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THE EFFECT OF SPICES ON LIPID
CHARACTERISTICS AND
ACCEPTABILITY OF SMOKED CATFISH
(CLARIAS SENEX)

A DISSERTATION SUBMITTED

BY

MBAKOCHA, UCHENNA CHIUDI OSOMOU
SG/MSc/83/1863

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE AWARD OF THE DEGREE OF SCIENCE
DEGREE IN FOOD SCIENCE AND TECHNOLOGY,
FACULTY OF AGRICULTURE OF THE UNIVERSITY
OF NIGERIA, NUGUMA.


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DR. N. I. ONWUKA
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HEAD OF DEPARTMENT
DEDICATION

This work is dedicated to my family whom I have denied my constant presence and attention this long.
I thank God for life, time and means without which this work could not have been.

I am grateful to my project adviser, Dr. Onwuka, N.D., for expertly guiding and shaping this work.

I am greatly indebted to Dr. Ikume, A.I. whose constant suggestions and attention were my privilege, which made the work actually take off and saw it to completion; and also to Mr. Okonkwo T.K. whose constructive criticism helped immensely.

I wish to thank Mr. Nwankwo, A.J.O., Mr. Kalu, U.M., Mr. Oyekwashi, C.A. and Mr. Onuchukwu, B.C.N. in whom I found brotherly attention at all times.

I enjoyed the assistance of Members Chima Nnanna, Diorua Clement, Kalu, E.U. and a host of other staffs of the Department, whose help cannot pass unmentioned.

Finally, Mr. Nwachukwu, the then Principal of C.S.S. Enada, who provided a clutching straw in turbulent waters, my unending love.
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<td>Changes in Iodine values During storage</td>
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An experiment was conducted to assay the efficacy of some spices as antioxidants and/or antimycotic agents in smoked dwarf catfish Clarias obiensis. Samples of the fish were cleaned, dipped for five minutes in six different treatment solutions \( T \) constituted as follows:

- \( T_1 \) - 6% potassium sorbate (KSB), 0.03% BHT, 10% NaCl, all dissolved in 1 litre of distilled water.
- \( T_2 \) - 6% KSB, 10% NaCl in 1 litre of 50% onion hot water extract.
- \( T_3 \) - 6% KSB, 10% NaCl in 1 litre of 50% ginger crude extract.
- \( T_4 \) - \( T_2 \) and \( T_3 \) mixed in equal volumes.
- \( T_5 \) - \( T_1 \), \( T_2 \) and \( T_3 \) mixed in equal volumes.
- \( T_6 \) - (Control) 10% NaCl solution of distilled water.

The fish samples were smoked to a moisture range of 13-15% to 40-50%, and stored at ambient temperature (except \( T_6 \) that was refrigerated) for 8 weeks and samples taken for chemical, sensory and microbiological analysis.

After storage, \( T_2 \), \( T_3 \), \( T_4 \) and \( T_6 \) did not develop any detectable rancidity but \( T_1 \) and \( T_5 \) had a slight rancid rancid taste on the 7th week. Ginger crude extract and onion hot water extract as used here were found effective antioxidant better than 0.03% BHT.
Cinnamon at 4% incorporation level in malt extract again inhibited mould growth, but failed to do some semi-dehydrated fish cubes. Other spices namely garlic, thyme and ginger did not inhibit mould growth.

At the end of storage samples with moisture range of 18% - 27% at ambient temperature and up to 30% for sample of CB in the refrigerator were still acceptable. Samples above the moisture range were not longer acceptable.
1.1 IMPORTANCE OF FISH

Food from the sea has been an important source of protein for man. Fish, by far the most sought after of sea foods contains about 12% protein in its flesh, thus comparing favourably with land animals which have 19%, and has the advantage of cheapness. It's protein supply the essential amino acids, namely, Isoleucine, Valine, Methionine, Phenylalanine, Lysine Threonine and Tryptophane, which are frequently deficient in plant protein in the amounts and proportions needed by the body, for growth, repair and synthesis of such protein compounds as hormones, enzymes and blood components. Fish is also a source of other nutrients such as lipids, vitamins and mineral salts, especially such rare ones as fluorine and iodine whose source is mostly sea foods.

1.2 VISCERA STOCKAGE

Fish is harvested from the sea with a high microbial load (usually bacteria) in the order of about $10^2$ to $10^7$ per cm$^2$ on their body surface, gills, and gut. This initial bacterial load does not attack the live fish due to its body defense mechanism. After the cessation of vigor, spoilage commences as autolysis, whose products such as amino acids, fatty acids and glycerol provide a rich medium for microbial growth.
Spoilage and pathogenic organisms simultaneously grow rapidly in and on the fish, causing wastage and constituting health problems for man. Species of micro-organisms encountered in fish spoilage depend on a number of factors which include fish type, its environment, handling practices and prevailing temperature.

As microbial deterioration goes on, chemical deterioration starts on the fat of the fish, causing off-flavours and off-odours. This deterioration called oxidative rancidity is a problem in foods containing unsaturated lipids, such as fish with polyunsaturated fatty acids and the rate is higher in heated foods.

Yeast and mould spoilage occurs through contamination and only when measures are taken to check and arrest bacterial growth. Their types of spoilage makes the fish product slimy to touch, pigmented, generate bad odours and are generally unacceptable.

Another spoilage organism in fish is insect. Insect infestation occurs in dehydrated fish with moisture content well below 15% and mostly as a result of inadequate packaging and storage. The insect vectors use the fish muscles as breeding ground and food, making numerous tunnels through the muscles, increasing the ease of fragmentation as well as reducing the quality and quantity of the product consumers pay for.

1.3 PRESERVATION OF FISH

Preservation involves the application of these measures which delay or prevent spoilage. Most preservative methods involve such processing procedures as splitting, gutting, washing/plenty of clean water, and at times for big fish, be-heading, filleting and deboning occurs.
The above process is followed by curing with salts, antioxidants, fungicides, anti-bacterial agents, spices, and smoke components (smoking). Other methods, which may be preceded by one or more curing methods, include drying and dehydration, freezing and refrigeration.

Traditional methods of fish preservation in West Africa is almost the same. This involves dressing, sundrying and/or hot-smoking. In the hot drier areas of West Africa, sundrying is used, which involves hanging fish on hooks supported on poles or spreading them on flat baskets on constructed platforms, where enough sunheat will reach them.

Smoke curing, more popular in this part of the world, is the infusion of the fish with smoke components and drying or dehydration is simultaneously achieved. Smoking is done in traditional kilns built of either mud or metal sheets, which may be round or rectangular. A vent is provided at the base for firewood and draught. The top has a grill of iron grating on which the fish is spread. Usually hardwood is employed, since it holds the embers longer, thus providing more heat and smoke with less smoke.

1.2 FISH IN NIGERIA ECONOMY.

Nigeria with an estimated population of 120 million has average fish catch of 0.5 million metric tonnes per annum from 1978 to 1982, (table 1.1). The fish available in Nigerian market comes from fresh water (inland rivers and lakes), brackish water (where fresh water empties into the sea) and marine or salt waters.
| Source: Settlements Unit of the Federal Department of Planning Victoria |

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<td>1,990</td>
<td>2,010</td>
<td>2,030</td>
<td>2,050</td>
<td>2,070</td>
<td>2,090</td>
<td>2,110</td>
<td>2,130</td>
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<td>Commercial Area</td>
<td>1,670</td>
<td>1,700</td>
<td>1,730</td>
<td>1,760</td>
<td>1,790</td>
<td>1,820</td>
<td>1,850</td>
<td>1,880</td>
<td>1,910</td>
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<td>1,480</td>
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<td>1,520</td>
<td>1,540</td>
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<td>Agricultural (Total)</td>
<td>1,276</td>
<td>1,296</td>
<td>1,316</td>
<td>1,336</td>
<td>1,356</td>
<td>1,376</td>
<td>1,396</td>
<td>1,416</td>
<td>1,436</td>
<td>1,456</td>
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<tr>
<td>Total</td>
<td>7,060</td>
<td>7,120</td>
<td>7,180</td>
<td>7,240</td>
<td>7,300</td>
<td>7,360</td>
<td>7,420</td>
<td>7,480</td>
<td>7,540</td>
<td>7,600</td>
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Note: Figures with interpolation by source 1966 - 1990 (March Quarter)
Nigeria imports a good quantity of all the fish she consumes, (Tables 1.1 and 1.2). Fish comes into Nigeria as dried/dehydrated, canned, smoked and a sizable proportion as frozen. This import is not healthy for the nation’s meagre foreign exchange, and increased local fish production is called for. Also a drastic action should be taken by the government against the rapidly spreading water hyacinth (weeds) on our coast lines, which further decreases catch and has laid many fishermen off job.

**TABLE 1.2**

**FISH IMPORTATION INTO NIGERIA (JANUARY-MARCH 1979)**

<table>
<thead>
<tr>
<th>FISH PRODUCT</th>
<th>QUANTITY (KG)</th>
<th>VALUE (N)</th>
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</thead>
<tbody>
<tr>
<td>Fresh preserved(chilled, frozen)</td>
<td>1,106,721</td>
<td>972,885</td>
</tr>
<tr>
<td>Stock fish (dehydrated)</td>
<td>4,536,259</td>
<td>8,841,595</td>
</tr>
<tr>
<td>Others-salted/dried/smoked</td>
<td>231,254</td>
<td>855,518</td>
</tr>
<tr>
<td>Canned fish/crustacea/molluscs</td>
<td>29,356,846</td>
<td>23,629,907</td>
</tr>
<tr>
<td>Crustacea/molluscs(chilled, frozen)</td>
<td>59,316</td>
<td>17,760</td>
</tr>
<tr>
<td>Others - fish and fish products</td>
<td>7,506,805</td>
<td>5,692,951</td>
</tr>
</tbody>
</table>

*Calculated from: Live stock and meat imported into Nigeria; January - March 1979*

*Source: Nigerian Trade Summary March 1979 for Lagos.*
Fresh fish with its perishability at the ambient tropical temperature is unsuited or smoked dried when caught in quantities much greater than can be disposed of immediately by our local fishermen, or when needed to be stored for use in times of short fall in catch. Also about 70% of all frozen fish imported is smoked (Kalabi 1977). This is due to the lack of continuous refrigeration during transportation, storage and marketing on one hand and on the other due to consumer preference for smoked fish products. Uyadu et al. (1967) reported the marketing of 5,000 - 6,000 metric tonnes of dried fish between 1960 and 1963 in Maiduguri.

Smoked fish with its characteristic odour and flavour is highly acceptable and relished in Nigerian traditional dishes. Quality smoked products stem from the raw material. Fresh fish which has undergone advanced deterioration cannot give prime smoked product. Prime products have firm, closely rigid texture as compared to the soft, flabby products from improper curing and poor quality raw materials. Generally prime products attract higher prices and faster sales, their flavour is unique and colour attractively bright. Poor quality products are dull and lack the characteristic flavour of prime smoked products.

1.5 JUSTIFICATION AND OBJECTIVE OF THE STUDY

Though freezing, refrigeration and canning have removed the necessity for heavy smoking, lightly smoked foods are still popular mainly because of the flavour (Watts, 1974).
In Nigeria, where communications are poor, climate conditions severe, a huge outlay for a "cold box" and NIFSA untrust worthy, dry-smoked still has a long lease of life. These days, mild smoked high moisture fish is in vogue, but this is prone to rapid growth and lipid oxidation soon after processing.

Research carried out by Okezie (1984), has successfully arrested lipid oxidation and mould growth with the use of synthetic antioxidants (butylated hydroxytoluene (BHT) and citric acid) and a mould inhibitor (potassium sorbate). Also Okezie (1985), used hot water onion extract, a natural antioxidant successfully in fish, thus replacing synthetic antioxidant with a natural one.

These synthetic antioxidants are known not only to be toxic above the recommended level but also need scientific management and are rarely within reach of the local fishermen.

It is against this background that this study is undertaken.

- To assay some local spices for their possible antioxidant and antimicrobial properties.
- To use each spice extract to cure fresh fish which would be mild smoked to intermediate moisture level.
- To store the smoked fish products for eight weeks and monitor their possible spoilage pattern.
- To compare the possible efficacy of such spice extracts against some synthetic antioxidants.

It is hoped that this work will achieve its objectives and thereby contribute to the change from heavily smoked and dehydrated products to high moisture, mild cured, spiced products with equally good shelf life and high acceptability.
2.1 CHEMICAL COMPOSITION AND NUTRITIVE VALUE OF FISH

The overall nutritive value of fish and fish products depend on their chemical composition, that is, the quantity and quality of their proteins, lipids, vitamins and mineral salts. Chemical composition depends on factors, some of which are intrinsic, bearing upon genetics, morphology and physiology or environmental relating to the living conditions, particularly feeding. Also among these factors are differences between species, sex and seasonal variations.

The composition of most fish fall within the ranges of 13% - 35% total solids, 14% - 20% protein, 0.3% - 2% fat and 1.0% - 1.8% ash (Potter, 1978). The moisture and lipid contents are inversely proportional to each other and their sum approximates 80%. The percentage of glycogen, mineral salts and vitamins are small though vital and nutritionally important.

2.1.1 WATER CONTENT

Water is a major component in all fishes, making up 70% - 80% fresh weight. It is an important solvent for substances and medium for most metabolic activities in the fish.
2.1.2 PROTEIN CONTENT

Fish muscle with protein content of 11% - 20% (Cowan, 1981; Murray and Burt, 1969) does not vary in microscopical structure, amino acid composition and nutritionally from those of land animals and has a high degree of digestibility. Generally, the amino acid composition favors that of land animals even with regards to the eight essential amino acids (Table 2.1).

Table 2.1 Summary of Essential Amino Acid Composition of Four Flesh Food Products (mg/100g Total Nitrogen)

<table>
<thead>
<tr>
<th>Amino Acid</th>
<th>Beef</th>
<th>Cow Milk</th>
<th>Egg White</th>
<th>Fish Flesh</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leucine</td>
<td>517</td>
<td>782</td>
<td>518</td>
<td>150</td>
</tr>
<tr>
<td>Valine</td>
<td>291</td>
<td>463</td>
<td>301</td>
<td>392</td>
</tr>
<tr>
<td>Isoleucine</td>
<td>337</td>
<td>399</td>
<td>351</td>
<td>288</td>
</tr>
<tr>
<td>Methionine</td>
<td>115</td>
<td>145</td>
<td>248</td>
<td>179</td>
</tr>
<tr>
<td>Phenylalanine</td>
<td>252</td>
<td>434</td>
<td>272</td>
<td>245</td>
</tr>
<tr>
<td>Lysine</td>
<td>523</td>
<td>140</td>
<td>415</td>
<td>569</td>
</tr>
<tr>
<td>Threonine</td>
<td>265</td>
<td>278</td>
<td>299</td>
<td>289</td>
</tr>
<tr>
<td>Tryptophan</td>
<td>70</td>
<td>91</td>
<td>99</td>
<td>70</td>
</tr>
</tbody>
</table>

Collected from: Comparative Indispensable Human Amino Acids Content of Protein in Food Stuff

Sources: FAO (1970).
2.1.3 LIPID CONTENT

Fish usually contain 0.2% - 20% lipids. The fat of true fish is found mainly in the dark muscle just below the skin and the lateral line area (Clucas, 1981). Other fat depots include the viscera and liver, the skeleton in flat fishes (Jacquot, 1963), muscles of the tail and near the head (Thorson and Groninger, 1957). The principal fatty acids of fish contain 5 to 6 double bonds, compared to 2 and at most 3 in vegetable and land animal fats. This poly unsaturation makes fish oil highly susceptible to oxidation, though containing more natural antioxidant of the vitamin E type (Murray and Burt, 1969).

2.1.4 CARBOHYDRATE CONTENT

Carbohydrates are not taken into account when estimating the food value of fish, since the quantity in teleosts is, at a maximum, 0.3% (Burgess et al., 1965). This quantity is very important though for rice, its resoluation and water holding capacity of the fish flesh.

2.1.5 VITAMIN CONTENT

The vitamin content of fish varies with species, age, season of catch, fishing locality and its diet. This compares favourably with vitamin content of land flesh foods. Fatty fishes are usually very valuable sources of the fat soluble vitamins (A, D and E), especially in the liver (Clucas 1981). The water soluble vitamins are contained in the flesh and gonads. Vitamin C is not stored by fishes.
2.1.6 Mineral Salt Content of Fish.

Mineral salts are substances that must be present in minute quantities in the diet, not only to promote good health but also maintain life itself (Nwogu and Hirt, 1969). These substances are varied and include potassium, calcium, sodium, magnesium, iron, phosphorus, sulphur, fluoride, chlorine, iodine, copper, manganese, bromine and others. The amount available in fish vary considerably in different species and the fish’s location.

2.2 Raw Material Handling.

Good quality processed fish products cannot be obtained from inferior raw material and processing such as soaking should never be used in an attempt to disguise stale fish or mask advanced deterioration (Jason, 1970). Most fishermen in the developing countries lose a good percentage of their catch through poor handling. Fish caught alive are simply kept on the bottom of the canoe, lying in a pool of warm dirty water, to struggle and die of asphyxiation. When the catch is heavy, the lower fish in the pile are crushed and bruised, and most times, spilling the gut content thus initiating and accelerating spoilage.

Microbial activities in a freshly caught fish can be considerably reduced by cleaning and chilling to the temperature of melting ice, 0°C, soon after capture (Ryan, 1970), and it is advisable that the fish be maintained at this temperature until landing to the end user.
Where the interval between catch and landing is long, FAO (1969) recommends that the fish should be properly frozen and stored frozen.

An important aspect of fish handling and pre-smoking is fish dressing, which is dependent on the ultimate product for which the fish is intended. This may include the cleaning operation (viscereation, fin removal, washing and scaling, for scaley fish) and at times beheading and filleting.

### 2.3 FISH PRESERVATION BY SMOKE CURING

Curing is an age-long process which involves the treatment of the flesh foods (fish) with chemicals such as table salt, phosphates, sugars, vinegar, alcohol, antioxidants, wood smoke and various spices (Kraulich et al., 1986). The basis of preservation stems from the dissolution of these chemicals in the fish fluid to form a concentrated solution in which the micro-organisms become dehydrated and die (Fox and Matthew, 1982). Fish is not cured with nitrates as meat because of the predominance of proline in its muscle which reacts with nitrates to give a carcinogen called nitrosopyrrolidine.

#### 2.3.1 SMOKING

Smoking is a primitive method of fish curing which is still in use. A considerable proportion of fish consumed is smoke cured basically because of the peculiar attractive colour and flavour imparted and secondly for the better keeping quality of smoked fish as compared to wet fish (Myers, 1960).
Smoking implies the exposure of fish to the action of wood smoke at some point during its processing. The smoking of fish products is accompanied by varying amounts of heat application in the smoke house, leading to cooking and sometimes drying of the product (Turbin, 1971). However, in modern processes, application of heat and smoke are now separable (Hollenbeck, 1979; Hsu et al., 1979). Thus there are hot and cold smoking.

Hot smoking is achieved through the combined action of heat, smoke, components and flow of gases over the fish. Cold smoking on the other hand is achieved by dipping the fish or spraying it with liquid smoke at relatively low temperatures.

2.3.2 SMOKE PRODUCTION AND COMPOSITION

Smoke is the vapour phase by-product of the thermal degradation of wood. During combustion, temperature gradient exists between the outer surface and the inner core of the wood, with the outer surface being oxidized while the inner core is being dehydrated. When the internal moisture content of the centre of the wood approaches zero, the temperature quickly rises from about 100°C to between 300°C - 400°C. This temperature favours the thermal decomposition of wood with production of smoke (Kranich et al., 1980).
The decomposition of the lignin of wood and production of phenols are greatest at temperatures above 100°C, but such high temperatures also favour the production of benzo(a)pyrene and polycyclic hydrocarbons which are known to be health hazards (Watts, 1974; Kralich et al., 1980).

The best quality smoke is produced at combustion temperature range of 300°C - 400°C, and plenty of air. In limited supply of air, the resulting smoke is dark and contains large amounts carboxylic acids.

The smoke for cold-smoking is got by using "elips" or coarse shavings with a layer of damp saw dust on top, which collapses continuously as determined by the burning of the underlying chips and thus damps down the flames, producing smoke rather than heat. Other innovations include generation of smoke from logs by friction, electrostatic charging of smoke particles to aid faster deposition and the experimental use of inert gas to fluidize the saucst, followed by controlled oxidation (Watts, 1974).

Smoke is a complex mixture of aliphatics, aromatics, carbon dioxide and water, with traces of hydrogen and carbon monoxide (Gibson, 1962). At the point of generation, smoke exists in the gas/particle state, but quickly partitions into the vapour and particulate phases.
This partitioning is the condensation of the compounds on
nuclei in the cool zone above the fire to form a stable aerosol
composed of minute tiny droplets which constitute the visible
smoke (Postet and Simpson, 1961). The vapour phase contains
the more volatile components including phenols, alcohols, \( \alpha \)-
carbon, organic acids, short-chained carbonyl compounds and
2 small quantity of hydrocarbons. This vapour phase is responsible
for the characteristic colour, flavour, aroma, texture and
preservative properties of smoked food while the contribution of
the particulate phase is negligible (Postet and Simpson, 1961)
gilbert and knowles, 1975; kambilich et al., 1980).

2.3.3 WOOD SYRES AND COMPOSITION.

Woods are classified as hard or soft depending on their
botanical origin. Hard woods are derived from typically broad-
leaved angiosperms and the latter from typically needle-leaved
gymnosperms. The overall composition of woods may be summarised
as cellulose (\( \beta \) - glucans) 40% - 60%; hemicellulose (hetero-
glycans containing pentoses and hexoses) 20% - 30%; lignins
(higher linked phenolic polymers) 20% - 30%. In addition are
a complex mixture of low molecular mass compounds, particularly
in soft wood and a rather variable water content.

In general, hard wood has higher hemicellulose content with
relatively greater content of pentoses than soft wood and a
greater but variable syringyl content while soft wood lignin
contains phenyl and guaiacyl (2 - methoxy phenyl) residues and
sometimes a small amount of syringyl(2,6-dimethoxy phenyl) residues
(clifford et al., 1989).
Thus hard wood is believed to be superior and yields smoke with more acid, producing a lower pH and bacteriologically more stable products. Soft wood is undesirable as it produces two much soot and in general, resinous wood is not recommended because they impart undesirable flavour to smoked products (Bay, 1979).

2.3.4 EVOLUTION OF SMOKING.

The smoking process has undergone some significant changes in the recent past. Improvements on the traditional methods have resulted in a rational process with strictly controlled parameters such as smoke quality, heat transfer, level of humidity and circulation of gases. These improvements have been made possible by the design and construction of modern smoking kilns with sophisticated recording and regulating instruments (Messina and Messina, 1977; Hellemeck, 1979), thus offering optimization in the smoking process. There are three main types of smoke houses in use today: natural air circulation type, forced air circulation or air-conditioned type and the continuous smoke house (Kromalich et al., 1980). There are modifications, though, of these three basic types.

2.3.5 ATTRIBUTES OF WOOD SMOKE.

Tigner et al., (1963) reported that the main components of the steam distillable fraction of wood smoke condensate were the carbohydrates, 21.6%; carboxylic acids, 39.1% and phenols, 15.7% and that the desirable attributes of wood smoke, which are anti-bacterial effects, anti-oxidant, flavour and colour effects seem to be associated with some of the above fractions.
1. **Antibacterial properties of smoke**.

One factor responsible for the preservative effects of smoke in its bactericidal and bacteriostatic properties is the fraction of vapour responsible for the product's biological stability, which are the phenolic compounds, acid, and carbonyls (Porter and Simpson, 1961; Porter et al., 1965). Glaen (1976) showed that the phenolic fraction at a level of 25 mg/kg has an inhibitory effect on *Staphylococcus aureus*. Yeasts and molds are however fairly resistant.

2. **Antioxidant properties of smoke**.

Lea (1973) observed that unsmoked bacon showed pronounced surface rancidity after 98 days at -10°C, whereas smoked bacon it was negligible under the same conditions. This antioxidant property is attributed to these phenolic compounds which undergo simple reactions to produce quinones (Pokorny, 1971; Demar, 1976), which are potent antioxidants.

3. **Aroma, Flavour and Colour Development**.

Phenols appear to play a three-fold role in smoking. They act as antioxidants, antibacterial agents and contribute to the smoking flavour of fish (Wasserman, 1966; Ridder et al., 1970 a, b).
The amount of loss is essentially proportional to the time and temperature of processing and may exceed 50% destruction on the surface but decline rapidly towards the centre (Cantlie, 1975).

About 8% - 30% weight loss due to water was recorded during smoking and brining (Ghawan, 1969). This leads to shrinkage and with this comes redistribution of fat in the mussels of the fish and concentration of salts which are likely to catalyze lipid oxidation faster.

Most of the vitamins are relatively stable but for thiamine and to a lesser extent vitamin B which are heat labile and are practically destroyed (Haun 1979). Most vitamins and mineral salts are lost in drip water from fish. But is only lost as drip at high temperatures.

2.3.7: TEXTURAL CHANGES IN SMOKED FISH

The basis of structural changes in smoked fish are water loss, fat diffusion, denaturation of structural and connective tissue protein and enzymatic activity, particularly proteolysis (Clifford et al. 1980). Howgate (1977), reported that the myosin and actomyosin in muscles, retain their structural integrity below 70°C, producing gaseous in sarcomere structure. The texture then, of cold smoked fish is soft and tender, if dehydration is not prolonged, but when dry is hard and compact. It does not rehydrate well and absorbs only half the water lost during drying.
The texture of hot smoked fish is tough and dry, takes time to rehydrate and mealy. This is dependent on the amount of moisture loss and prevailing temperature during smoking. Smoking temperatures, in the excess of 71.1°C and 60% relative humidity have been shown to cause excessive darkening and distortion to the product (Kasack and Toledo, 1980). Codlids smoked between 38°C - 40°C had mild flavour, good colour and flaky texture, while temperatures above 40°C and up to 65°C produced darker and heavy flavoured product which is mealy in texture (Lantz and Irvedale, 1966).

2.3.3: ADVERSE EFFECTS OF SMOKE

The most dangerous known components of natural smoke are polycyclic hydrocarbons, several of which are implicated as carcinogens. The major among them found in smoked foods, benz(a)pyrene (3,4-benzpyrene), is present in lesser amount in the vapour phase (Watts, 1974; Ymelich et al., 1980). Cold smoked foods, therefore have lesser content than hot smoked, since production of polycyclic hydrocarbons increases with increasing temperatures. The safety limit of these substances is complicated by the fact that their carcinogenic effect can be greatly increased by components of the diet, including phenols and certain metals (Watts '74)