

Studies on the Nutritional and Microbiological Quality of Smoked Tuna Fish (*Auxis thazard*) in Tuticorin, South East Coast of India

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Abstract

The study was carried out to assess the quality of the smoked tuna fish from dry fish processing center of Tuticorin. The fishes having less nutritive value because of overtime salting leads to leaching of water soluble nutrients. Based on the quality indicators the fishes having high salt content and less amount of volatile amine production, without any oxidative changes. Apart from this microbial population, diversity was also studied and the results showed the presence of indicator organism's revealed the need of improvement in the processing methods. It is recommended that in order to prevent the spread of organisms that are of public health importance, fish should be processed in a correct manner, stored and distributed under safe hygienic conditions and good sanitary practices should be followed.

Key words: Tuna, Smoking, Processing centers, Chemical, Microbial quality.

1. Introduction

Fish provides a high source of protein required in the diets of man as it contains essential nutrients such as vitamins, fats and minerals which help in the maintenance of life (Ashano and Ajayi, 2003). Apart from its food value, fish has been reported to possess medicinal values, such as, in the amelioration of asthma, arthritis, coronary heart diseases, goitre and cancer (Cobiac *et al.*, 1991). In spite of these valuable nutrients derivable from fish, it is, however fish is an extremely perishable food commodity as it is highly susceptible to autolysis, rancidity as a result of oxidation of fat which creates unpleasant odors and flavours (FSA, 2004)]. Generally, fish have soft tissues and high amount of water and this enhances its susceptibility to microbial contamination (Olayemi *et al.*, 2012). Recently, many researchers had evaluated the spoilage of seafood in general and fish in particular. The spoilage activity of food samples depend on several factors such intrinsic (nutrient content, pH and buffering capacity, redox potential, water activity and antimicrobial barriers and constituents), extrinsic (relative humidity, temperature and gaseous atmosphere), implicit and microbial factors (Adams and Moss, 2008). Chemical spoilage is the result of enzyme action or non-enzymatic reactions like oxidation and the Maillard reaction. The main contributions of chemical spoilage to food are flavour and colour changes due to oxidation, lipolysis and heat. These changes may be induced by light, metal ions or excessive heat during processing or storage (Huss,

1994). Microbial spoilage results from the activity of bacteria with spoilage potential (i.e. the ability to produce off-odors). The microbial density is a reflection of the processing methods and hygienic level of processors and sellers. Therefore fishes requiring prompt processing and preservation to avoid spoilage.

Fish is soft and easily damaged; therefore rough handling and bruising results in contamination of fish flesh. Fish will become unfit for human consumption within a one day of capture, unless it is subjected to some form of processing or preservation. Even after the fish has been processed, particularly if traditional methods have been used, the fish is still subject to many forms of loss and spoilage (Shewan, 2000). However, there are different methods or ways of prolonging the shelf-life of fish. These include chilling, freezing, canning, drying, salting and smoking. Smoking of fish and/or meat products is one of the most ancient processing technologies. Hard curing by salting and smoking permits lengthy preservation by removing moisture, which is essential for bacteriological and enzymatic spoilage. Consumers are rediscovering the good taste of smoked seafood and to satisfy the consumer demand, it is necessary to produce good quality and safe smoked seafood products. Fish smoking which involves the application of smoke from smoldering wood for the preservation of fish dates back to civilization. The bacteriostatic, bactericidal and antioxidant function of smoke and dehydration effect of the process were used inadvertently by the early fish processors in the preservation of fish (Eyo, 2001). The

smoking of fish is done for the enhancement of flavor and texture. This form of processing sometimes provides little protection against microbiological, enzymatic and chemical deteriorative alterations, and in some instances, smoked foods spoil as readily as non-smoked foods. Although smoking increases shelf life of the fish products, hygienic standards of the fish products before, during and after smoking are suspects. Fish smoking helps in slowing down fish deterioration thereby giving the commodity a longer shelf-life. However, investigations have shown the presence of microbial contaminants even on smoked fish (Nyarko *et al.*, 2011). Most of the post processing microbial contaminants such as bacteria and fungi originate from poor handling practices while some could be from the air, the source of the fish, or from other degrading substances. In humid tropical conditions, very dry smoked fish with low moisture contents are prone to insect infestation, while others not so dry, having medium to high moisture contents suffer from both bacterial and mould contaminations (Banwart, 2004). Contamination by these microorganisms can cause human infections. Fungal contaminants found in fish, which are known to cause disease in humans. Prolonged intake of smoked fish with these metabolites may constitute potential public health hazard. The quality of smoked products is dependent on several factors, including, the quality of the fish at the time of smoking, the preparation of the raw material, the nature of wood and the type of the smoking procedure employed (Da Silva, 2002).

In tropical area of Tuticorin, apart from the fresh fish processing some quantity of the fishes used for salting and sun drying and used as a dried fish in local and export market. Tuna fish locally called choorai used to develop the byproducts of mass preserved only in the form of smoke drying. Previously these fishes are not processed locally that are imported from Lakshadweep. But now a day fish processor processes the tuna fish in Tuticorin including brining, sun drying, smoking and packaging. All the processing was carried out in simple manner. In some places the belief most people have is that smoked fish is sterile and can be eaten without further heat processing. In fact some people even eat the fish at the market before any post-smoking processing is done. The study was aimed at understanding the safety of smoked fish products after the smoking process. It identified microorganisms that contaminate smoked fish and made appropriate recommendations for mitigation. The present study was carried out to assess the quality characteristics of locally smoked tuna fish.

2. Materials and Methods

Smoked dried tuna fish (*Auxis thazard*) obtained from a local dried fish wholesaler at Tuticorin, Tamil Nadu. The process of smoking includes different preservative steps such as salting, drying and hot smoking with application of heat. They were selecting the fish for smoking in high quality, fresh and free from diseases. The first step, preparation of raw material for smoking, depends on the species and size of the fish and on the intended form of the product. The whole fish are gutted, the gut cavity scraped and all blood was removed. This fish are then usually beheaded and opened, although the long bones are often left on the fillets to give the finished product a better appearance. Salting is almost always done by soaking the fish in strong brine. The concentration of brine and time of brining depends on the type of product size and fattiness of the fish. The amount of salt that is desired for the final product they use minimum of 3.5g of salt per 100 g of tissue. After salting, a combination of drying for removing wetness of about 60% and smoking with a temperature of about 60-70°C for six to eight hours was done. The smoked samples were then stored at ambient temperature until sale. The experimental samples for this study was taken from the processing center and transported to the laboratory in sterile polythene bags. Then the samples were analyzed for both microbial and chemical changes.

2.1 Physico-Chemical Analysis

2.1.1 Moisture Content

Moisture content was determined by drying of 5 g of minced smoked fish in a convection oven at 105 °C until constant weight (AOAC, 1995).

2.1.2 Salt Content

Sodium chloride content in smoked fish samples was determined by volumetric method of Volhard (AOAC, 1990).

2.1.3 Protein

The protein content of the samples was estimated by Lowry's method (Lowry *et al.*, 1951).

2.1.4 Lipid

Lipid content of the sample was estimated using gravimetric method (Folch *et al.*, 1957).

2.1.5 Ash

The ash content was measured by the method of Clucas and Ward (1996) using Muffle furnace.

2.1.6 Determination of pH

pH value was estimated according to Goulas and Kontominas (2005) as follows. Ten gram of sample was homogenized in 100 ml of distilled water and the mixture was filtered. The pH of filtrate was measured using a pH meter (HANNA pH213) at ambient temperature.

2.1.7 Determination of Total Volatile Basic Nitrogen (TVB-N)

Total Volatile Base Nitrogen (TVB-N) value was estimated by the semi-micro distillation procedure (AMC, 1979; Kirk and Sawyer, 1991). The bases are steam distilled into standard acid and back-titration with standard alkali.

2.1.8 Determination of Trimethylamine Nitrogen

Trimethylamine Nitrogen (TMAN) was determined using the above mentioned TVBN method after appropriate modification: formaldehyde was used to block the primary and secondary amines (AMC, 1979).

2.1.9 Determination of 2-Thiobarbituric Acid (TBA)

2-Thiobarbituric acid (TBA) value of smoked fish samples was determined colorimetrically by using the method published by Kirk and Sawyer (1991).

2.1.10 Extraction of Lipids and Peroxide Value

Lipid was extracted from the mixed smoked fish samples with a mixture of chloroform / methanol (2: 1 v/v) according to the method described by Folch *et al.* (1957). Peroxide value (PV) was expressed in unit's meq / kg lipid was determined by the titration method (Kirk and Sawyer, 1991).

2.2 Bacteriological Methods

Total bacterial count (TBC), Coliform bacteria and yeast and mold counts of smoked fish were determined by using Nutrient agar, MacConkey agar, and Potato Dextrose agar media, respectively according to the procedures described by APHA (1976). Incubations were carried out at 37°C/48 h for TBC; and Coliform; at 25°C/5 day for yeasts and molds count.

2.2.1 Detection of *Salmonella*

The presence or absence of salmonella was determined according to the methods described by FAO (1979) using buffered peptone as a pre-enrichment, while tetrathionate broth was used as a selective enrichment broth and Xylose Lysine Desoxycholate (XLD) was used as a selective plating media.

2.2.2 Detection of *Clostridium* spp

This method is based on the detection of typical Gram positive *Bacilli* with subterminal oval spores grow on cooked meat medium and producing turbidity, gas production and digestion of the meat particles (FAO, 1979).

2.2.3 Detection of *Vibrio*

The presence or absence of *Vibrio* was determined according to the methods described by FAO (1979) using alkaline peptone as a pre-enrichment, while TCBS and CPC agar was used as a selective plating media.

2.2.4 Detection of *Staphylococcus* spp

The species was determined using Mannitol Salt Agar (MSA) (37±1°C, 48 hours), *Staphylococcus aureus* was determined by applying coagulase test on bright yellow halo colonies on (MSA).

2.2.5 *Listeria monocytogenes*

The ISO 11290 method was used for isolation and identification of *L. monocytogenes* described by Becker *et al.* (2006). 25 g of samples were added to 225 ml of half Frazer broth as the first enrichment and incubated 24h. On the other hand 0.1ml of half Fraser broth was added to 10 ml of Fraser broth as a second enrichment culture at 37°C for 48 h. A loopful of culture inoculated to *Listeria* selective agar and incubated at 24-48h at 37°C. The colonies were confirmed using biochemical tests (Gram staining, catalase, oxidase, urea, SIM, TSI and MR-VP).

3. Results and Discussion

The purpose of this study was to assess nutritional and chemical quality of hot smoking of Tuna (*Auxis thazard*). In this modern world, there are several smoking methods such as the cold, hot, liquid and electrostatic. However, the two major methods of fish smoking are cold and hot smoking. In cold smoking, the proteins of raw fish turn edible as a result of their enzymatic ripening, while in hot smoking, this is accomplished due to their thermal denaturation. In both methods, the operations are similar; however, different parameters of time and temperature are used. The temperature in the kilns does not exceed 30°C during cold-smoking, while in hot-smoking; it is not lower than 60°C. Consequently, the products of these two smoking procedures differ in their sensory properties and in their shelf life. In both methods, various techniques of dressing, salting, smoke development and deposition, heating, cooling and packaging are used (Nikitin, 1965). Unfortunately, cold-smoked fishes may deteriorate very rapidly due to oxidative reactions, bacteria or mold, inappropriate processing/preservation, fragmentation and insect -



a. Dry salting process



b. Wet salting process



c. Drying process



d. Smoking process



e. Smoked tuna final product

Fig 1: Smoking process carried out in the processing centers

infestation (Tobor, 1990). Cold-smoked fish retains relatively high percentage of moisture, making it susceptible to microbial growth or contamination. This is largely due to the cold smoking method; whose duration is shorter compared to hot-smoked fish products. In the present study fish samples were processed by hot smoking method. Before that all the fishes were dried under the sun for 2 to 3 hours. But the drying was not taking long time because if the surface is too dry the smoke is not adequately absorbed. Best method is hanging of the fishes done overnight before smoking. Also during the hanging, proteins dissolved in brine dry on the cut and produce the familiar glossy skin, which is one of the commercial criteria for quality. Meanwhile, one major way of contaminating these products is the poor handling technique often adopted by the retailers. Apart from giving the fish a desirable taste and odour, smoking provides a longer shelf-life through its anti-bacterial and oxidative effect, imparting desirable coloration as well as accelerating the drying process and acting as antagonist to spoilage (Abolagba and Uwagbai, 2011). Smoking time was not desired in this study area. But fish can be dried sufficiently to take the smoke well in 3 to 4 hours or less and a complete smoking can be finished well within one day. However, no investigation had been made on the microbiological and nutritional safety of the widely consumed smoked Tuna, *Auxis thazard*; especially in Tuticorin and its environs. This justifies the need for this investigative research work.

The smoke produce antibacterial components like formaldehyde and phenols. Its heat effect resulting in reduced water activity of the fish allow better preservation causing microbial destruction and thus minimizes spoilage, increase storage and therefore increase fish availability to consumers (Gram, 2001). The antimicrobial effect of smoking depends on temperature, humidity and density of the smoke, duration of smoking and concentration of active components in smoke preparations (Kolodziejska et al., 2002). In the present study 16.20% of moisture content was observed from the smoked tuna fish samples. The lower moisture content values with the sample might be due to the loss of water during smoking (Asiedu et al., 1991). Jittinandana et al. (2002) reported that, increasing the brine concentration decreased moisture content of rainbow trout fillets. Industrial specifications for smoked finished products generally are recommended with water content in the fish flesh of less than 65% (Cardinal et al., 2001). Goulas and Kontominos (2005) reported that the moisture content of smoked chum Mackerel samples were 58.1 and 59%. Kolodziejska et al. (2002) also reported that moisture content of smoked Mackerel was 56.7%. Here

results of moisture content (16.20%) were less than this value. This might be due to the various treatments prior to smoking such as salting and drying.

The protein and lipid content of the smoked tuna fishes were 12 and 6.2% respectively. According to Sinduja et al. (2014) the protein and lipid content of the fresh Tuna fish was 24% and 11.2%. In this study the nutrient content was decreased after processing. According to Stroud (1988), smoking process has been found to affect the nutritional value of fish, mainly by reducing the biological availability of proteins. Similarly, Emokpae (1980), observed changes in protein and lipid content during smoking may have been due to leaching out of some extractable soluble protein fraction and hydrolysis of some of the lipid fractions. The protein percentage decreased during the first hours of salting, probably due to leaching of water soluble proteins such as myogen (an albumin type protein) and salt soluble fractions, myosin (a globulin). Myosin constitutes about 75% to 80% of the total protein (Munasinghe, 1999). After the salting step, the ratio of protein was high and it was not stable during drying and smoking. Degradation of the crude protein in the fish species gradually to more volatile products such as Total Volatile Bases (TVB), Hydrogen sulphide and Ammonia (Eyo, 2001). In the present study the protein content of the smoked fish was good it indicated leaching and volatile amine production and leaching of nutrients was more. However, fish oil has been found to be more liable to spoilage than other oils due to their greater number of unsaturated fatty acids as shown by the lower specification number and higher iodine value (Eyo, 2001). The greater the degree of unsaturation, the greater would be the tendency for fat oxidation (rancidity). Meanwhile, Balogun (1992) stated that there might be high risks of rancidity during prolonged salting conditions due to fatty nature of the fish. Also, reduction in the lipid content could be attributed to oxidation of poly-unsaturated fatty acids (PUFA) contained in the fish tissue to products such as peroxides, aldehydes, ketones and free fatty acids. From this study, there was a high ash content of the smoked fish sample was observed. This agreed with Daramola et al. (2007) who reported an increase in ash content of the smoked *Clarias gariepinus* on storage.

Salt content of the tuna smoked fish sample was analyzed to be 2.04g. Birkeland and Bjerkeng (2005) reported that acceptable salt content of smoked fish was 1.80g and it was increased in experimental sample by increasing the time of salting. Jittinandana et al. (2002) found that salt content of products soaked in higher brine concentration was greater than of those from the lower brine concentration for the same brining time. Brining and prolonged smoking has been found

useful in increasing the storage life of cold smoked fish by retarding the development of mold growth without increasing the development of lipid oxidation (Sadiku, 1991). The salt content slightly higher in the present study concluded that prolonged salting time and approximate salting not at a correct proportion in the processing center. Erkan (2004) reported brine salting for 24 hours with 0.134 kg pure salt and 0.066 kg salt with nitrite sodium in 1 lit was give better salted product. Normal brining producers do not produce a uniform salt content even in fish of uniform size. Better results are obtained if the brine is stirred during the dip. A mechanical process would improve matters as well as allowing continuous control of brine strength.

Table 1: Proximate composition of Smoked tuna fish

Nutrient Parameter	Proximate composition
Moisture (%)	16.20
Protein (%)	12
Lipid (%)	6.2
Ash (%)	6.6

Table 2: Quality parameters for the smoke dried tuna fish

Quality Parameter	Quality indicators
Salt (g)	2.04
pH	6.16
TVB-N (mg N/100g)	17
TMA-N (mg N/100g)	8.05
Peroxide value (meq peroxide/kg fish fat)	9.04
Thiobarbituric Acid (mg malonaldehyde/kg)	2.66

Table 3: Microbial quality study of smoked tuna fish

Microbial Parameter	Microbial count
Total plate count (CFU/g)	2.1×10^5
Total fungal count (CFU/g)	1.1×10^3
<i>Escherichia coli</i>	Present
<i>Staphylococci aureus</i>	3.5×10^2
Coliforms (CFU/g)	2.0×10^2
<i>Salmonella</i>	Present
<i>Listeria monocytogenes</i>	Absent
<i>Clostridium botulinum</i>	Absent
Yeast and mold count	30 no. of colonies

pH value of smoked tuna fish was 6.16 indicating the freshness of samples. These values are partially in agreement with that of Goulas and Kontominas (2005) found a pH value of 6.12 for smoked chub mackerel. The increase in pH may be

attributed to production of volatile basic components such as ammonia, trimethylamine and total volatile nitrogen by fish spoilage bacteria (Ruiz-Capillas and Moral, 2005).

TVB-N (Total volatile base nitrogen) is widely used as an indicator of fish spoilage; its increase is related to the activity of spoilage bacteria and endogenous enzymes (Ruiz-Capillas and Moral, 2005). In the present study TVB-N of smoked tuna was 17 mgN/100g fish flesh. Changes in total volatile nitrogen of smoked tuna fish as affected not only by time of salting and concentrations of brine solution. In this study, this is associated with lower moisture content and higher salt level which reducing spoilage bacteria growth and activity of endogenous enzymes. These results are in agreement with that reported by Yanar et al. (2006) found that increased salt concentration had a positive effect on reduction of TVN of hot smoked tilapia. Upper acceptability limit set the EU (1995) and Connell (1990) for TVN values of fish (35 mg N/100 g fish flesh). An increase of TVB in both methods of salting and smoking was most likely caused by an autolytic process which produces volatile amine compounds and bacterial spoilage.

Trimethylamine Nitrogen (TMA-N) is produced from Trimethylamine Oxide (TMAO) possible partly by action of intrinsic enzymes but certainly through bacterial action, is the main component responsible for a pleasant "fishy" odor (Rodriguez et al., 1999; Shakila et al., 2003). In the present study TMA-N content of smoked tuna was 8.05 mg N/100 g. Hansen et al. (1995) reported that decreasing salt levels resulted higher concentration of TMA-N in cold-smoked salmon. Leroi et al. (2000) reported TMA-N of treatment prepared with 8% brine reached the value of 14.67 mg N/100 g after 3 months of cold storage, exceeding the upper acceptability limit set by Egyptian Standards (2005) for TMN-A values of smoked fish (10 mg N/100 g). But here it will not exceeding the acceptable limit due to higher concentration of salt and reduction of moisture content.

To evaluate the degree of lipid oxidation, the Thiobarbituric Acid (TBA) and Peroxide Value (PV) were determined. The highly unsaturated fatty acids found in fish lipids are very susceptible to oxidation. In the present study PV and TBA of smoked tuna sample was 9.04 meq peroxide/kg fish fat and 2.66 mg malonaldehyde/kg. According to Augbourg and Ugliano (2002) and Yanar et al. (2006) lipid oxidation was enhanced by method of salting, salting time, smoking and drying method. In the present study lipid oxidation values were lower than the general PV and TBA limit for smoked fish as mentioned by Egyptian Standards (2005) which reported that PV values should not be above 10-20 meq/kg fish fat and TBA values not

exceed 4.5 mg malonaldehyde/kg. A low PV and TBA was observed in this study indicate both an early phase of auto oxidation and a late stage of oxidized product, where most hydroperoxides have been broken down in dried fish (Smith *et al.*, 1990). TBA assay is a widely used indicator for the assessment of degree of lipid oxidation. The result of TBA assay corroborated that obtained by the PV. Fatty fish are of course; particularly vulnerable to lipid oxidation which can create severe quality problems such as unpleasant (rancid) taste and smell, and also it may produce alterations in texture, color, and nutritional value, even on storage at sub-zero temperatures (Olafsdottir *et al.*, 1997; Huss, 1995). The sample collection for processing was good it was freshly processed but avoiding of prolonged storage reduce the lipid oxidation but, samples stored in the present study in ambient temperature without packing. It has been proposed that the maximum level of TBA value indicating the good quality of the fish (frozen, chilled or stored with ice) is 5 mg malonaldehyde/kg, while the fish may be consumed up to the level of 8 mg malonaldehyde/kg. Papadopoulos *et al.* (2003) reported that TBA above 10 μmol MDA-equiv per 1 kg fish will probably have rancid flavours.

In the present study microbial quality of smoked dried tuna fish sample (*Auxis thazard*) from dried fish processing center was 2.1×10^5 CFU/g of TPC and 1.1×10^3 CFU/g of TFC. The result of this study shows that smoked fishes had microbial contamination. This could be due to the unhygienic environment of the processing centers. Exposure and improper hygiene handling seems to be other explainable reasons for the high bacterial contamination as the commodity was observed to be displayed in open area, exposing it to contact by insects, dust particles and even workers who were observed to be making direct contact with the fishes with bare hands while collection after drying. The TPC lower than 7.0×10^6 CFU/g in smoked products which is the recommended limit (ICMSF, 1986). Connell (1990) stated that the maximum total plate count for the processed food to be consumed safely was $10^7 - 10^8$. Nyarko *et al.* (2011) who reported that smoked sardine from marketing centre's had higher microbial counts than those from smoking sites due to the better sanitary conditions of the latter. This conforms to the findings of Adegunwa *et al.* (2013) who reported that smoked fish collected at a polluted site had higher microbial load than other locations. Adegunwa *et al.* (2013) studied the microbial quality of smoked herring (*Sardinella eba*) and reported total plate counts (1.26×10^6 to 3.00×10^7 cfu/g), total fungi (0 to 3.50×10^3 cfu/g). Daniel *et al.* (2013) reported aerobic bacteria from smoked fish sold in Benin City Nigeria as 1.58×10^6 cfu/g (*T. trachurus*), 2.08×10^6

cfu/g (*Scomber scombrus*), 1.24×10^6 cfu/g (*Clarias gariepinus*), 1.85×10^6 cfu/g (*Ethmallosa fimbriata*) and 1.38×10^6 (*Pseudolithus croaker*), while the mean fungal counts is 4.98×10^6 cfu/g, 3.00×10^6 cfu/g, 1.72×10^6 cfu/g, 2.56×10^6 cfu/g and 2.20×10^6 cfu/g for *T. trachurus*, *S. scombrus*, *C. gariepinus*, *E. fimbriata* and *P. croaker*, respectively. The present microbial population study revealed that smoked fish sample sold in Tuticorin had slightly higher microbial load due to processing defect and also storage in ambient temperature in poorly ventilated cut. Abolagba and Iyeru (1998) who reported that lack of proper smoking and proper hygienic handling of smoked fish products would result in a varying microbial load.

Even though fish are smoked, the heat supplied might not kill all the pathogens. Smoked fish could be stored satisfactorily for three weeks at 5°C and less than one week at 10°C (Poulter *et al.*, 1988). But in the processing center before 10 days processed samples they stored at 37°C . Apart from the microbial load the diversity of bacteria in smoked samples were also observed in this study. According to Aberoumand (2010) *Escherichia coli* is a classic example of enteric bacteria causing gastroenteritis. *E. coli* including other coliforms and bacteria as *Staphylococcus* spp and sometimes *Enterococci* are commonly used as indices of hazardous conditions during processing of fish. Scientists have shown that the contamination of food of fish origin with pathogenic *E. coli* probably occur during handling of fish and during the production process (Novotny *et al.*, 2004). *E. coli* was observed in the experimental fish samples in this study indicate improper handling of fish with fecal contamination. The *Staphylococci aureus* count was 3.5×10^2 observed in this present study from smoked tuna sample and is capable of producing enterotoxins that cause gastroenteritis (Novotny *et al.*, 2004). Thus, food poisoning and food borne diseases could occur as a result of intake of this fish commodity. The occurrence of *Staphylococcus aureus* and *E. coli* in the smoked-dried fish samples were in accordance with Martin (1994) when he stated that these organisms were the commonest micro-organisms associated with smoked fish. The presence of *Staphylococcus aureus* in fish samples according to Okonko *et al.* (2008) might have been through contamination by handling. Okareh and Erhahon (2015) reported that *Staphylococcus* spp has pathogenic strains which could cause food poisoning due to the heat stable *Staphylococcus* enterotoxin which is resistant to gastrointestinal enzymes.

Coliforms are indicators of contamination when they occur in small numbers. In the present study coliforms was observed (2.0×10^2 cfu/g) indicated presence of very small number in smoked fish sample and their occurrence in large numbers indicates

mishandling such as temperature abuse in product handling (Mossel, 1967). Coliforms count (10^3) is the acceptable limit in smoked fish product even immediately after smoking. *Salmonella* causes gastroenteritis and typhoid fever. The bacteria are more likely to multiply in food at warm temperatures. Typhoid fever is caused by serotype, *Salmonella typhi*. Lapses in sanitation can lead to outbreaks of salmonellosis. *Salmonella* are fecal borne pathogens and they could occur as a result of contamination from the handlers. Drinking fecal contaminated water can also lead to an outbreak of the same. Fish harvested from contaminated waters can carry *Salmonella sp* (Pelczar et al., 1993). In the present study *Salmonella* was not detected in all the smoked samples indicates hygienic processing of the fishes. If presence of *Salmonella sp.* may indicates poor food preparation and handling practices (Yusuf and Hamid, 2012) and it is associated with food borne diseases. Meanwhile, smoked fish products have also tested for the source of microbial hazards including *Listeria monocytogenes* and *Clostridium botulinum*. Outbreaks of botulism, listeriosis, and salmonellosis resulting from smoked fish have been reported for over 30 years (CDC, 1979; Heinitz and Johnson, 1998; Heinitz et al., 2000). But in the present study all the pathogens were found to be absent in the smoked products.

The yeast and mold count in the smoked fish sample was 30 numbers of colonies. Molds have reported to germinate and grow particularly rapidly on fish stored under damp, poorly ventilated conditions in climates with high ambient relative humidity and temperature (Doe PE and Olley, 1990). Meanwhile, Jallow (1995) who stated that increase in moisture content could be attributed to the difference in moisture of the smoked fish relative to the surroundings. Also a standard moisture content of 12% was reported by FAO (1989) as the level beyond which fish products begin to grow mold after a few days. In this study smoked samples having moisture content 16.20%, it may be possible for growing molds in stored fish samples.

The level of micro-organisms in fish reduces with smoking but increases with storage period and during transportation. It is therefore imperative that the necessary measures to arrest this situation be put in place if the smoked fish products have to remain wholesome and hygienic. Rogers and Mosille (1989), reported smoking process in the kilns is essentially similar. Air temperatures of 120°C-140°C are generated in the kiln, with the temperature of the fish rising to around 100°C. With this kind of temperatures, the smoked fish are expected to be sterile immediately after smoking. The temperatures in the kiln is such that the fish is initially cooked, denaturing the enzymes and

protein, killing most bacteria and halting spoilage. But here the smoking process carried out in open space not in closed area. So generation of heat and smoke are distributed heat intensity are not fully utilized by the fishes and it may be the reason for the smoked product not attaining the good quality product after all the processing. Post-processing handling of smoked fish products is not properly done. The smoked fish were observed to be put on dirty mats on the floor. These are stores that are poorly ventilated and are generally dirty. There are no cold stores at the processing centers and the fish are left in the ambient temperatures and these temperatures go up to 37°C. The fish are put in the floor of cuts where houseflies contaminate them very much with dirt from the surrounding environment. The result suggests that one single factor may not account for these microbial changes. Cross contamination, pH, purity of preservatives is among other factors that can influence microbial changes. The hazards related to contamination, recontamination or survival of biological hazards during processing could be controlled by applying good manufacturing practice and good hygiene practice.

4. Conclusion

This study shows that tuna fish is a good raw material for traditional hot smoking. The nutritional quality is good but the processing should be properly done by the salting method to avoid the nutrient leaching. Thus, fish processors have to take extra care in ensuring proper processing and handling of fish and fish products by observing sanitary and hygiene rules. Appropriate authorities should enforce sanitary and hygiene rules in the centers and ensure preservation of fish prior to smoking. Drying of fishes should be done in solar drier and avoid the drying in open area to minimize the contamination. Workers should avoid making direct contact with bare hands that limits the cross contamination. The processing environment is more important than the processing technology in determining the microbial quality of smoked fish. If it is unsatisfactory, probably due to the mode of storage, handling, exposure and poor environmental and sanitary conditions. Environmental sanitation, education and orientation should be organized for fish processors and workers to improve quality of smoked fish for the benefit of public health and to enhance food safety in the country.

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