Investigation of bacteriological quality of smoked fish

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Abstract

The project examined the bacteriological quality of smoked *Lates niloticus* (L) and tilapiine fishes. A total of 45 tilapiine fishes and 44 *Lates niloticus* specimens were analysed. Counts of *Escherichia coli* (E), *Salmonella* sp. detection , and detection of *Vibrio* spp., were undertaken. Samples of smoked fish specimens were collected from selected beaches and markets within the Winam Gulf of Lake Victoria and taken to the laboratory within 24 - 48 hours. *Salmonella enterica* species were found to be absent. *Vibrio* spp. were found to be absent from all the specimens except in the tilapiine fishes from Homa-Bay Pier market. *Escherichia coli* was present in samples from all the markets except Homa-Bay pier market. It was present in samples from Mainuga and Balarawi beaches. Generally, the markets had higher counts of the bacteria than the beaches. The number of bacteria reduced with smoking but increased again with increase in storage period. Sanitary conditions at the beaches and markets should be improved. Likewise, roads to the beaches should be made all-weather roads so that the fish can reach the markets fast. Refrigeration facilities and/or ice should be provided at the landing beaches and at the smoking villages.

Key: *Lates niloticus, Escherichia coli, Salmonella enterica, Vibrio* spp.,

Introduction

Lake Victoria is the source of most of fresh water fish, both for local and export market in Kenya. Kenya earns 7 billion from the sale of fish and fish products (Ikiara, 1999) from the lake. Locally, fish from the lake is marketed as fresh, smoked, sun dried, or fried forms. Currently, Nile perch available to the local market are of poor quality and are rejected by the processing industries. These fish are often putrified. While established quality control measures exist for the export-oriented fish, none exists for the fish consumed locally and this poses a great danger to the health of local consumers.

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). The need for proper refrigeration cannot be over- emphasized. The finished product should not be distributed until it has been properly cooled to 4.2° C or below. Furthermore, because of perishable nature of smoked fish, it is imperative that finished product be maintained in a refrigerated condition at 4.2° C or below until consumed (Otwell *et al.,* 1980). Most food poisoning outbreaks related to smoked fish have been related to abusive storage temperature conditions. In the Lake region, the fish is just kept at room temperatures after the smoking process.

Microorganisms inhabit nearly every niche of the earth and our food is no exception (Pelczar *et al,* 1993). Food items are easily contaminated with microorganisms in nature, during handling and during processing. After contamination, the food serves as a medium for the growth of the microorganisms. If allowed to proliferate, these organisms can change the

physical and chemical nature of the food resulting in spoilage. Microorganisms in food may also be responsible for food poisoning and food-borne infections.

In industrialized countries, 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. It is nonetheless used as a method of food preservation in developing countries (Hsu *et al*, 1979). In the Lake region, traditional methods of smoking fish are common. A variety of different woods such as *Accasia seyal, A. Senegal, Balanite egyptica, Syzgium cumnii* among others and dried fish skin are used for smoking. Almost invariably, smoking is done to the fish that is getting spoilt (Ogunja, 1994).

As the fish spoils the price falls and, in most developing countries, even what would normally be considered as heavily spoilt fish would find a market, albeit at a low price (particularly among the poor sectors of the community) (Poulter *et al*, 1988). The species of fish that are usually smoked are *Lates niloticus*, the tilapiines, and *Haplochromis* spp. Although smoking increases shelf life of the fish products, hygienic standards of the fish products before, during and after smoking are suspect (Fisheries dept., 1996). European Union banned fish imports from Kenya in 1996, citing poor sanitary conditions at the landing beaches and lack of refrigeration /icing facilities (Fisheries dept. 1999). Other factors included the use of poisonous substances to catch fish and in poor handling conditions in the landing beaches and at the factories. The European Union ban on fish imports from Kenya negatively impacted on the fishermen and economy of Kenya. The price of a kilogram of Nile Perch dropped from Ksh. 50.00 to Ksh.15.00 (Abila and Jansen, 1997). This eroded the buying power of the people. The ban also led to loss of jobs in the fish processing factories, reduction of employment opportunities in the fishing and fish trade industries. So many students dropped out of schools due to lack of school fees.

Table 1. Minimum Water activity for microbial growth

Micro-organism	**Minimum a_w for growth**
Clostridium botulinum	0.970
Salmonella sp.	0.950f
Vibrio parahaemolyticus	0.945
Staphylococcus aureus	0.860
Yeast	0.620
Molds	0.605

Adapted from Troller (1979).

Literature review

Fisheries play a significant role in rural African economy; earning livelihood for as much as 10% of the African rural population. The fisheries sector can play a significant role in creating new employment opportunities for Africa's rapidly expanding population. For every

new job created in the primary fish production sector, another 3 to 5 jobs are consequently created in the post-harvest sector (Bernacsek, 1991). Smoking and frying of fish along the majority of the beaches no longer exist; in fact, some of the settlements in such beaches as Luanda K'otieno are now dying out (Ogunja, 1991). This is because filleting companies purchases most of the fish and the fish catches have also gone down.

Hot smoking.
This is carried out largely in mud-walled, often rectangular, smoking ovens. Weld-mesh is commonly used for the trays and shelves used to hold the fish in the kiln. Fish to be smoked are just gutted and washed and then cut into smaller pieces, and left in the open to drip-dry so as to prevent hardening during smoking. The smoke density and temperature are controlled crudely by opening or closing the shutter, and also by adding or reducing firewood. The smoking process takes about one to three days depending on the size, thickness and quantity of the fish.

As the smoking process continues, moisture is removed from the fish, until a level is reached where microbial spoilage, even at ambient temperature, will be prevented or will proceed slowly.

Pathogenic *Escherichia coli*
Six clinically distinct categories of disease causing *E. coli* have been described (Riley *et al,* 1983). Different virulence and infective characteristics are derived from a combination of the factors determining surface adsorption and adherence of the bacterial cells to the intestinal epithelium and the toxins that may or may not be produced.

Most of these organisms are not distinguishable from one another by simple biochemical or physiological tests. Since the time viro-toxigenic *E. coli* (VTEC) were first reported as human pathogens, several incidences of food-borne infections have been linked to it in many countries (Riley et al, 1983).

Salmonella sp.
Salmonella are Gram-negative facultative rods with peritrichous flagella. They are members of the enterobacteriaceae and are closely related to the genera *Escherichia* and *Shigella*. The genus *Salmonella* has only one species- *Salmonella enterica,* but more than 2000 serotypes exist, many of them pathogenic to humans and other animals.

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. Drinking fecal contaminated water can also lead to an outbreak of the same. Fish harvested from contaminated waters can carry *Salmonella* sp. (FDA, 1984), (Pelzar *et al*, 1993).

Vibrio spp.
Vibrio is a genus of predominantly oxidase-positive, fermentative, motile gram- negative straight or curved rods. Thus a key characteristic differentiating them from the Enterobacteriaceae is their positive reaction to the oxidase test, although *V. metschnikovii* is

oxidase negative. Many *Vibrio* spp. are pathogenic to humans and have been implicated in food-borne diseases. *Vibrio* spp. other than *Vibrio cholera* and *V.mimicus* do not grow in media that lack added sodium chloride, and are referred to as halophilic.

Pathogenic *V. cholera* produces a heat sensitive enterotoxin that causes the characteristic cholera symptoms, including rice water stool (FDA, 1992). *V. Cholerae,* the causative organism of cholera, is found in small numbers in freshwater environments. However, disease outbreaks are caused predominantly by contamination of water by faeces from infected persons, which lead to an increase in bacterial concentration in the water to above the minimum infective dose.

V. Parahaemoliticus is a halophilic bacterium found naturally in estuarine waters and animals. It has a world- wide distribution in estuarine and coastal environments and has been isolated from many species of fish, shellfish, and crustaceans. *V. Vulnificus* is a halophilic bacterium found in the estuarine environment and is similar phenotipically to *V. parahaemoliticus.* It causes food-borne and wound disease, either of which may progress to rapidly fatal septicaemia, especially in individuals with liver disease (cirrhosis) or other underlying illnesses such as diabetes (Blake *et al*, 1980).

Other halophilic *Vibrio* spp., including *V. fluvialis, V. hollisae, V. alginoliticus, V. furnissii,* and *V. metschnikovii,* have been associated with gastroenteritis and are present in estuarine environments with other pathogenic and non pathogenic species of *Vibrio cincinematiensis, V. damsela and V. carchanae*. *V. anguilae*, *V. damsela* and *V. carchanae* are pathogenic to fish (Pelzar *et al*, 1993).

Problem statement and justification

Fish is the main source of protein for the people living around Lake Victoria and given the prevalence of water and food-borne diseases in the riparian districts of the lake, it is in order that all possible infection routes of the pathogens be investigated and possible mitigation measures outlined. It is with this in mind that the research proposal was developed. Fish also forms a major source of employment. It's transportation from the landing beaches to the markets is done using baskets, manila sacks and to a lesser extent tin-cans. Most of the landing beaches lack electricity and this makes it impossible for the fish dealers to have cold storage facilities. In addition, roads serving these areas are very poor and inaccessible during rainy seasons. These have led to a scenario where the fish that is not sold fresh to the processing industries or individuals, being processed in some way. Processing is done in the form of smoking, sun-drying or frying. The treatments employed in the processing are mostly inadequate resulting in the spoilage of the processed products.

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 during and after the smoking process. It identified microorganisms that contaminate smoked fish and made appropriate recommendations for mitigation. The findings of the study should be used to design steps necessary in lengthening shelf-life of smoked fish products and ways of avoiding smoked fish contamination with microorganisms.

Main objective
To examine the microbiological load of the smoked fish.

Specific objectives
1. To determine the number of *E. coli* counts in smoked fish.
2. To detect and quantify Salmonella species in smoked fish.
3. To enumerate Vibrio spp. in smoked fish.

Materials and methods

Study Area:
The major portion of Kenyan waters of Lake Victoria is a narrow gulf, known to various authors by several names: the Victoria Nyanza, Kavirondo Gulf, Nyanza gulf and the Winam gulf. All these refer to one and the same place. The Winam gulf has an area of approximately 1920 km with a length of about 60 km and width varying between 6 and 30 km (Rabuor and Manyala, 1991).

The Gulf lies within the equatorial region. The water temperature and solar radiation are relatively constant throughout the year (mean values are 22° ± 3°c and 1200 ± 140 E-' S-' respectively) (Rabuor and Manyala, 1991).

Sample collection.
Smoked fish samples were obtained from Awana, Mainuga, Balarawi beaches and Oyugis market in Rachuonyo District. Asat and Kaloka beaches and Kibuye market in Kisumu District and lastly from Homa-Bay Pier wholesale market in Homa Bay District. Tilapiine fishes and *Lates niloticus* samples, which were freshly smoked and others that had taken varied durations were bought from beaches and markets. Sampling was done using sterile plastic sample bags from the month of August 1999 to March 2000. They were labeled, kept in cooler boxes, indicating their beaches of origin and their history. Microbiological analysis was done on all the samples at the Kenya Marine and Fisheries Research Institute Laboratories (Kisumu) within 24 hours. The following parameters were analyzed viz: *Vibrio*, *Salmonella,* and *Escherichia coli.* A total of 45 tilapiine fishes and 44 *Lates niloticus* were analysed.

Laboratory Procedures

Microbiological analysis of fish

Enumeration of *Escherichia coli* biotype 1
E. coli biotype 1 was enumerated by the APHA (1992) method. 25g of test sample was homogenised in 225 ml. Serial dilution of 1/10, 1/100/ and 1/1000 were prepared as follows:

Step 1. Homogenized sample 1 ml + 9 ml blank (1:10)
Step 2. Homogenized sample 1 ml + 9 ml blank (1:100)
Step 3. Homogenized sample 1 ml + 9 ml blank (1: 1000)

Using forceps, sterile cellulose acetate membranes were transferred to the surface of dried nutrient agar. The membranes were gently flattened on the surface to minimize air pocket. Duplicate 0.5 and 1ml aliquots of the last dilution were transferred to cellulose acetate membranes. The fluid was spread over entire membrane except periphery, using a sterile glass spreader.

The plates were incubated for 4 hr at 35°C to facilitate resuscitation. Each membrane was then transferred to tryptone bile agar (TBA,Oxoid) plate and incubated for 18 hr at 44.5 ± 0.2°C. 2 ml of Vracko-Sherris Indole reagent were pippeted into each lid of the plates. Membranes were then removed from the agar and immersed in reagent for 5 min. After drying the membranes in sunlight for 20 min, pink stained colonies were counted within 30 min.

Isolation of Salmonella species

For isolation and confirmation of *Salmonella* sp., procedures recommended by FDA (1984) were followed. Analytical samples of 25g were aseptically weighed in duplicate. One portion was homogenized in 225 ml of selenite cystine broth in one blender jar. The other portion was also homogenized in tetrathionate broth base without brilliant green dye. The blending continued for 2 min. The blended samples were transferred to 500 ml Erlenmeyer flasks and left to stand for 60 min at room temperature with the jar securely capped. The pH was adjusted to 6.8 ± 0.2. 2.25 ml of 0.1% brilliant green dye was added to sample enriched in tetrathionate broth and swirled thoroughly. The jar caps were loosened 1/4 turn and the samples incubated for 18 - 24 hrs at 37^0C. Lids of the incubated samples were tightened and the samples shaken gently. Transfers of 1ml mixture to 10ml selenite cystine broth and another 1ml of mixture to10 ml tetrathionate broth were made. These were then incubated for 18 - 24 hrs at 37^0C.

The products that were directly enriched in selective broths were streaked on selective agars of bismuth sulfite agar (BSA) (Difco) and xylose lysine desoxycholate (XLD) agar (Oxoid), and Hektoen enteric agar (HEA) by applying 3mm loopful of incubated selenite cystine broth on each. The same was also done with tetrathionate broth. The BSA plates were prepared the day before streaking and kept in the dark. The plates were incubated at 37^0C for 18 - 24 hrs. Suspect *Salmonella* colonies were picked and inoculated into triple-sugar iron agar (TSI) (oxoid) and Lysine-iron agar (LIA) (oxoid). For identification, suspect colonies were confirmed by serological tests using polyvalent anti-sera (Fisher Diagnostics).

Detection and Isolation of pathogenic Vibrio species

Detection and isolation of pathogenic Vibrio species was done according to FDA method (1992). Samples of 25g were homogenized with 225ml sterile alkaline peptone water. Homogenates were transferred to sterile 500ml Erlenmeyer flasks and incubated at 37°C for 6h. A loopful was then inoculated on Thiosulphate-citrate-bile-salts-sucrose (TCBS) agar (Oxoid) and incubated for 18 - 24hrs at 37°C. 3 suspect colonies were picked from each plate, streaked for isolation on tryptic soy agar (2% total NaCl concentration), and incubated for 12hrs at 37°C.

Results

E. coli counts for beaches and markets.

E. coli were absent in the fish sampled from Awana, Asat and Kaloka beaches but Mainuga and Balarawi beaches had 3.2×10^4 cfu/g and 2.1×10^5 cfu/g respectively (Table 2). Tilapiine fishes from Kibuye had no *E. coli* counts. The Nile perch fish from the same market however, had 1.87×10^4 cfu/g of the organism. Tilapiine and Nile perch fishes from Oyugis market had 1.5×10^4 cfu/g and 1.3×10^4 cfu/g of *E. coli* respectively. The fish from Homa-Bay pier market had no colonies of the micro-organism.

Salmonella sp. counts for beaches and markets.

Salmonella sp. were absent from all the samples taken from both markets and beaches (Tables 2).

Table2: Average counts of colony forming units per gram (cfu/g) of fish samples from different beaches and markets

Beach/Market	*E. coli*	**Salmo**	**Vibrio**
Mainuga	3.2×10^4	0	3.2×10^3
Balarawi	2.1×10^5	0	0
Awana	0	0	0
Asat	0	0	0
Kaloka	0	0	5.7×10^3
Kibuye (T)	0	0	0
(N/P)	1.9×10^4	0	0
Oyugis	1.5×10^4	0	0
T) N/P)	1.3×10^4	0	0
H-Bay **(T)**	0	0	2.5×10^5

Vibrio spp. counts for beaches and markets

The V*ibrio* spp. were absent from fish caught from beaches except for Kaloka and Mainuga beaches which had 3.2×10^3 cfu/g and5.7×10^3 cfu/g respectively. Likewise, Kibuye and Oyugis markets were devoid of V*ibrio* spp. However, Homa-Bay Pier market had 2.5×10^5 cfu/g. (Table 2).

Observations and Interviews

A garbage heap was observed within the market just where the fish is also displayed for sale in Oyugis market (Plate 2). At Homa-Bay Pier market, fish was displayed on manila sacks on the ground, which was littered with sugar-cane bargass and other forms of garbage. It was not

uncommon to see the fish traders helping themselves, just less than 20 meters away from the market, hidden under some thickets.

Discussion

Although Nyagambi (1991), in his study showed that artisanal women fish processors and traders purchase fresh fish of good quality to ensure better end products, this study shows that smoking is usually done to the fish that were meant to be sold fresh, but due to saturation of the market with the commodity, could not be sold; or alternatively, fish that is rejected by large commercial filleting plants because it has started spoiling or is under-size. Instead of discarding this kind of fish, the fish is smoked and then transported to the markets to be sold. This situation is unlike Canada, (Dillion *et al,* 1994) where the fish processors choose fish of high quality.

It is envisaged in this study that fish processors be advised to choose high quality fish products. This is because, people eat smoked fish due to the flavour and texture that the fish acquires on smoking and they deserve to eat products of high quality. Choice of good quality raw material will also ensure longer shelf life of the products.

Awana beach smokes their fish in a similar way to the way it is done in Lake Turkana region (Ogunja, 1991), where the fish is smoked over simmering fire for two to three days. This ensures better end products. Such products have a more enhanced flavour, longer shelf life and appearance that is pleasing to the eye. However, the other beaches of Asat, Balarawi and Mainuga smoke their fish for less than a day and over flaming fire. This form of smoking does not produce fish products with the desired qualities. The processors rely on the hope that such fish are sold off to consumers the same day the fish are removed from the kilns, otherwise, such fish get spoilt and they would loose their money.

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 at Mainuga and Balarawi beaches. These are stores that are poorly ventilated and are generally dirty. There are no cold stores at the beaches and the fish are left in the ambient temperatures prevailing at the beaches. These temperatures go up to 37ºC. The fish are put in the stores where houseflies contaminate them very much with dirt from the surrounding environment.

Salmonella sp. was absent from all the samples analysed from the beaches Likewise Vibrio spp. was absent from those beaches except Mainuga beach (Table 1 and 3). This is in line with the requirements of Kenya bureau of standards (KBS) and EEC, (1991) regulations, which require that the pathogen should be absent from food. This is an indication that the smoking process kills the pathogens. It further implies good manufacturing practices being employed at the beaches.

It was observed in Homa-Bay pier market that the fish were just displayed on dirty manila sacks on the ground. This exposes fish products to contamination. Within the same market area were heaps of garbage and litters all over (pers. comm..).There were no toilet facilities anywhere in the vicinity of this open market at the shore of the Lake. The fish dealers and other people were seen attending to calls of nature within 50 meters from the market area. The condition observed in Homa-Bay applies to other fish market centers such as Oyugis and

very many others along the lake region. Even the beaches that were sampled were in a serious wanting state for sanitary facilities.

Faeces and untreated water are the most likely modes for the contamination of foods. Human beings are believed to be the carriers of toxigenic and invasive strains of E. coli isolated from foods (Nieto and Magno-Orejana, 1984). This study concurs with the above observations and concludes that this is the major reason why disease outbreaks related to poor sanitary conditions are common along the beaches.

Fish are transported in non-insulated open trucks, where both the fish and the traders occupy the back of the open trucks. This post-harvest infection of smoked fish is in line with what Dillon *et al* (1994), studying microbiology of smoked fish in Canada found out , that 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.

The people trading in the fish should be medically examined on a routine basis and be certified to be healthy before they can be allowed to handle the fish. This is not properly done usually. The markets should have raised racks for display of the fish. They should also be clean, have portable water and good V.I.P. latrines. These would go along way in averting the frequent disease outbreaks that have characterized these areas over the years.

Fish from the processing villages do not reach the outlet markets in time, as most of the feeder roads to these areas are poor and are impassable during the rainy season. This observation corroborates what Poulter *et al* (1988), found out in Zambia. Their study decried the pathetic state of roads to the villages. This study also underscores the need to make these roads all-weather roads to facilitate easy access to the markets.

Some of these smoked fish products are done poorly that if they don't reach the markets the same day, then they would be spoilt. This means loss of revenue to the fish processors.

TABLE 3: Anova comparison of the natural logarithm (LN) of number of bacterial load in *Lates niloticus* from Mainuga, Balarawi, Awana and Asat beaches

PARAMETER	NUMBER n	MEAN ± SD	F 0.05; 6, 6,9, 9	P
LN *E. coli*	7 m 7 b 10 aw 10 as	6.345 ± 5.965 1.374 ± 3.634 0.000± 0.000 0.000± 0.000	7.15	0.001
LN *Vibrio spp.*	7 m 7 b 10 aw 10 as	2.316±4.104 0.00 ± 0.00 0.00 ± 0.00 0.00 ± 0.00	2.95	0.048
LN *Salmonella sp.*	7 m 7 b 10 aw 10 as	0.00 ± 0.00 0.00 ± 0.00 0.00 ± 0.00 0.00 ± 0.00	0.00	0.00

m⇒Mainuga b⇒Balarawi aw⇒Awana as⇒Asat
n⇒Number of samples analyzed

TABLE 4: ANOVA comparison of the natural logarithm (LN) of number of bacterial load in *Lates niloticus* from Kibuye and Oyugis markets

Parameter	Number n	Mean ± SD	F 0.05,3, 5	P
LN *E. coli*	4 k 6 o	2.806 ± 5.613 3.450 ± 5.364	0.03	0.860
LN *Vibrio spp.*	4 k 6 o	0.00 ± 0.00 0.00 ± 0.00	0.00	0.00
LN *Salmonella sp.*	4 k 6 o	0.00 ± 0.00 0.00 ± 0.00	0.00	0.00

k⇒Kibuye market o⇒Oyugis market n⇒Number of samples analyzed

It was encouraging to note that no colonies of *Salmonella* sp. were observed for all the three markets of Kibuye, Oyugis and Homa Bay Pier (Table 5). Presence of one single colony of *Salmonella* sp. in the fish exported to the European union market would cause the whole consignment to be rejected. Previously, there have been bans of fish products from Kenya due to such reasons. These bans affect the economies of the people and should be avoided by following the good processing practices.

Rogers and Mosille (1991), in their study of Nile perch smoking in Tanzania, wrote that the smoking process in the kilns is essentially similar. Air temperatures of 120ºC-140ºC are generated in the kiln, with the temperature of the fish rising to around 100ºC. With this kind of temperatures, the smoked fish are expected to be sterile immediately after smoking. As Rogers and Mosille (1991) reported, the temperatures in the kiln is such that the fish is

initially cooked, denaturing the enzymes and protein, killing most bacteria and halting spoilage.

Since even one colony of Vero-toxigenic *E. coli* is enough to cause a disease (ICMSF, 1978), proper hygiene procedure must be put in place to curb possible disease outbreaks as a result of food, from these markets, being contaminated with the pathogens as all the markets had a lot of *E. coli.*

Infrequent outbreaks, which often involve *Clostridium botulinum* toxin, consistently appear related to improper processing procedures applied by inexperienced or un-knowledgeable processors, inadequate sanitation, abuse of product storage conditions (primarily by the consumer), and sometimes to consumer's erroneous belief that smoking negates the need for refrigeration or that the product has unlimited shelf-life.

TABLE 5: Anova comparison of the natural logarithm (LN) of number of bacterial load in *Lates niloticus* from markets versus beaches

Parameter	**Number Y**	**Mean ± Sd**	**F 0.05; 9, 33**	**P**
LN *E. coli*	10 Z	3.192± 5.157	1.13	0.295
	34 X	1.589±3.900		
LN *Vibrio spp.*	10 Z	0.00 ± 0.00	0.56	0.457
	34 X	0.477± 1.991		
LN *Salmonella sp.*	10 Z	0.000 ± 0.000	0.00	0.00
	34 X	0.000±0.000		

Z⇒Markets X⇒Beaches Y⇒Number of samples analyzed

Form the ANOVA results it is clear that markets have higher loads of bacteria that were analyzed for compared to the beaches (Table 2 and 6). This indicates cross contamination of the fish products by the traders at the markets or poor sanitary conditions during storage and distribution. The fish handlers at the beaches and markets should be taught about good food handling practices. Those with wounds should not be allowed to handle fish (Dillon *et al*, 1994).

There were nil *Salmonella* sp. cfu counts for both the markets and the beaches. This is an indication of proper handling procedures in both the markets and the beaches as far as the pathogen is concerned.

The standard deviation for the markets was also high indicating that the fish from different sources undergo different processing standards. It also indicates differences in hygienic conditions observed in different markets.

Even though smoking used to be a major fish processing technique earlier on, it is no longer the same now. Other more preferred processing methods such as filleting has taken up its place, deep-frying and sun drying. This observation can partly be explained by the scarcity of

wood fuel. Smoking process requires a lot of selected wood fuel. This is unlike deep-frying that does not discriminate on the type of wood used. More so, deep-frying requires less wood. It also uses other materials such as offal. The kilns that are in use in this area are not economical, as they do not conserve fuel.

To keep losses to a minimum, the cured fish should be distributed and sold as soon as possible. In remote areas, however, this is not always possible since transport may only be available periodically. Furthermore, it is often necessary to accumulate sufficient fish to fill a truck completely, for small- scale producers, this can take many weeks. Also, where communication is poor, regular transport often breaks down and hence cannot be relied upon. In addition, roads are often in poor condition, regularly impassable for part of the year due to floods etc. Under these conditions, storage losses can be very high (Morrisey, 1988).

Conclusion

In order to lengthen the shelf life of smoked fish products, it is necessary for the smoking process to be longer as is done in Uganda (Achieng pers. Comm.), and to reduce the moisture content to less than 50% below which the bacteria will not thrive.

Though a lot have been done in creating awareness among the fish traders and processors on the need to conduct their operations under good sanitary conditions. In spite of the above achievements, much still need to be done especially among the markets where the bacterial loads were still very high. Homa-Bay pier market in particular, needs serious sanitation improvements, ranging from the way the fish is displayed for sales to provision and enforcement of proper use of toiletry facilities.

The measures that have been taken by the various institutions in ensuring production of high quality fish products should be maintained in order for us to continue exporting our fish products to the European market.

Recommendation

A slow simmering fire for about three days should be used during the smoking process. This will result in properly smoked fish products with low water activity. Such products take up to more than a month to spoil thereby allowing ample time for marketing.

Post-processing handling of smoked fish products should be improved. The fish should be stored in clean, well-ventilated stores in the absence of cold storage facilities. The fish products should be packed in well-ventilated baskets and be transported in properly- sanitized trucks.

Smoked fish products must be properly cooked before they can be eaten.

For extended storage life, smoked fish products should be frozen to protect quality except for hard-cured items. Adequate toilet facilities and good sanitary conditions should be put in place in all the smoking villages and markets. Raised racks for fish displayed for sale in the markets are recommended. Good management practices at the fish processing plants and

improved health status of the local population would ensure continuous acceptability of fish products from Kenya.
Further research should be done with the aim of innovating smoking-kilns that conserve fuel-wood. Re-forestation programmes to be instituted in the areas surrounding the smoking villages. Road network along the landing beaches and fish processing villages should be improved so as to make them all-weather roads. This would facilitate delivery of the fish products to the markets in time.

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