.31	108.67 ± 1.15
135	74.67 ± 2.15	105.33 ± 1.57
150	70.67 ± 2.15	100.07 ± 1.15
165	70.67 ± 2.15	103.33 ± 1.16
180	70.67 ± 2.15	100.67 ± 1.05
195	65.33 ± 3.60	98.00 ± 1.00
210	62.00 ± 2.50	91.33 ± 1.31
225	57.33 ± 2.15	83.33 ± 1.16
240	50.67 ± 2.31	84.00 ± 1.00
255	50.67 ± 2.31	78.00 ± 1.00
270	41.33 ± 2.31	70.00 ± 1.00
285	39.3 2.31	62.67 ± 1.05
300	39.33 ± 1.15	57.33 ± 1.05
315		52.00 ± 1.00

Appendix IIIc: Temperature in the fish smoking kiln using 0.5kg of sawdust and 1.5kg charcoal with and without fan operations

Time (min)	Temperature without Fan (^{O}C)	Temperature with Fan (^{O}C)
0	152.167 ± 6.43	168.67 ±2.08
15	150.00 ± 6.00	168.67 ±2.08
30	134.67 ± 8.32	164.67 ± 2.06
45	132.00 ± 7.21	162.67 ± 1.62
60	132.67 ± 5.06	156.00 ± 2.00
75	121.33 ± 4.16	150.67 ± 2.15
90	103.33 ± 4.16	150.00 ± 2.00
105	100.00 ± 3.00	142.00 ± 1.15
120	102.00 ± 6,00	150.00 ± 2.00
135	100.00 ± 3.00	142.00 ± 2.46
150	93.33 ± 3.15	132.67 ± 2.15
165	90.67 ± 3.15	122.00 ± 2.00
180	88.67 ± 3.15	116.00 ± 1.29
195	86.00 ± 3.00	96.67 ± 1.16
210	82.67 ± 3.15	92.67 ± 1.31
225	80.67 ± 3.35	86.00 ± 1.00
240	78.00 ± 3.00	82.00 ± 1.00
255	75.33 ± 2.31	79.33 ± 1.15
270	72.00 ± 2.00	80.00 ± 1.00
285	68.00 ± 2.00	72.00 ± 1.00
300	64.00 ± 2.00	68.67 ± 1.31
315	60.00 ± 2.00	64.00 ± 2.00
330	56.67 ± 2.31	60.67 ± 1.15
345	54.67 ± 2.15	54.67 ± 1.15
360	51.33 ± 2.15	49.33 ± 1.15
375	49.33 ± 2.15	49.33 ± 1.31
390	44.67 ± 2.15	46.67 ± 1.05
405	42.00 ± 2.00	44.00 ± 1.00
420	42.00 ± 2.00	42.00 ± 1.46
435	39.33 ± 2.15	40.67 ± 1.05
450	40.67 ± 1.75	

Appendix IIId: Temperature of smoking kiln during drying

Time (min)	Temperature ^{o}C
0	35
30	70
60	68
90	66
120	67
150	65
180	54
210	60
240	59
270	60
300	62
330	60
360	60
390	62
420	65
450	70
480	80
510	85
540	85
570	85

APPENDIX IV: PROXIMATE COMPOSITION OF STORED CATFISH

	Mth	CN	NC	NCN	PN	NP	NPN	C
	0	*7.3*	7.3	7.3	7.3	7.3	7.3	7.3
	1	9.4	9.5	8.7	9.1	9.2	7.6	8.4
Moisture	2	10.1	9.7	8.1	9.6	9.9	9.1	9.9
content	3	11.3	9.8	8.4	9.6	9.9	9.5	9.6
(%)	4	11.1	10.1	9.5	10.2	10.3	9.2	9.9
	5	10.5	9.5	9.1	10.6	10.8	10.4	10.5
	6	10.4	9.8	9	10.3	9.4	9.3	9.1
	MEAN	***10.5***	9.7	8.8	9.9	9.9	9.2	9.6
	0	1.8	1.8	1.8	1.8	1.8	1.8	1.8
	1	2.4	2.2	2.0	2.1	2.4	2.7	2.3
Crude	2	2.5	2.5	2.5	2.4	2.8	2.6	2.8
fibre (%)	3	2.8	2.5	2.3	3.1	3.0	2.4	3.4
	4	2.6	2.4	2.6	2.9	3.1	3.4	4.6
	5	2.9	2.6	2.5	3.1	3.3	3.4	4.8
	6	3.4	3.1	3.0	3.2	3.6	3.2	3.7
	Mean	**2.8**	**2.6**	**2.5**	**2.8**	**3.3**	**3.0**	**3.6**
	0	6.4	6.4	6.4	6.4	6.4	6.4	6.4
	1	6.3	6.1	6.3	6.1	6.0	6.1	6.2
	2	6.4	6.4	6.6	6.7	6.1	5.8	5.0
Ash	3	6.1	6.5	6.3	6.8	6.9	6.0	5.8
content	4	6.5	6.3	5.4	5.8	6.4	5.2	5.9
(%)	5	6.3	6.2	6.0	5.8	5.9	5.1	5.9
	6	6.0	5.8	5.8	5.6	5.9	5.2	5.3
	Mean	**6.3**	**6.2**	**6.1**	**6.1**	**6.2**	**5.6**	**5.7**
	0	12.5	12.5	12.5	12.5	12.5	12.5	12.5
	1	12.1	11.2	11.7	12.3	11.2	11.8	12.4
Fat	2	12.0	11.6	10.8	11.2	11.3	10.8	12.3
content	3	10.3	11.4	10.9	11.6	11.8	11.2	12.5
(%)	4	11.9	11.7	10.5	11.7	11.6	10.4	12.5
	5	11.5	13.5	10.5	11.4	13.6	10.1	12.3
	6	11.3	13.8	10.6	11.4	13.7	11.6	12.6
	Mean	**11.5**	**12.2**	**10.8**	**11.6**	**12.2**	**11.0**	**12.4**
	0	3.6	3.6	3.6	3.6	3.6	3.6	3.6
	1	0.2	3.3	1.2	1.9	3.6	1.9	3.8
	2	0.6	3.4	1.2	1.5	2.8	1.6	4.2
	3	1.4	3.6	1.2	0.8	2.9	1.1	6.2
NFE	4	1.5	8.1	1.0	3.2	6.8	1.4	7.0
	5	6.0	8.7	1.2	5.2	5.6	1.6	7.4
	6	7.8	9.2	2.1	6.2	6.9	1.3	8.9
	Mean	**2.9**	**6.0**	**1.3**	**3.1**	**4.8**	**1.5**	**6.2**
	0	68.4	68.4	68.4	68.4	68.4	68.4	68.4
	1	69.6	68.6	70.1	68.5	68.4	70.2	68.9
	2	68.4	68.5	78.8	68.6	68.2	71.1	65.3
Protein	3	68.2	68.0	70.9	68.1	67.5	70.6	65.5
content	4	66.4	63.4	71.0	66.2	63.8	70.4	62.1
(%)	5	62.8	63.4	70.9	63.9	64.8	69.4	62.1
	6	61.1	62.3	69.5	63.3	64.5	69.4	62.8
	Mean	**66.1**	**65.7**	**71.9**	**66.4**	**66.4**	**70.2**	**64.4**

APPENDIX V: MICROBIAL ANALYSIS OF STORED CATFISH

	Month	CN	NC	NCN	PN	NP	NPN	C
Total bacteria count	*0*	2	2	2	2	2	2	2
	1	9	7	4	5	8	3	10
	2	15	15	15	15	12	10	23
	3	20	22	10	16	20	15	25
	4	25	23	20	25	20	10	20
	5	15	15	15	25	18	12	18
	6	10	15	14	10	12	10	12
	Mean	**16**	**16**	**13**	**16**	**15**	**10**	**18**
Salmonella count	0	0	0	0	0	0	0	0
	1	0	0	0	3	0	0	0
	2	3	10	0	0	2	0	2
	3	0	0	0	3	1	0	0
	4	2	10	0	0	7	0	2
	5	3	0	0	0	1	0	0
	6	4	4	0	0	1	0	2
	Mean	**2**	**4**	**0**	**1**	**2**	**0**	**2**
E. coli count	0	0.7	0.7	0.7	0.7	0.7	0.7	0.7
	1	0	0	1	2	0	0	0
	2	0	4	3	2	3	3	3
	3	0	4	3	3	0	2	3
	4	0	0	3	4	3	3	4
	5	0	0	4	3	0	1	4
	6	0	4	2	4	0	3	4
	Mean	**0**	**2**	**3**	**3**	**1**	**3**	**6**
Pseudomonas count	0	0	0	0	0	0	0	0
	1	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0
	3	0	0	0	0	0	0	0
	4	0	0	0	0	0	0	0
	5	0	0	0	0	0	0	0
	6	0	0	0	0	0	0	0
	Mean	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Yeast count	0	0.7	0.7	0.7	0.7	0.7	0.7	0.7
	1	4	2	3	3	7	2	5
	2	21	20	10	2	5	10	16
	3	6	24	3	15	5	3	26
	4	10	25	15	20	5	8	30
	5	13	30	2	2	10	0	18
	6	12	13	3	0	4	7	7
	Mean	**11**	**19**	**6**	**7**	**6**	**5**	**17**

APPENDIX VI: SENSORY EVALUATION OF STORED CATFISH

	Month	CN	NC	NCN	PN	NP	NPN	C
	0	6.633	6.63	6.63	6.63	6.63	6.63	6.63
	1	5.98	5.03	6.99	5.73	5.21	6.43	5.02
Sensory evaluation of smell	2	6.50	5.56	7.41	6.42	5.36	7.02	4.63
	3	5.61	4.69	6.92	6.03	6.02	7.61	4.99
	4	5.94	5.02	6.99	5.31	4.34	6.75	4.48
	5	5.52	4.03	7.66	6.22	3.69	6.67	3.67
	6	6.54	5.00	7.27	5.94	4.22	6.93	4.33
	Mean	**6.02**	**4.89**	**7.21**	**5.94**	**4.81**	**6.90**	**4.52**
	0	6.90	6.90	6.90	6.90	6.90	6.90	6.90
	1	6.10	5.33	7.10	6.60	5.24	6.87	6.33
Sensory evaluation of texture	2	6.01	5.69	6.92	5.59	4.93	7.21	4.65
	3	5.62	5.03	6.10	6.20	5.69	6.93	5.03
	4	5.43	4.49	6.21	5.65	4.35	6.75	4.73
	5	6.34	4.41	6.59	5.12	3.99	7.33	4.02
	6	5.73	4.71	7.48	6.67	4.51	7.11	4.61
	Mean	**5.87**	**4.94**	**6.73**	**5.97**	**4.79**	**7.03**	**4.90**
	0	6.75	6.75	6.75	6.75	6.75	6.75	6.75
	1	5.30	5.62	7.05	5.10	5.79	7.09	5.95
Sensory evaluation of taste	2	6.73	4.94	6.95	6.02	4.88	7.13	4.55
	3	5.68	4.49	4.64	5.91	5.83	6.99	4.63
	4	5.36	4.31	7.00	5.73	4.18	7.00	4.13
	5	5.39	4.00	7.01	6.05	3.76	7.21	4.01
	6	6.21	4.05	7.13	5.61	4.02	6.94	3.98
	Mean	**5.78**	**4.57**	**6.63**	**5.74**	**4.74**	**7.06**	**4.54**
	0	7.78	7.78	7.78	7.78	7.78	7.78	7.78
	1	6.33	5.66	7.36	6.48	5.66	7.21	5.42
	2	5.62	4.97	7.09	6.23	5.15	6.63	4.03
Sensory evaluation of colour	3	5.99	5.22	6.91	5.53	4.89	7.15	4.33
	4	5.20	4.36	6.33	5.12	4.85	7.23	4.28
	5	5.37	4.09	6.43	5.62	3.90	6.38	3.60
	6	5.04	4.21	6.03	6.01	4.12	7.04	4.92
	Mean	**5.59**	**4.75**	**6.69**	**5.83**	**4.76**	**6.94**	**4.43**
	0	7.02	7.02	7.02	7.02	7.02	7.02	7.02
	1	5.93	5.41	7.13	5.98	5.48	6.90	5.68
	2	6.21	5.29	7.10	6.07	5.08	7.00	4.47
General acceptance	3	7.16	4.89	6.64	5.92	5.61	7.17	4.75
	4	5.48	4.55	6.65	5.65	4.43	6.93	4.41
	5	5.66	4.13	6.92	5.75	3.83	6.90	3.83
	6	5.88	4.50	6.9	6.06	4.22	7.01	4.46
	Mean	**6.05**	**4.80**	**6.90**	**5.90**	**4.78**	**6.96**	**4.60**

APPENDIX VII: ANOVA PROCEDURE

The ANOVA Procedure

Class Level Information

Class	Levels	Values
TRT	7	(C, CN, NC, NCN, NP, NPN and PN)

Number of observations 42

ANOVA for Moisture Content

Dependent Variable: Moisture

Source	DF	Sum of Square	Mean Square	F Value	Pr > F
Model	6	10.5280	1.7546	4.4000	0.0021
Error	35	13.9566	0.3987		
Corrected Total	41	24.4847			
TRT	6	10.5280	1.7546	4.4000	0.0021

R-Square	Coeff Var	Root MSE	Moisture Mean
0.4299	6.5421	0.6314	9.6523

ANOVA for Protein

Dependent Variable: Protein

Source	DF	Sum of Square	Mean Square	F Value	Pr > F
Model	6	259.7228	43.2871	6.1100	0.0002
Error	35	247.8783	7.0822		
Corrected Total	41	507.6011			
TRT	6	259.7228	43.2871	6.1100	0.0002

R-Square	Coeff Var	Root MSE	Protein Mean
0.5116	3.9558	2.6612	67.2738

ANOVA for Specific Heat Capacity

Dependent Variable: SHC_(kJKg)_ _

Source	DF	Sum of Square	Mean Square	F Value	Pr > F
Model	6	0.0507	43.2871	6.1100	0.0002
Error	35	0.0558	7.0822		
Corrected Total	41	0.1065			
TRT	6	0.0507	0.0084	5.3000	0.0006
	R-Square	Coeff Var	Root MSE	SHC_Kj_Kg Mean	
	0.4761	2.1525	0.0399	1.8550	

ANOVA for Thermal Conductivity

Dependent Variable: TC_(w_m^{o}c)_ _

Source	DF	Sum of Square	Mean Square	F Value	Pr > F
Model	6	0.0003	0.0001	3.2000	0.0131
Error	35	0.0005	0.0000		
Corrected Total	41	0.0009			
TRT	6	0.0003	0.0001	3.2000	0.0131
	R-Square	Coeff Var	Root MSE	TC_w_moc Mean	
	0.3540	2.1500	0.0041	0.1917	

ANOVA for Thermal Diffusity

Dependent Variable: TD_m2_s_X10_7 TD_(m^2/s)_X10^{-7}

Source	DF	Sum of Square	Mean Square	F Value	Pr > F
Model	6	0.9647	0.1607	6.6000	<0.0001
Error	35	0.8532	0.0243		
Corrected Total	41	1.8179			
TRT	6	0.9647	0.1607	6.6000	<0.0001
	R-Square	Coeff Var	Root MSE	TD_m2_s_X10_7 Mean	

0.5306	2.0180	0.1561	7.7371	

ANOVA for Latent Heat

Dependent Variable: LH_KJ_kg_ LH_(KJ_kg)_

Source	**DF**	**Sum of Square**	**Mean Square**	**F Value**	**Pr > F**
Model	6	109.5105	18.2517	3.2100	0.0129
Error	35	199.0908	5.6883		
Corrected Total	41	308.6014			
TRT	6	109.5105	18.2517	3.2100	0.0129
	R-Square	Coeff Var	Root MSE	LH_KJ_kg Mean	
	0.3548	7.4214	2.3850	32.1369	

ANOVA for CF

Dependent Variable: CF CF

Source	**DF**	**Sum of Square**	**Mean Square**	**F Value**	**Pr > F**
Model	6	4.9933	0.8322	3.1400	0.0144
Error	35	9.2850	0.2652		
Corrected Total	41	14.2783			
TRT	6	4.9933	0.8322	3.1400	0.0144
	R-Square	Coeff Var	Root MSE	CF Mean	
	0.3497	17.8633	0.5150	2.8833	

ANOVA for Ash

Dependent Variable: Ash Ash

Source	**DF**	**Sum of Square**	**Mean Square**	**F Value**	**Pr > F**
Model	6	2.7947	0.4657	3.0000	0.0179
Error	35	5.4300	0.1551		
Corrected Total	41	8.2247			
TRT	6	2.7947	0.4657	3.0000	0.0179
	R-Square	Coeff Var	Root MSE	Ash Mean	
	0.3397	6.5439	0.3938	6.0190	

ANOVA for Fat

Dependent Variable: Fat Fat

Source	DF	Sum of Square	Mean Square	F Value	Pr > F
Model	6	22.8133	3.8022	13.7800	<0.0001
Error	35	9.6600	0.2760		
Corrected Total	41	32.4733			
TRT	6	22.8133	3.8022	13.7800	<0.0001
	R-Square	Coeff Var	Root MSE	Fat Mean	
	0.7025	4.9406	0.5253	10.6333	

The ANOVA Procedure

NOTE: This test controls the Type I comparisonwise error rate, not the experimentwise error rate.

Duncan's Multiple Range Test for Moisture Content

Alpha					0.05	
Error Degrees of Freedom					35	
Error Mean Square					0.3987	
Number of Means	2	3	4	5	6	7
Critical Range	0.7401	0.7781	0.8028	0.8205	0.8340	0.8446

Means with the same letter are not significantly different

Duncan Grouping	Mean	N	TRT
A	10.4667	6	CN
A		6	
BA	9.9167	6	NP
BA		6	
BA	9.9000	6	PN
BA		6	
BA	9.7333	6	NC
B		6	
BC	9.5667	6	C
BC		6	
BC	9.1833	6	NPN
C		6	
C	8.8000	6	NCN

Duncan's Multiple Range Test for Protein

Alpha					0.05	
Error Degrees of Freedom					35	
Error Mean Square					7.0822	
Number of Means	2	3	4	5	6	7
Critical Range	3.1190	3.2790	3.3830	3.4580	3.5150	3.5590

Means with the same letter are not significantly different

Duncan Grouping	Mean	N	TRT
A	71.8670	6	NCN
A			
A	70.1830	6	NPN
A			
B	66.4330	6	PN
B			
B	66.2000	6	NP
B			
B	66.0830	6	CN
B			
B	65.7000	6	NC
B			
B	64.4500	6	C

Duncan's Multiple Range Test for SHC_Kj_Kg_

Alpha					0.05	
Error Degrees of Freedom					35	
Error Mean Square					0.0015	
Number of Means	2	3	4	5	6	7
Critical Range	.0468	.0492	.0507	.0518	.0527	.0534

Means with the same letter are not significantly different

Duncan Grouping	Mean	N	TRT
A	1.8996	6	NCN
A			
BA	1.8888	6	CN
BA			
BA	1.8731	6	NPN
BA			
BA	1.8675	6	PN
B			
BC	1.8410	6	NP
C			
C	1.8158	6	NC
C			
C	1.7993	6	C

Duncan's Multiple Range Test for TC (w_m^{o}c)

Alpha					0.05	
Error Degrees of Freedom					35	
Error Mean Square					0.0000	
Number of Means	2	3	4	5	6	7
Critical Range	.00483	.00507	.00524	.00535	.00544	.00551
	1	9	0	6	4	3

Means with the same letter are not significantly different

Duncan Grouping	Mean	N	TRT
A	0.1950	6	PN
A			
A	0.1950	6	CN
A			
BA	0.1935	6	NP
BA			
BAC	0.1915	6	NPN
BAC			
ABC	0.1910	6	NCN
BC			
BC	0.1888	6	NC
C			
C	0.1871	6	C

Duncan's Multiple Range Test for TD_m2_s_X10_7

Alpha					0.05	
Error Degrees of Freedom					35	
Error Mean Square					0.0243	
Number of Means	2	3	4	5	6	7
Critical Range	.1830	.1924	.1985	.2029	.2062	.2088

Means with the same letter are not significantly different

Duncan Grouping	Mean	N	TRT
A	7.8986	6	NPN
A			
A	7.8615	6	NCN
A			
A	7.8590	6	CN
A			
BA	7.8326	6	PN
B			
BC	7.6498	6	NP
C			
C	7.5545	6	NC
C			
C	7.5041	6	C

Duncan's Multiple Range Test for LH_KJ_kg_

Alpha					0.05	
Error Degrees of Freedom					35	
Error Mean Square					5.6883	
Number of Means	2	3	4	5	6	7
Critical Range	2.7950	2.9390	3.0320	3.0990	3.1500	3.1900

Means with the same letter are not significantly different

Duncan Grouping	Mean	N	TRT
A	35.0080	6	CN
A			
BA	33.1650	6	NP
BA			
BAC	32.4340	6	C
BAC			
BAC	32.1720	6	NC
BAC			
BAC	32.1040	6	PN
BC			
BC	30.2060	6	NCN
C			
C	29.8710	6	NPN

Duncan's Multiple Range Test for CF

Alpha					0.05	
Error Degrees of Freedom					35	
Error Mean Square					0.2652	
Number of Means	2	3	4	5	6	7
Critical Range	.6037	.6346	.6548	.6692	.6802	.6889

Means with the same letter are not significantly different

Duncan Grouping	Mean	N	TRT
A	3.6000	6	C
A			
BA	3.0333	6	NP
B			
B	2.9500	6	NPN
B			
B	2.8000	6	PN
B			
B	2.7667	6	CN
B			
B	2.5500	6	NC
B			
B	2.4833	6	NCN

Duncan's Multiple Range Test for Ash

Alpha					0.05	
Error Degrees of Freedom					35	
Error Mean Square					0.1551	
Number of Means	2	3	4	5	6	7
Critical Range	.4617	.4853	.5007	.5118	.5202	.5268

Means with the same letter are not significantly different

Duncan Grouping	Mean	N	TRT
A	6.2667	6	CN
A			
A	6.2167	6	NC
A			
A	6.2000	6	NP
A			
BA	6.1333	6	PN
BA			
BA	6.0667	6	NCN
B			
BC	5.6833	6	C
C			
C	5.5667	6	NPN

Duncan's Multiple Range Test for Fat

Alpha					0.05	
Error Degrees of Freedom					35	
Error Mean Square					0.2760	
Number of Means	2	3	4	5	6	7
Critical Range	.6158	.6473	.6679	.6826	.6938	.7027

Means with the same letter are not significantly different

Duncan Grouping	Mean	N	TRT
A	11.6000	6	PN
A			
A	11.5167	6	CN
A			
BA	10.9833	6	NPN
B			
B	10.8333	6	NCN
C	9.8833	6	NP
C			
C	9.8333	6	NC
C			
C	9.7833	6	C

APPENDIX VIII: PEARSON CORRELATION ANALYSIS

---------- TRT=C ----------

The CORR Procedure

9 Variables: Moisture Protein SHC_Kj_Kg_ TC_w_moc_ TD_m2_s_X10_7 LH_KJ_kg_ CF Ash Fat

Simple Statistics

Variables	N	Mean	Std. Dev.	Sum	Minimum	Maximum	Label
Moisture	6	9.5666	0.7312	57.4000	8.4000	10.5000	Moisture
Protein	6	64.4500	2.6606	386.7000	62.1000	68.9000	Protein
SHC (kJkg)	6	1.7993	0.0249	10.7960	1.7570	1.8290	SHC (kJkg)
TC (Wm^oC)	6	0.1871	0.0037	1.1230	0.1830	0.1920	TC (Wm^oC)
TD (m^2S) x 10^7	6	7.5041	0.0887	45.0250	7.3620	7.6230	TD (m^2S) x 10^7
LH kJkg	6	32.4336	2.3325	194.6020	28.1400	35.1750	LH kJkg
CF	6	3.6000	0.9818	21.6000	2.3000	4.8000	CF
Ash	6	5.6833	0.4446	34.1000	5.0000	6.2000	Ash
Fat	6	9.7833	0.6853	58.7000	8.8000	10.5000	Fat

Pearson Correlation Coefficients, N = 6
Prob > |r| under H0: Rho=0

	Moisture	Protein	SHC (kJkg)	TC (Wm^oC)	TD (m^2S) x 10^7
Moisture	1.0000	-0.7278	-0.0915	0.8671	-0.2148
Moisture		-0.2148	-0.2148	0.0253	0.6827
Protein	-0.7278	1.0000	0.5103	-0.5741	0.5708
Protein	0.1010		0.3009	0.2334	0.2368
SHC (kJkg)	-0.0915	0.5103	1.0000	0.3193	0.9883
SHC (kJkg)	0.8631	0.3009		0.5373	0.0002
TC (Wm^oC)	0.8671	-0.5741	0.3193	1.0000	0.2125
TC (Wm^oC)	0.0253	0.2334	0.5373		0.6860
TD (m^2S) x 10^7	-0.2148	0.5708	0.9883	0.2125	1.0000
TD (m^2S) x 10^7	0.6827	0.2368	0.0002	0.6860	
LH kJkg	0.9205	-0.8899	0.4363	0.6889	-0.5461
LH kJkg	0.0092	0.0175	0.3870	0.1301	0.2622

Pearson Correlation Coefficients, N = 6
Prob > |r| under H0: Rho=0

	LH (kJkg)	**CF**	**Ash**	**Fat**
Moisture	0.9205	0.7382	-0.2296	-0.5840
Moisture	0.0092	0.0938	0.6615	0.2236
Protein	-0.8899	-0.9194	0.2460	0.0411
Protein	0.0175	0.0095	0.6384	0.9383
SHC (kJkg)	-0.4363	-0.1488	0.8152	0.1070
SHC (kJkg)	0.3870	0.7784	0.0481	0.8401
TC (Wm^oC)	0.6889	0.7685	0.2529	-0.3088
TC (Wm^oC)	0.1301	0.0742	0.6286	0.5515
TD (m^2S) x 10^7	-0.5461	-0.2202	0.8317	0.2224
TD (m^2S) x 10^7	0.2622	0.6750	0.0401	0.6718
LH (kJkg)	1.0000	0.7980	-0.4102	-0.4870
LH (kJkg)		0.0571	0.4192	0.3272

---------- TRT=C ----------

The CORR Procedure

Pearson Correlation Coefficients, N = 6
Prob > |r| under H0: Rho=0

	Moisture	**Protein**	**SHC (kJkg)**	**TC (Wm^oC)**	**TD (m^2S) x 10^7**
CF	0.7382	-0.9194	-0.1488	0.7685	-0.2202
CF	0.0938	0.0095	0.7784	0.0742	0.6750
ASH	-0.2296	0.2460	0.8152	0.2529	0.8317
ASH	0.6615	0.6384	0.0481	0.6286	0.0401
FAT	-0.5840	0.0411	0.1070	-0.3088	0.2224
FAT	0.2236	0.9383	0.8401	0.5515	0.6718

Pearson Correlation Coefficients, N = 6
Prob > |r| under H0: Rho=0

	LH (kJkg)	**CF**	**Ash**	**Fat**
CF	0.7980	1.0000	0.1328	0.0653
CF	0.0571		0.8019	0.9021
ASH	-0.4102	0.1328	1.0000	0.5568
ASH	0.4192	0.8019		0.2511
FAT	-0.4870	0.0653	0.5568	1.0000
FAT	0.3272	0.9021	0.2511	

---------- TRT=CN ----------

The CORR Procedure

9 Variables: Moisture Protein SHC_Kj_Kg_ TC_w_moc_ TD_m2_s_X10_7 LH_KJ_kg_ CF Ash Fat

Simple Statistics

Variables	N	Mean	Std. Dev.	Sum	Minimum	Maximum	Label
Moisture	6	10.4666	0.6889	62.8000	9.4000	11.3000	Moisture
Protein	6	66.0833	3.4037	396.5000	61.1000	69.6000	Protein
SHC (kJkg)	6	1.8888	0.0539	11.3330	1.8050	1.9310	SHC (kJkg)
TC (Wm^oC)	6	0.1950	0.0050	1.1700	0.1900	0.2020	TC (Wm^oC)
TD (m^2S) x 10^7	6	7.8590	0.2272	47.1540	7.5090	8.0100	TD (m^2S) x 10^7
LH kJkg	6	35.0075	2.2297	210.04500	31.4900	37.5200	LH kJkg
CF	6	2.7666	0.3614	16.6000	2.4000	3.4000	CF
Ash	6	6.2666	0.1861	37.6000	6.0000	6.5000	Ash
Fat	6	11.5166	0.6705	69.1000	10.3000	12.1000	Fat

Pearson Correlation Coefficients, N = 6
Prob > |r| under H0: Rho=0

	Moisture	Protein	SHC (kJkg)	TC (Wm^oC)	TD (m^2S) x 10^7
Moisture	1.0000	-0.2058	0.1579	0.5852	0.0489
Moisture		0.6956	0.7651	0.2224	0.9267
Protein	-0.2058	1.0000	0.9144	0.3820	0.9485
Protein	0.6956		0.0107	0.4548	0.0039
SHC (kJkg)	0.1579	0.9144	1.0000	0.6986	0.9938
SHC (kJkg)	0.7651	0.0107		0.1226	<0.0001
TC (Wm^oC)	0.5852	0.3820	0.6986	1.0000	0.6435
TC (Wm^oC)	0.2224	0.4548	0.1226		0.1680
TD (m^2S) x 10^7	0.0489	0.9485	0.9938	0.6435	1.0000
TD (m^2S) x 10^7	0.9267	0.0039	<.0001	0.1680	
LH kJkg	0.9987	-0.2317	0.1400	0.5938	0.0306
LH kJkg	<.0001	0.6586	0.7914	0.2139	0.9540

Pearson Correlation Coefficients, N = 6
Prob > |r| under H0: Rho=0

	LH (kJkg)	**CF**	**Ash**	**Fat**
Moisture	0.9987	0.2998	-0.0883	-0.6738
Moisture	<0.0001	0.5638	0.8678	0.1422
Protein	-0.2317	-0.2317	0.4313	0.1622
Protein	0.6586	0.0171	0.3932	0.7588
SHC (kJkg)	0.1400	-0.8377	0.5545	0.0614
SHC (kJkg)	0.7914	0.0373	0.2535	0.9080
TC (Wm^oC)	0.5938	-0.4264	0.6156	0.0235
TC (Wm^oC)	0.2139	0.3991	0.1932	0.9646
TD (m^2S) x 10^7	0.0306	-0.8751	0.5619	0.1324
TD (m^2S) x 10^7	0.9540	0.0224	0.2458	0.8025
LH kJkg	1.0000	0.3075	-0.0645	-0.6430
LH kJkg		0.5532	0.9033	0.1684

---------- TRT=CN ----------

The CORR Procedure

Pearson Correlation Coefficients, N = 6
Prob > |r| under H0: Rho=0

	Moisture	**Protein**	**SHC (kJkg)**	**TC (Wm^oC)**	**TD (m^2S) x 10^7**
CF	0.2998	0.8913	-0.8377	-0.4264	-0.8751
CF	0.5638	0.0171	0.0373	0.3991	0.0224
ASH	-0.0883	0.4313	0.5545	0.6156	0.5619
ASH	0.8678	0.3932	0.2535	0.1932	0.2458
FAT	-0.6738	0.1622	0.0614	0.0235	0.1324
FAT	0.1422	0.7588	0.9080	0.9646	0.8025

Pearson Correlation Coefficients, N = 6
Prob > |r| under H0: Rho=0

	LH (kJkg)	**CF**	**Ash**	**Fat**
CF	0.3075	1.0000	-0.7627	-0.4840
CF	0.5532		0.0778	0.3306
ASH	-0.0645	-0.7627	1.0000	0.6941
ASH	0.9033	0.0778		0.1260
FAT	-0.6430	-0.4840	0.6941	1.0000
FAT	0.1684	0.3306	0.1260	

---------- TRT=NC ----------

The CORR Procedure

9 Variables: Moisture Protein SHC_Kj_Kg_ TC (Wm^{o}C) TD_m^{2}_s_X10^{-7} LH_KJ_kg_ CF Ash Fat

Simple Statistics

Variables	N	Mean	Std. Dev.	Sum	Minimum	Maximum	Label
Moisture	6	9.7333	0.2250	58.4000	9.5000	10.1000	Moisture
Protein	6	65.7000	2.9556	394.2000	62.3000	68.6000	Protein
SHC (kJkg)	6	1.8158	0.0487	10.8950	1.7640	1.8690	SHC (kJkg)
TC (Wm^{o}C)	6	0.1888	0.0041	1.1330	0.1840	0.1940	TC (Wm^{o}C)
TD (m^{2}S) x 10^{7}	6	7.5545	0.2268	45.3270	45.3270	7.3150	TD (m^{2}S) x 10^{7}
LH kJkg	6	32.1716	1.2319	193.0300	30.1500	33.8350	LH kJkg
CF	6	2.5500	0.3016	15.3000	2.2000	3.1000	CF
Ash	6	6.2166	0.2483	37.3000	5.8000	6.5000	Ash
Fat	6	9.8333	0.3076	59.0000	9.5000	10.3000	Fat

Pearson Correlation Coefficients, N = 6
Prob > |r| under H0: Rho=0

	Moisture	Protein	SHC (kJkg)	TC (Wm^{o}C)	TD (m^{2}S) x 10^{7}
Moisture	1.0000	-0.3457	-0.1690	0.3269	-0.2103
Moisture		0.5021	0.7489	0.5271	0.6891
Protein	-0.3457	1.0000	0.9793	0.3945	0.9828
Protein	0.5021		0.0006	0.4389	0.0004
SHC (kJkg)	-0.1690	0.9793	1.0000	0.5337	0.9935
SHC (kJkg)	0.7489	0.0006		0.2754	<.0001
TC (Wm^{o}C)	0.3269	0.3945	0.5337	1.0000	0.5245
TC (Wm^{o}C)	0.5271	0.4389	0.2754		0.2853
TD (m^{2}S) x 10^{7}	-0.2103	0.9828	0.9935	0.5245	1.0000
TD (m^{2}S) x 10^{7}	0.6891	0.0004	<.0001	0.2853	
LH kJkg	0.4714	0.3000	0.3592	0.0678	0.2978
LH kJkg	0.3452	0.5635	0.4844	0.8984	0.5665

Pearson Correlation Coefficients, N = 6
Prob > |r| under H0: Rho=0

	LH (kJkg)	**CF**	**Ash**	**Fat**
Moisture	0.4714	0.1472	0.1669	-0.3080
Moisture	0.3452	0.7807	0.7519	0.5526
Protein	0.3000	-0.6527	0.5695	0.6047
Protein	0.5635	0.1599	0.2381	0.2034
SHC (kJkg)	0.3592	-0.5994	0.6036	0.5982
SHC (kJkg)	0.4844	0.2085	0.2045	0.2097
TC (Wm^oC)	0.0678	0.2465	0.3897	0.0675
TC (Wm^oC)	0.8984	0.6376	0.4450	0.8988
TD (m^2S) x 10^7	0.2978	-0.5692	0.5664	0.5817
TD (m^2S) x 10^7	0.5665	0.2384	0.2412	0.2259
LH kJkg	1.0000	-0.7163	0.8268	-0.1241
LH kJkg		0.1093	0.0424	0.8147

---------- TRT=NC ----------

The CORR Procedure

Pearson Correlation Coefficients, N = 6
Prob > |r| under H0: Rho=0

	Moisture	**Protein**	**SHC (kJkg)**	**TC (Wm^oC)**	**TD (m^2S) x 10^7**
CF	0.1472	-0.6527	-0.5994	0.2465	-0.5692
CF	0.7807	0.1599	0.2085	0.6376	0.2384
ASH	0.1669	0.5695	0.6036	0.3897	0.5664
ASH	0.7519	0.2381	0.6036	0.4450	0.2412
FAT	-0.3080	0.6047	0.5982	0.0675	0.5817
FAT	0.5526	0.2034	0.2097	0.8988	0.2259

Pearson Correlation Coefficients, N = 6
Prob > |r| under H0: Rho=0

	LH (kJkg)	**CF**	**Ash**	**Fat**
CF	-0.7163	1.0000	-0.6007	-0.3878
CF	0.1093		0.2073	0.4474
ASH	0.8268	-0.6007	1.0000	-0.1657
ASH	0.0424	0.2073		0.7536
FAT	-0.1241	-0.3878	-0.1657	1.0000
FAT	0.8147	0.4474	0.7536	

---------- TRT=NCN ----------

The CORR Procedure

9 Variables: Moisture Protein SHC_Kj_Kg_ TC_w_moc_ TD_m2_s_X10_7 LH_KJ_kg_ CF Ash Fat

Simple Statistics

Variables	**N**	**Mean**	**Std. Dev.**	**Sum**	**Minimum**	**Maximum**	**Label**
Moisture	6	8.8000	0.5059	52.8000	8.1000	9.5000	Moisture
Protein	6	71.8666	3.4471	431.2000	69.5000	78.8000	Protein
SHC (kJkg)	6	1.8996	0.0472	11.3980	1.8670	1.9920	SHC (kJkg)
TC (Wm^oC)	6	0.1910	0.0039	1.1460	0.1850	0.1960	TC (Wm^oC)
TD (m^2S) x 10^7	6	7.8615	0.0693	47.1690	7.7780	7.9750	TD (m^2S) x 10^7
LH kJkg	6	30.2058	2.6834	181.2350	27.1350	34.5050	LH kJkg
CF	6	2.4833	0.3311	14.9000	2.0000	3.0000	CF
Ash	6	6.0666	0.4274	36.4000	5.4000	6.6000	Ash
Fat	6	10.8333	0.4546	65.0000	10.5000	11.7000	Fat

Pearson Correlation Coefficients, N = 6
Prob > |r| under H0: Rho=0

	Moisture	**Protein**	**SHC (kJkg)**	**TC (Wm^oC)**	**TD (m^2S) x 10^7**
Moisture	1.0000	-0.6490	-0.4648	0.4968	0.9122
Moisture		0.1631	0.3530	0.3161	0.0112
Protein	-0.6490	1.0000	0.9704	-0.1145	-0.5068
Protein	0.1631		0.0013	0.8289	0.3049
SHC (kJkg)	-0.4648	0.9704	1.0000	-0.0010	-0.3294
SHC (kJkg)	0.3530	0.0013		0.9984	0.5238
TC (Wm^oC)	0.4968	-0.1145	-0.0010	1.0000	0.7985
TC (Wm^oC)	0.3161	0.8289	0.9984		0.0568
TD (m^2S) x 10^7	0.9122	-0.5068	-0.3294	0.7985	1.0000
TD (m^2S) x 10^7	0.0112	0.3049	0.5238	0.0568	
LH kJkg	0.7599	-0.6328	-0.5040	-0.1857	0.4334
LH kJkg	0.0795	0.1775	0.3079	0.7246	0.3905

Pearson Correlation Coefficients, N = 6
Prob > |r| under H0: Rho=0

	LH (kJkg)	**CF**	**Ash**	**Fat**
Moisture	0.7599	0.3580	-0.9526	-0.4086
Moisture	0.0795	0.4858	0.0033	0.4211
Protein	-0.6328	-0.0338	0.5882	-0.0846
Protein	0.1775	0.9492	0.2194	0.8733
SHC (kJkg)	-0.5040	0.0378	0.4189	-0.1454
SHC (kJkg)	0.3079	0.9432	0.4083	0.7834
TC (Wm^oC)	-0.1857	-0.4337	-0.3600	-0.0451
TC (Wm^oC)	0.7246	0.3902	0.4832	0.9323
TD (m^2S) x 10^7	0.4334	0.0343	-0.8370	-0.2771
TD (m^2S) x 10^7	0.3905	0.9484	0.0377	0.5950
LH kJkg	1.0000	0.7325	-0.8042	-0.4247
LH kJkg		0.0977	0.0537	0.4012

---------- TRT=NCN ----------

The CORR Procedure

Pearson Correlation Coefficients, N = 6
Prob > |r| under H0: Rho=0

	Moisture	**Protein**	**SHC (kJkg)**	**TC (Wm^oC)**	**TD (m^2S) x 10^{-7}**
CF	0.3580	-0.0338	0.0378	-0.4337	0.0343
CF	0.4858	0.9492	0.9432	0.3902	0.9484
ASH	-0.9526	0.5882	0.4189	-0.3600	-0.8370
ASH	0.0033	0.2194	0.4083	0.4832	0.0377
FAT	-0.4086	-0.0846	-0.1454	-0.0451	-0.2771
FAT	0.4211	0.8733	0.7834	0.9323	0.5950

Pearson Correlation Coefficients, N = 6
Prob > |r| under H0: Rho=0

	LH (kJkg)	**CF**	**Ash**	**Fat**
CF	0.7325	1.0000	-0.5134	-0.7926
CF	0.0977		0.2975	0.0600
ASH	-0.8042	-0.5134	1.0000	0.5215
ASH	0.0537	0.2975		0.2886
FAT	-0.4247	-0.7926	0.5215	1.0000
FAT	0.4012	0.0600	0.2886	

---------- TRT=NP ----------

The CORR Procedure

9 Variables: Moisture Protein SHC_Kj_Kg_ TC_w_moc_ TD_m2_s_X10_7 LH_KJ_kg_ CF Ash Fat

Simple Statistics

Variables	**N**	**Mean**	**Std. Dev.**	**Sum**	**Minimum**	**Maximum**	**Label**
Moisture	6	9.9166	0.5845	59.5000	9.2000	10.8000	Moisture
Protein	6	66.2000	2.0562	397.2000	63.8000	68.4000	Protein
SHC (kJkg)	6	1.8410	0.0319	11.0460	1.7930	1.8760	SHC (kJkg)
TC (Wm^oC)	6	0.1935	0.0042	1.1610	0.1870	0.1990	TC (Wm^oC)
TD (m^2S) x 10^7	6	7.6498	0.1331	45.8990	7.4750	7.8100	TD (m^2S) x 10^7
LH kJkg	6	33.1650	2.0211	198.9900	30.8200	36.1800	LH kJkg
CF	6	3.0333	0.4131	18.2000	2.4000	3.6000	CF
Ash	6	6.2000	0.3898	37.2000	5.90000	6.9000	Ash
Fat	6	9.8833	0.3371	59.3000	9.6000	10.4000	Fat

Pearson Correlation Coefficients, N = 6
Prob > |r| under H0: Rho=0

	Moisture	Protein	SHC (kJkg)	TC (Wm^oC)	TD (m^2S) x 10^7
Moisture	1.0000	-0.4842	0.1788	0.5878	0.0074
Moisture		0.3304	0.7346	0.2198	0.9888
Protein	-0.4842	1.0000	0.7706	-0.2546	0.8656
Protein	0.3304		0.0729	0.6263	0.0259
SHC (kJkg)	0.1788	0.7706	1.0000	0.1872	0.9774
SHC (kJkg)	0.7346	0.0729		0.7224	0.0008
TC (Wm^oC)	0.5878	-0.2546	0.1872	1.0000	0.1142
TC (Wm^oC)	0.2198	0.6263	0.7224		0.8293
TD (m^2S) x 10^7	0.0074	0.8656	0.9774	0.1142	1.0000
TD (m^2S) x 10^7	0.9888	0.0259	0.0008	0.8293	
LH kJkg	0.9981	-0.4417	0.2230	0.5579	0.0507
LH kJkg	<.0001	0.3805	0.6710	0.2499	0.9239

Pearson Correlation Coefficients, N = 6
Prob > |r| under H0: Rho=0

	LH (kJkg)	CF	Ash	Fat
Moisture	0.9981	0.3533	0.0877	-0.6478
Moisture	<.0001	0.4920	0.8687	0.1642
Protein	-0.4417	-0.8005	0.1796	0.8799
Protein	0.3805	0.0557	0.7335	0.0208
SHC (kJkg)	0.2230	-0.5984	0.3146	0.4863
SHC (kJkg)	0.6710	0.2095	0.5436	0.3280
TC (Wm^oC)	0.5579	0.6563	-0.0719	-0.5338
TC (Wm^oC)	0.2499	0.1568	0.8923	0.2753
TD (m^2S) x 10^7	0.0507	-0.6627	0.1841	0.6388
TD (m^2S) x 10^7	0.9239	0.1515	0.7269	0.1721
LH kJkg	1.0000	0.2969	0.1105	-0.6096
LH kJkg		0.5677	0.8349	0.1989

---------- TRT=NP ----------

The CORR Procedure

Pearson Correlation Coefficients, N = 6
Prob > |r| under H0: Rho=0

	Moisture	**Protein**	**SHC (kJkg)**	**TC (Wm^oC)**	**TD (m^2S) x 10^{-7}**
CF	0.3533	-0.8005	-0.5984	0.6563	-0.6627
CF	0.4920	0.0557	0.2095	0.1568	0.1515
ASH	0.0877	0.1796	0.3146	-0.0719	0.1841
ASH	0.8687	0.7335	0.5436	0.8923	0.7269
FAT	-0.6478	0.8799	0.4863	-0.5338	0.6388
FAT	0.1642	0.0208	0.3280	0.2753	0.1721

Pearson Correlation Coefficients, N = 6
Prob > |r| under H0: Rho=0

	LH (kJkg)	**CF**	**Ash**	**Fat**
CF	0.2969	1.0000	-0.1365	-0.8567
CF	0.5677		0.7964	0.0293
ASH	0.1105	-0.1365	1.0000	-0.1673
ASH	0.8349	0.7964		0.7513
FAT	-0.6096	-0.8567	-0.1673	1.0000
FAT	0.1989	0.0293	0.7513	

---------- TRT=NPN ----------

The CORR Procedure

9 Variables: Moisture Protein SHC_Kj_Kg_ TC_w_moc_ TD_m2_s_X10_7 LH_KJ_kg_ CF Ash Fat

Simple Statistics

Variables	**N**	**Mean**	**Std. Dev.**	**Sum**	**Minimum**	**Maximum**	**Label**
Moisture	6	9.1833	0.9064	55.1000	7.6000	10.4000	Moisture
Protein	6	70.1833	0.6765	421.1000	69.4000	71.1000	Protein
SHC (kJkg)	6	1.8731	0.0319	11.2390	1.83700	1.9160	SHC (kJkg)
TC (Wm^oC)	6	0.1915	0.0049	1.1490	0.1870	0.1990	TC (Wm^oC)
TD (m^2S) x 10^7	6	7.8986	0.0962	47.3920	7.7760	8.0120	TD (m^2S) x 10^7
LH kJkg	6	29.8708	3.2646	179.2250	25.4600	34.8400	LH kJkg
CF	6	2.9500	0.4370	17.7000	2.4000	3.4000	CF
Ash	6	5.5666	0.4501	33.4000	5.1000	6.1000	Ash
Fat	6	10.9833	0.6705	65.9000	10.1000	11.8000	Fat

Pearson Correlation Coefficients, N = 6
Prob > |r| under H0: Rho=0

	Moisture	**Protein**	**SHC (skJkg)**	**TC (Wm^oC)**	**TD (m^2S) x 10^7**
Moisture	1.0000	-0.3299	0.7381	0.0643	0.7818
Moisture		0.5230	0.0939	0.9036	0.0662
Protein	-0.3299	1.0000	-0.6446	-0.3420	-0.7510
Protein	0.5230		0.1670	0.5070	0.0852
SHC (kJkg)	0.7381	-0.6446	1.0000	0.3532	0.6507
SHC (kJkg)	0.0939	0.1670		0.4922	0.1616
TC (Wm^oC)	0.0643	-0.3420	0.3532	1.0000	-0.0184
TC (Wm^oC)	0.9036	0.5070	0.4922		0.9724
TD (m^2S) x 10^7	0.7818	-0.7510	0.6507	-0.0184	1.0000
TD (m^2S) x 10^7	0.0662	0.0852	0.1616	0.9724	
LH kJkg	0.5686	-0.1875	0.0994	-0.4191	0.6994
LH kJkg	0.2389	0.7219	0.8513	0.4081	0.1219

Pearson Correlation Coefficients, N = 6
Prob > |r| under H0: Rho=0

	LH (kJkg)	**CF**	**Ash**	**Fat**
Moisture	0.5686	0.4215	-0.6583	-0.7310
Moisture	0.2389	0.4051	0.1551	0.0988
Protein	-0.1875	-0.6798	0.6413	0.0080
Protein	0.7219	0.1373	0.1699	0.9879
SHC (kJkg)	0.0994	0.1940	-0.3915	-0.1799
SHC (kJkg)	0.8513	0.7126	0.4427	0.7330
TC (Wm^oC)	-0.4191	0.0230	0.1251	-0.1650
TC (Wm^oC)	0.4081	0.9655	0.8133	0.7547
TD (m^2S) x 10^7	0.6994	0.8120	-0.9225	-0.5023
TD (m^2S) x 10^7	0.1219	0.0497	0.0088	0.3098
LH kJkg	1.0000	0.5893	-0.6686	-0.5442
LH kJkg		0.2183	0.1465	0.2642

---------- TRT=NPN ----------

The CORR Procedure
Pearson Correlation Coefficients, N = 6
Prob > |r| under H0: Rho=0

	Moisture	**Protein**	**SHC (kJkg)**	**TC (Wm^oC)**	**TD (m^2S) x 10^7**
CF	0.4215	-0.6798	0.1940	0.0230	0.8120
CF	0.4051	0.1373	0.7126	0.9655	0.0497
ASH	-0.6583	0.6413	-0.3915	0.1251	-0.9225
ASH	0.1551	0.1699	0.4427	0.8133	0.0088
FAT	-0.7310	0.0080	-0.1799	-0.1650	-0.5023
FAT	0.0988	0.9879	0.7330	0.7547	0.3098

Pearson Correlation Coefficients, N = 6
Prob > |r| under H0: Rho=0

	LH (kJkg)	**CF**	**Ash**	**Fat**
CF	0.5893	1.0000	-0.9352	-0.5220
CF	0.2183		0.0062	0.2880
ASH	-0.6686	-0.9352	1.0000	0.5874
ASH	0.1465	0.0062		0.2202
FAT	-0.5442	-0.5220	0.5874	1.0000
FAT	0.2642	0.2880	0.2202	

---------- TRT=PN ----------

The CORR Procedure

9 Variables: Moisture Protein SHC_Kj_Kg_ TC_(w_m^{o}c)_ TD_(m2_s_X10^{-7}) LH_(KJ_kg)_ CF Ash Fat

Simple Statistics

Variables	**N**	**Mean**	**Std. Dev.**	**Sum**	**Minimum**	**Maximum**	**Label**
Moisture	6	9.9000	0.5585	59.4000	9.1000	10.6000	Moisture
Protein	6	66.4333	2.3678	398.6000	63.3000	68.6000	Protein
SHC (kJkg)	6	1.8675	0.0312	11.2050	1.8230	1.8990	SHC (kJkg)
TC (Wm^oC)	6	0.1950	0.0019	1.1700	0.1920	0.1970	TC (Wm^oC)
TD (m^2S) x 10^7	6	7.8326	0.1669	0.1669	7.6510	8.0770	TD (m^2S) x 10^7
LH kJkg	6	32.1041	2.4380	192.6250	28.8100	35.5100	LH kJkg
CF	6	2.8000	0.4472	16.8000	2.1000	3.2000	CF
Ash	6	6.1333	0.5046	36.8000	5.6000	6.8000	Ash
Fat	6	11.6000	0.3847	69.6000	11.2000	12.3000	Fat

Pearson Correlation Coefficients, N = 6
Prob > |r| under H0: Rho=0

	Moisture	**Protein**	**SHC (kJkg)**	**TC (Wm^oC)**	**TD (m^2S) x 10^7**
Moisture	1.0000	-0.8921	-0.7394	-0.5850	-0.2625
Moisture		0.0168	0.0930	0.2226	0.6152
Protein	-0.8921	1.0000	0.9062	0.8725	0.3951
Protein	0.0168		0.0128	0.0233	0.4381
SHC (kJkg)	-0.7394	0.9062	1.00000	0.8471	0.5627
SHC (kJkg)	0.0930	0.0128		0.0333	0.2450
TC (Wm^oC)	-0.5850	0.8725	0.8471	1.0000	0.3384
TC (Wm^oC)	0.2226	0.0233	0.0333		0.5117
TD (m^2S) x 10^7	-0.2625	0.3951	0.5627	0.3384	1.0000
TD (m^2S) x 10^7	0.6152	0.4381	0.2450	0.5117	
LH kJkg	0.7379	-0.6089	-0.4914	-0.3476	0.3058
LH kJkg	0.0940	0.1995	0.3222	0.4996	0.5556

Pearson Correlation Coefficients, N = 6
Prob > |r| under H0: Rho=0

	LH (kJkg)	**CF**	**Ash**	**Fat**
Moisture	0.7379	0.7926	-0.6314	-0.5863
Moisture	0.0940	0.0600	0.1787	0.2213
Protein	-0.6089	-0.7271	0.8140	0.3710
Protein	0.1995	0.1015	0.0487	0.4690
SHC (kJkg)	-0.4914	-0.4553	0.7702	0.2629
SHC (kJkg)	0.3222	0.3642	0.0731	0.6146
TC (Wm^oC)	-0.3476	-0.4006	0.9190	-0.0000
TC (Wm^oC)	0.4996	0.4311	0.0096	1.0000
TD (m^2S) x 10^7	0.3058	-0.1449	0.0569	0.6229
TD (m^2S)x 10^7	0.5556	0.7841	0.9147	0.1865
LH kJkg	1.0000	0.6329	-0.5318	-0.0357
LH kJkg		0.1774	0.2774	0.9464

---------- TRT=PN ----------

The CORR Procedure

Pearson Correlation Coefficients, N = 6
Prob > |r| under H0: Rho=0

	Moisture	**Protein**	**SHC (kJkg)**	**TC (Wm^0C)**	**TD (m^2S) x 10^7**
CF	0.7926	-0.7271	-0.4553	-0.4006	-0.1449
CF	0.0600	0.1015	0.3642	0.4311	0.7841
ASH	-0.6314	0.8140	0.7702	0.9190	0.0569
ASH	0.1787	0.0487	0.0731	0.0096	0.9147
FAT	-0.5863	0.3710	0.2629	-0.0000	0.6229
FAT	0.2213	0.4690	0.6146	1.0000	0.1865

Pearson Correlation Coefficients, N = 6
Prob > |r| under H0: Rho=0

	LH (kJkg)	**CF**	**Ash**	**Fat**
CF	0.6329	1.0000	-0.3101	-0.5347
CF	0.1774		0.5497	0.2743
ASH	-0.5318	-0.3101	1.0000	-0.1133
ASH	0.2774	0.5497		0.8307
FAT	-0.0357	-0.5347	-0.1133	1.0000
FAT	0.9464	0.2743	0.8307	

APPENDIX IX: MODEL ANALYSIS

---------- TRT=C ----------

The REG Procedure
Model: MODEL1
Dependent Variable: LH_KJ_kg_ LH_KJ_kg_

Analysis of Variance

Source	DF	Sum of Square	Mean Square	F Value	Pr > F
Model	4	27.0918	6.7729	59.8800	59.8800
Error	1	0.1131	0.1131		
Corrected Total	5	27.2049			

	R-Square	Adj. R-Square	Root MSE	Dependent Mean	Coeff Var
	0.9958	0.9792	0.3363	32.4336	1.0369

Parameter Estimates

Variable	Label	DF	Parameter Estimate	Standard Error	t-value	Pr>|t|
Intercept	Intercept	1	-174.0475	107.0420	-1.6300	0.3510
Protein	Protein	1	3.7628	2.0206	1.8600	0.3137
Ash	Ash	1	-11.9952	5.4079	-2.2200	0.2696
Moisture	Moisture	1	-1.4549	1.6085	-0.9000	0.5319
CF	CF	1	12.7935	6.2279	2.0500	0.2884

---------- TRT=CN ----------

The REG Procedure
Model: MODEL1
Dependent Variable: LH_KJ_kg_ LH_KJ_kg_

Analysis of Variance

Source	DF	Sum of Square	Mean Square	F Value	Pr > F
Model	4	24.8569	6.2142	7208.4700	0.0088
Error	1	0.0008	0.0008		
Corrected Total	5	24.8578			

R-Square	Adj. R-Square	Root MSE	Dependent Mean	Coeff Var
1.0000	0.9998	0.0293	35.0075	0.0838

Parameter Estimates

Variable	Label	DF	Parameter Estimate	Standard Error	t-value	Pr>|t|
Intercept	Intercept	1	-8.3139	3.6548	-2.2700	0.2637
Protein	Protein	1	0.0179	0.0210	0.8500	0.5497
Ash	Ash	1	1.1275	0.2741	4.1100	0.1518
Moisture	Moisture	1	3.1707	0.0269	117.7500	0.0054
CF	CF	1	0.6793	0.2911	2.3300	0.2578

---------- TRT=NC ----------

The REG Procedure
Model: MODEL1
Dependent Variable: LH_KJ_kg_ LH_KJ_kg_

Analysis of Variance

Source	DF	Sum of Square	Mean Square	F Value	Pr > F
Model	4	7.5662	1.8915	85.1500	0.0811
Error	1	0.0222	0.0222		
Corrected Total	5	7.58848			

R-Square	Adj. R-Square	Root MSE	Dependent Mean	Coeff Var
0.9971	0.9854	0.1490	32.1716	0.4632

Parameter Estimates

Variable	Label	DF	Parameter Estimate	Standard Error	t-value	Pr>|t|
Intercept	Intercept	1	10.4140	4.6063	2.2600	0.2651
Protein	Protein	1	-0.1274	0.0353	-3.6100	0.1722
Ash	Ash	1	2.7740	0.3970	6.9900	0.0905
Moisture	Moisture	1	2.0017	0.3589	5.5800	0.1130
CF	CF	1	-2.5883	0.3145	-8.2300	0.0770

---------- TRT=NCN ----------

The REG Procedure
Model: MODEL1
Dependent Variable: LH_KJ_kg_ LH_KJ_kg_

Analysis of Variance

Source	DF	Sum of Square	Mean Square	F Value	Pr > F
Model	4	33.7196	8.4299	3.6900	0.3699
Error	1	2.2858	2.2858		
Corrected Total	5	36.0055			

R-Square	Adj. R-Square	Root MSE	Dependent Mean	Coeff Var
0.9365	0.6826	1.5119	30.2058	5.0053

Parameter Estimates

Variable	Label	DF	Parameter Estimate	Standard Error	t-value	Pr>|t|
Intercept	Intercept	1	11.1645	91.0187	0.1200	0.9223
Protein	Protein	1	-0.3601	0.2689	-1.3400	0.4083
Ash	Ash	1	1.6072	6.5512	0.2500	0.8468
Moisture	Moisture	1	2.4321	5.1935	0.4700	0.7212
CF	CF	1	5.5436	2.8445	1.9500	0.3018

---------- TRT=NP ----------

The REG Procedure
Model: MODEL1
Dependent Variable: LH_KJ_kg_ LH_KJ_kg_

Analysis of Variance

Source	DF	Sum of Square	Mean Square	F Value	Pr > F
Model	4	20.4248	5.1062	90128.2000	0.0025
Error	1	0.0000	0.0000		
Corrected Total	5	20.4249			

R-Square	Adj. R-Square	Root MSE	Dependent Mean	Coeff Var
1.0000	1.0000	0.0075	33.1650	0.0227

Parameter Estimates

Variable	Label	DF	Parameter Estimate	Standard Error	t-value	Pr>|t|
Intercept	Intercept	1	11.1645	91.0187	0.1200	0.9223
Protein	Protein	1	-0.3601	0.2689	-1.3400	0.4083
Ash	Ash	1	1.6072	6.5512	0.2500	0.8468
Moisture	Moisture	1	2.4321	5.1935	0.4700	0.7212
CF	CF	1	5.5436	2.8445	1.9500	0.3018

---------- TRT=NPN ----------

The REG Procedure
Model: MODEL1
Dependent Variable: LH_KJ_kg_ LH_KJ_kg_

Analysis of Variance

Source	DF	Sum of Square	Mean Square	F Value	Pr > F
Model	4	30.5761	7.6440	0.3400	0.8401
Error	1	22.7120	22.7120		
Corrected Total	5	53.2881			

R-Square	Adj. R-Square	Root MSE	Dependent Mean	Coeff Var
0.5738	-1.1311	4.7657	29.8708	15.9544

Parameter Estimates

Variable	Label	DF	Parameter Estimate	Standard Error	t-value	Pr>|t|
Intercept	Intercept	1	-124.5650	398.4361	-0.3100	0.8071
Protein	Protein	1	2.0516	4.3119	0.4800	0.7173
Ash	Ash	1	-1.9772	23.5528	-0.0800	0.9467
Moisture	Moisture	1	1.1678	4.5762	0.2600	0.8409
CF	CF	1	3.6355	20.8415	0.1700	0.8901

---------- TRT=PN ----------

The REG Procedure
Model: MODEL1
Dependent Variable: LH_KJ_kg_ LH_KJ_kg_

Analysis of Variance

Source	DF	Sum of Square	Mean Square	F Value	Pr > F
Model	4	21.1333	5.2833	0.6200	0.7286
Error	1	8.5875	8.5875		
Corrected Total	5	29.7209			

R-Square	Adj. R-Square	Root MSE	Dependent Mean	Coeff Var
0.7111	-0.4447	2.9304	32.1041	9.1279

Parameter Estimates

Variable	Label	DF	Parameter Estimate	Standard Error	t-value	Pr>|t|
Intercept	Intercept	1	-89.4249	158.3884	-0.5600	0.6728
Protein	Protein	1	1.4998	2.1243	0.7100	0.6086
Ash	Ash	1	-4.5110	6.3266	-0.7100	0.6057
Moisture	Moisture	1	3.9485	5.8723	0.6700	0.6232
CF	CF	1	3.7371	6.3591	0.5900	0.6618

Please note that for any simple linear regression, the equation is given as Y= a+bx
Where, Y is the Dependent variable, a is the intercept, b is the slope and
X is the independent variable.
for more than one independent or explanatory variable the equation is given by
Y=a+bx1+bx2+bx3...+bxn eg
if we consider LH_KJ_kg in PN the equation will be given as LH_KJ_kg= -89.425+1.4999Protein-4.5111ash_3.9485moisture+3.7371cf

---------- TRT=C ----------

The REG Procedure
Model: MODEL1
Dependent Variable: SHC_Kj_Kg_ SHC_Kj_Kg_

Analysis of Variance

Source	DF	Sum of Square	Mean Square	F Value	Pr > F
Model	2	0.0023	0.0011	4.9300	0.1126
Error	3	0.0007	0.0002		
Corrected Total	5	0.0031			

R-Square	Adj. R-Square	Root MSE	Dependent Mean	Coeff Var
0.7668	0.6113	0.0155	1.7993	0.8629

Parameter Estimates

Variable	Label	DF	Parameter Estimate	Standard Error	t-value	Pr>|t|
Intercept	Intercept	1	1.3666	0.1752	7.8000	0.0044
Protein	Protein	1	0.0030	0.0026	1.1500	0.3348
Ash	Ash	1	0.0411	0.0161	2.5500	0.0838

---------- TRT=CN ----------

The REG Procedure
Model: MODEL1
Dependent Variable: SHC_Kj_Kg_ SHC_Kj_Kg_

Analysis of Variance

Source	DF	Sum of Square	Mean Square	F Value	Pr > F
Model	2	0.0126	0.0063	9.8400	0.0481
Error	3	0.0019	0.0006		
Corrected Total	5	0.0145			

R-Square	Adj. R-Square	Root MSE	Dependent Mean	Coeff Var
0.8677	0.7796	0.0253	1.8888	1.3417

Parameter Estimates

Variable	Label	DF	Parameter Estimate	Standard Error	t-value	Pr>|t|
Intercept	Intercept	1	0.6619	0.3865	1.7100	0.1853
Protein	Protein	1	0.0131	0.0036	3.5600	0.0377
Ash	Ash	1	0.0570	0.0674	0.8500	0.4600

---------- TRT=NC ----------

The REG Procedure
Model: MODEL1
Dependent Variable: SHC_Kj_Kg_ SHC_Kj_Kg_

Analysis of Variance

Source	DF	Sum of Square	Mean Square	F Value	Pr > F
Model	2	0.0114	0.0057	38.2500	0.0073
Error	3	0.0004	0.0001		
Corrected Total	5	0.0118			

R-Square	Adj. R-Square	Root MSE	Dependent Mean	Coeff Var
0.9623	0.9371	0.0122	1.8158	0.6728

Parameter Estimates

Variable	Label	DF	Parameter Estimate	Standard Error	t-value	Pr>|t|
Intercept	Intercept	1	0.7142	0.1467	4.8700	0.0166
Protein	Protein	1	0.0155	0.0022	6.8900	0.0063
Ash	Ash	1	0.0133	0.0267	0.5000	0.6525

---------- TRT=NCN ----------

The REG Procedure
Model: MODEL1
Dependent Variable: SHC_Kj_Kg_ SHC_Kj_Kg_

Analysis of Variance

Source	DF	Sum of Square	Mean Square	F Value	Pr > F
Model	2	0.0109	0.0054	64.1500	0.0035
Error	3	0.0002	0.0000		
Corrected Total	5	0.0111			

R-Square	Adj. R-Square	Root MSE	Dependent Mean	Coeff Var
0.9772	0.9619	0.0092	1.8996	0.4857

Parameter Estimates

Variable	Label	DF	Parameter Estimate	Standard Error	t-value	Pr>|t|
Intercept	Intercept	1	0.9641	0.0866	11.1200	0.0016
Protein	Protein	1	0.0151	0.0014	10.2600	0.0020
Ash	Ash	1	-0.0257	0.0119	-2.1500	0.1204

---------- TRT=NP ----------

The REG Procedure
Model: MODEL1
Dependent Variable: SHC_Kj_Kg_ SHC_Kj_Kg_

Analysis of Variance

Source	DF	Sum of Square	Mean Square	F Value	Pr > F
Model	2	0.0032	0.0016	2.5100	0.2287
Error	3	0.0019	0.0006		
Corrected Total	5	0.0051			

R-Square	Adj. R-Square	Root MSE	Dependent Mean	Coeff Var
0.6260	0.3767	0.0252	1.8410	1.3704

Parameter Estimates

Variable	Label	DF	Parameter Estimate	Standard Error	t-value	Pr>|t|
Intercept	Intercept	1	0.9892	0.3814	2.5900	0.0809
Protein	Protein	1	0.0114	0.0055	2.0600	0.1320
Ash	Ash	1	0.0149	0.0294	0.5100	0.6469

---------- TRT=NPN ----------

The REG Procedure
Model: MODEL1
Dependent Variable: SHC_Kj_Kg_ SHC_Kj_Kg_

Analysis of Variance

Source	DF	Sum of Square	Mean Square	F Value	Pr > F
Model	2	0.0021	0.0010	1.0700	0.4459
Error	3	0.0029	0.0009		
Corrected Total	5	0.0051			

R-Square	Adj. R-Square	Root MSE	Dependent Mean	Coeff Var
0.4163	0.0272	0.0315	1.8731	1.6827

Parameter Estimates

Variable	Label	DF	Parameter Estimate	Standard Error	t-value	Pr>|t|
Intercept	Intercept	1	4.0747	1.7690	2.3000	0.1047
Protein	Protein	1	-0.0315	0.0271	-1.1600	0.3290
Ash	Ash	1	0.0026	0.0408	0.0600	0.9525

---------- TRT=PN ----------

The REG Procedure
Model: MODEL1
Dependent Variable: SHC_Kj_Kg_ SHC_Kj_Kg_

Analysis of Variance

Source	DF	Sum of Square	Mean Square	F Value	Pr > F
Model	2	0.0040	0.0020	7.0400	0.0736
Error	3	0.0008	0.0002		
Corrected Total	5	0.0048			

R-Square	Adj. R-Square	Root MSE	Dependent Mean	Coeff Var
0.8244	0.7073	0.0169	1.8675	0.9047

Parameter Estimates

Variable	Label	DF	Parameter Estimate	Standard Error	t-value	Pr>|t|
Intercept	Intercept	1	1.1055	0.2536	4.3600	0.0223
Protein	Protein	1	0.0109	0.0054	1.9900	0.1411
Ash	Ash	1	0.0059	0.0257	0.2300	0.8317

---------- TRT=C ----------

The REG Procedure
Model: MODEL1
Dependent Variable: TC_w_moc_ TC_w_moc_

Analysis of Variance

Source	DF	Sum of Square	Mean Square	F Value	Pr > F
Model	3	0.0001	0.0000	20.6100	0.0466
Error	2	0.0000	0.0000		
Corrected Total	5	0.0001			

R-Square	Adj. R-Square	Root MSE	Dependent Mean	Coeff Var
0.9687	0.9217	0.0010	0.1871	0.5628

Parameter Estimates

Variable	Label	DF	Parameter Estimate	Standard Error	t-value	Pr>|t|
Intercept	Intercept	1	0.1110	0.0245	4.5300	0.0454
Protein	Protein	1	0.0000	0.0002	0.2300	0.8414
Ash	Ash	1	0.0040	0.0011	3.6600	0.0673
Moisture	Moisture	1	0.0051	0.0009	5.5000	0.0315

---------- TRT=CN ----------

The REG Procedure
Model: MODEL1
Dependent Variable: TC_w_moc_ TC_w_moc_

Analysis of Variance

Source	DF	Sum of Square	Mean Square	F Value	Pr > F
Model	3	0.0001	0.0000	3.9500	0.2086
Error	2	0.0000	0.0000		
Corrected Total	5	0.0001			

R-Square	Adj. R-Square	Root MSE	Dependent Mean	Coeff Var
0.8556	0.6390	0.0030	0.1950	1.5588

Parameter Estimates

Variable	Label	DF	Parameter Estimate	Standard Error	t-value	Pr>|t|
Intercept	Intercept	1	0.0193	0.0534	0.3600	0.7518
Protein	Protein	1	0.0004	0.0004	0.9400	0.4451
Ash	Ash	1	0.0150	0.0080	1.8600	0.2042
Moisture	Moisture	1	0.0050	0.0020	2.5200	0.1276

---------- TRT=NC ----------

The REG Procedure
Model: MODEL1
Dependent Variable: TC_w_moc_ TC_w_moc_
Analysis of Variance

Source	DF	Sum of Square	Mean Square	F Value	Pr > F
Model	3	0.0000	0.0000	0.4500	0.7462
Error	2	0.0001	0.0000		
Corrected Total	5	0.0001			

R-Square	Adj. R-Square	Root MSE	Dependent Mean	Coeff Var
0.4008	-0.4979	0.0051	0.1888	2.7010

Parameter Estimates

Variable	Label	DF	Parameter Estimate	Standard Error	t-value	Pr>|t|
Intercept	Intercept	1	0.0387	0.1365	0.2800	0.8031
Protein	Protein	1	0.0008	0.0011	0.7700	0.5210
Ash	Ash	1	-0.000	0.0126	-0.0700	0.9529
Moisture	Moisture	1	0.0101	0.0122	0.8300	0.4953

---------- TRT=NCN ----------

The REG Procedure
Model: MODEL1
Dependent Variable: TC_w_moc_ TC_w_moc_

Analysis of Variance

Source	DF	Sum of Square	Mean Square	F Value	Pr > F
Model	3	0.0000	0.0000	0.6400	0.6566
Error	2	0.0000	0.0000		
Corrected Total	5	0.0001			

R-Square	Adj. R-Square	Root MSE	Dependent Mean	Coeff Var
0.4904	-0.2740	0.0044	0.1910	2.3039

Parameter Estimates

Variable	Label	DF	Parameter Estimate	Standard Error	t-value	Pr>|t|
Intercept	Intercept	1	-0.0599	0.2299	-0.2600	0.8186
Protein	Protein	1	0.0004	0.0007	0.6400	0.5864
Ash	Ash	1	0.0124	0.0152	0.8100	0.5010
Moisture	Moisture	1	0.0159	0.0137	1.1700	0.3639

---------- TRT=NP ----------

The REG Procedure
Model: MODEL1
Dependent Variable: TC_w_moc_ TC_w_moc_

Analysis of Variance

Source	DF	Sum of Square	Mean Square	F Value	Pr > F
Model	3	0.0000	0.0000	0.3800	0.7789
Error	2	0.0001	0.0000		
Corrected Total	5	0.0001			

R-Square	Adj. R-Square	Root MSE	Dependent Mean	Coeff Var
0.3656	-0.5859	0.0053	0.1935	2.7841

Parameter Estimates

Variable	Label	DF	Parameter Estimate	Standard Error	t-value	Pr>|t|
Intercept	Intercept	1	0.1457	0.1187	1.2300	0.3447
Protein	Protein	1	0.0001	0.0013	0.1200	0.9147
Ash	Ash	1	-0.0015	0.0064	-0.2400	0.8301
Moisture	Moisture	1	0.0046	0.0048	0.9700	0.4333

---------- TRT=NPN ----------

The REG Procedure
Model: MODEL1
Dependent Variable: TC_w_moc_ TC_w_moc_

Analysis of Variance

Source	DF	Sum of Square	Mean Square	F Value	Pr > F
Model	3	0.0000	0.0000	0.4500	0.7462
Error	2	0.0001	0.0000		
Corrected Total	5	0.0001			

R-Square	Adj. R-Square	Root MSE	Dependent Mean	Coeff Var
0.4008	-0.4980	0.0060	0.1915	3.1763

Parameter Estimates

Variable	Label	DF	Parameter Estimate	Standard Error	t-value	Pr>|t|
Intercept	Intercept	1	0.5192	0.3415	1.5200	0.2679
Protein	Protein	1	-0.0057	0.0053	-1.0800	0.3943
Ash	Ash	1	0.0096	0.0100	0.9700	0.4349
Moisture	Moisture	1	0.0021	0.0040	0.5200	0.6527

---------- TRT=PN ----------

The REG Procedure
Model: MODEL1
Dependent Variable: TC_w_moc_ TC_w_moc_

Analysis of Variance

Source	DF	Sum of Square	Mean Square	F Value	Pr > F
Model	3	0.0000	0.0000	94.34	0.0105
Error	2	1.2630E-7	6.3152E-8		
Corrected Total	5	0.0000			

R-Square	Adj. R-Square	Root MSE	Dependent Mean	Coeff Var
0.9930	0.9825	0.0002	0.1950	0.1288

Parameter Estimates

Variable	Label	DF	Parameter Estimate	Standard Error	t-value	Pr>|t|
Intercept	Intercept	1	0.0951	0.0127	7.4400	0.0176
Protein	Protein	1	0.0009	0.0001	6.5000	0.0229
Ash	Ash	1	0.0015	0.0004	3.7100	0.0656
Moisture	Moisture	1	0.0025	0.0004	5.4000	0.0326

---------- TRT=C ----------

The REG Procedure
Model: MODEL1
Dependent Variable: TD_m2_s_X10_7 TD_m2_s_X10_7

Analysis of Variance

Source	DF	Sum of Square	Mean Square	F Value	Pr > F
Model	4	0.0389	0.0097	22.8400	0.1555
Error	1	0.0004	0.0004		
Corrected Total	5	0.0393			

R-Square	Adj. R-Square	Root MSE	Dependent Mean	Coeff Var
0.9892	0.9459	0.0206	7.5041	0.2750

Parameter Estimates

Variable	Label	DF	Parameter Estimate	Standard Error	t-value	Pr>|t|
Intercept	Intercept	1	15.9635	6.5699	2.4300	0.2486
Protein	Protein	1	-0.1930	0.1240	-1.5600	0.3636
Ash	Ash	1	0.7353	0.3319	2.2200	0.2699
Moisture	Moisture	1	0.2324	0.0987	2.3500	0.2557
CF	CF	1	-0.6729	0.3822	-1.7600	0.3289

---------- TRT=CN ----------

The REG Procedure
Model: MODEL1
Dependent Variable: TD_m2_s_X10_7 TD_m2_s_X10_7

Analysis of Variance

Source	DF	Sum of Square	Mean Square	F Value	Pr > F
Model	4	0.2580	0.0645	312.3700	0.0424
Error	1	0.0002	0.0002		
Corrected Total	5	0.2582			

R-Square	Adj. R-Square	Root MSE	Dependent Mean	Coeff Var
0.9992	0.9960	0.0143	7.8590	0.1828

Parameter Estimates

Variable	Label	DF	Parameter Estimate	Standard Error	t-value	Pr>|t|
Intercept	Intercept	1	-4.3327	1.7889	-2.4200	0.2493
Protein	Protein	1	0.0945	0.0103	9.1800	0.0691
Ash	Ash	1	0.6515	0.1341	4.8600	0.1293
Moisture	Moisture	1	0.0541	0.0131	4.1100	0.1519
CF	CF	1	0.4681	0.1425	3.2800	0.1882

---------- TRT=NC ----------

The REG Procedure
Model: MODEL1
Dependent Variable: TD_m2_s_X10_7 TD_m2_s_X10_7

Analysis of Variance

Source	DF	Sum of Square	Mean Square	F Value	Pr > F
Model	4	0.2568	0.0642	135.2700	0.0644
Error	1	0.0004	0.0004		
Corrected Total	5	0.2572			

R-Square	Adj. R-Square	Root MSE	Dependent Mean	Coeff Var
0.9982	0.9908	0.0217	7.5545	0.2883

Parameter Estimates

Variable	Label	DF	Parameter Estimate	Standard Error	t-value	Pr>|t|
Intercept	Intercept	1	-0.0151	0.6732	-0.0200	0.9857
Protein	Protein	1	0.0885	0.0051	17.1400	0.0371
Ash	Ash	1	-0.0353	0.0580	-0.6100	0.6519
Moisture	Moisture	1	0.1763	0.0524	3.3600	0.1841
CF	CF	1	0.1011	0.0459	2.2000	0.2715

---------- TRT=NCN ----------

The REG Procedure
Model: MODEL1
Dependent Variable: TD_m2_s_X10_7 TD_m2_s_X10_7

Analysis of Variance

Source	DF	Sum of Square	Mean Square	F Value	Pr > F
Model	4	0.0237	0.0059	19.2700	0.1690
Error	1	0.0003	0.0003		
Corrected Total	5	0.0240			

R-Square	Adj. R-Square	Root MSE	Dependent Mean	Coeff Var
0.9872	0.9360	0.0175	7.8615	0.2233

Parameter Estimates

Variable	Label	DF	Parameter Estimate	Standard Error	t-value	Pr>|t|
Intercept	Intercept	1	7.1936	1.0570	6.8100	0.0929
Protein	Protein	1	0.0059	0.0031	1.8900	0.3101
Ash	Ash	1	-0.0792	0.0760	-1.0400	0.4870
Moisture	Moisture	1	0.1118	0.0603	1.8500	0.3148
CF	CF	1	-0.1044	0.0330	-3.1600	0.1950

---------- TRT=NP ----------

The REG Procedure
Model: MODEL1
Dependent Variable: TD_m2_s_X10_7 TD_m2_s_X10_7

Analysis of Variance

Source	DF	Sum of Square	Mean Square	F Value	Pr > F
Model	4	0.0885	0.0221	376.6700	0.0386
Error	1	0.0001	0.0001		
Corrected Total	5	0.0886			

R-Square	Adj. R-Square	Root MSE	Dependent Mean	Coeff Var
0.9993	0.9967	0.0076	7.6498	0.1002

Parameter Estimates

Variable	Label	DF	Parameter Estimate	Standard Error	t-value	Pr>|t|
Intercept	Intercept	1	0.9005	0.2603	3.4600	0.1792
Protein	Protein	1	0.0824	0.0030	27.1800	0.0234
Ash	Ash	1	-0.0260	0.0091	-2.8500	0.2145
Moisture	Moisture	1	0.1323	0.0068	19.2800	0.0330
CF	CF	1	0.0455	0.0138	3.2800	0.1886

---------- TRT=NPN ----------

The REG Procedure
Model: MODEL1
Dependent Variable: TD_m2_s_X10_7 TD_m2_s_X10_7

Analysis of Variance

Source	DF	Sum of Square	Mean Square	F Value	Pr > F
Model	4	0.0448	0.0112	7.3400	0.2693
Error	1	0.0015	0.0015		
Corrected Total	5	0.0463			

R-Square	Adj. R-Square	Root MSE	Dependent Mean	Coeff Var
0.9671	0.8353	0.0390	7.8986	0.4945

Parameter Estimates

Variable	Label	DF	Parameter Estimate	Standard Error	t-value	Pr>|t|
Intercept	Intercept	1	11.7638	3.2658	3.6000	0.1724
Protein	Protein	1	-0.0480	0.0353	-1.3600	0.4036
Ash	Ash	1	-0.1302	0.1930	-0.6700	0.6221
Moisture	Moisture	1	0.0340	0.0375	0.9100	0.5305
CF	CF	1	-0.0270	0.1708	-0.1600	0.9001

---------- TRT=PN ----------

The REG Procedure
Model: MODEL1
Dependent Variable: TD_m2_s_X10_7 TD_m^2_s_$X10^{-7}$

Analysis of Variance

Source	DF	Sum of Square	Mean Square	F Value	Pr > F
Model	4	0.1323	0.0330	4.7500	0.3298
Error	1	0.0069	0.0069		
Corrected Total	5	0.1393			

R-Square	Adj. R-Square	Root MSE	Dependent Mean	Coeff Var
0.9500	0.7501	0.0834	7.8326	1.0654

Parameter Estimates

Variables	Label	DF	Parameter Estimate	Standard Error	t-value	Pr>|t|
Intercept	Intercept	1	-6.9987	4.5105	-1.5500	0.3645
Protein	Protein	1	0.2466	0.0605	4.0800	0.1531
Ash	Ash	1	-0.6919	0.1801	-3.8400	0.1622
Moisture	Moisture	1	0.1210	0.1672	0.7200	0.6012
CF	CF	1	0.5334	0.1810	2.9500	0.2084