Evaluation of Microbial Safety and Quality of Traditional Smoked Bonga Shad (*Ethmalosa frimbriata*) Fish from Lagos State, Nigeria.

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ABSTRACT

Smoked fish has become a delicacy in Nigeria and in the West African sub–region and there is now a corresponding concern for safety issues in smoked fish consumption. Traditional smoked bonga shad fish (*Ethmalosa frimbriata*) that floods the smoked fish market of the Lagos State of Nigeria are not microbiologically shelf-stable; hence, the need for a study on their microbiological quality and safety.

Fresh bonga shad fish (100 samples) were collected from 20 different fishing/processing centres and the fresh bonga shad fish samples were divided into two batches. One batch was smoked with local drum kiln at processing centres and the second batch was smoked with convective smoking kiln as control in the laboratory. Each batch was assessed for; Total Viable Count (TVC), *Fungal count (FC), Listeria monocytogenes* (LM) count, *Staphylococcus aureus* (SA) count, *Salmonella paratyphi* (SP) count and presence or absence of *Escherichia coli* (EC).

The results obtained showed significant variations ($p<0.05$) for all the microbial counts of the smoked fish samples. TVC of fresh unsmoked bonga shad fish samples were 6.8×10^6 - 8.7×10^8 cfu/g and TVC of samples of smoked bonga shad fish and the control were 2.0×10^4 – 6.3×10^4 cfu/g and 1.0×10^3 – 1.8×10^3 cfu/g respectively. *Listeria monocytogenes* count of fresh unsmoked bonga shad fish samples was 1.4×10^2 - 2.7×10^2 cfu/g and that of samples of smoked bonga shad fish ranged from 1.3×10^1 – 18.3×10^1 cfu/g. *Salmonella paratyphi* was not detected in smoked bonga shad fish samples and control samples. *Staphylococcal* count of fresh unsmoked bonga shad fish samples ranged from 6.3×10^3 – 8.4×10^3 cfu/g and that of samples of smoked bonga shad fish ranged from 16.3×10^2 – 87.3×10^2 cfu/g and 1.1×10^2 – 2.2×10^2 cfu/g. *Fungal count* of samples of smoked bonga shad fish ranged from 1.0×10^1 – 8.0×10^1 cfu/g. The samples of smoked bonga shad fish using conventional smoke kiln showed no count for *Listeria monocytogenes, Salmonella paratyphi and Escherichia coli*.

(Keywords: bonga shad, traditional foods, quality, microbiological safety, *Staphylococcal, Listeria monocytogenes*)

INTRODUCTION

Fish is a highly nutritious food and it is particularly valued for its protein which is of high quality compared to those of meat and egg (Ojutiku et al., 2009, Ikutegbe and Sikoki, 2014). It contains high quality protein, amino acids and absorbable dietary minerals (Bruhiyan et al., 1993). In West Africa, fish has been reported to provide 40–70% of the protein intake of the population (Béné and Heck, 2005; Ikutegbe and Sikoki, 2014) and is a critical source of dietary protein that is not readily available in the carbohydrate-based staple foods of the population.

Depending on consumer preference, there are several forms in which fish can be consumed; fresh, dried, frozen, fermented, brined etc. In a study by Mafimisebi (2012), it was discovered that majority of the Nigerian people reported a preference for fresh fish; however limitations such as the low keeping quality of the fish after harvest and the distances between fishing grounds and marketing outlets make this very difficult. This results in a higher reported consumption of

smoke-dried fish, which has a longer shelf-life (Mafimisebi, 2012).

In Nigeria, fish has an edge over meat because it is cheaper and relatively more abundant (Eyo, 2001) and constitutes about 40 % of the animal protein intake (Eyo, 2001; Abolagba and Melle, 2008). Fish is a cheap source of animal protein with little or no religious rejection of it, which gives it an advantage over pork or beef. Fish is a rich source of lysine suitable for supplementing high carbohydrate diet. It is also a valuable source of vitamin A, B and E, iodine and oils containing polyunsaturated fatty acids (Eyo, 2001, da Silva, 2002, Abolagba and Melle, 2008). Fish are important sources of protein to millions of people worldwide. It is known to be one of the cheapest sources of animal protein and other essential nutrients required in human diets in Nigeria (Afolabi *et al.,* 1984; Abolagba and Melle, 2008).

Because fish is highly perishable foodstuff, a considerable effort has been directed to extend the shelf-life of fish using preservation and processing techniques, such as refrigeration, freezing, canning, smoking, salting, and drying (Nwachukwu and Madubuko, 2013). Besides this, some of these techniques can also be used to enhance the value of fish, such as smoked fish.

Smoked fish is a relished food item in many dishes in Nigeria. The technique has developed to a point where once common food has become a delicacy and there is need for corresponding concern for safety issues in smoked fish consumption (Riches, 2012). Da Silva et al. (2008) examined the microbial safety and quality of smoked blue catfish (*Ictalurus furcatus*) steaks treated with antimicrobials and antioxidants during 6 weeks ambient storage. Fafioye et al. (2002) studied the fungal infestation of five traditionally smoked dried freshwater fish in Ago-Iwoye, Nigeria and isolated and identified eleven different fungal species of which *Aspergillus flavus* was the most frequently encountered fungi on the fish species. Adebayo-Tayo et. al., (2008) reported the presence of aflatoxin and other metabolites in smoked fish due to *Aspergilus flavus* in smoked fish sold in Uyo, Akwa Ibom State, Nigeria and confirmed that consumers could have been at risk of aflatoxin poison.

According to (Aberoumand, 2010), *Escherichia coli* is a classic example of enteric bacteria causing gastroenteritis. *Escherichia coli* including other coliforms and bacteria such as *Staphylococcus sp.* 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 *Escherichia coli* probably occur during handling of fish and during the production process (Jimoh et al., 2009). The microorganisms associated with smoked fish pose a great threat to the populace as the transfer of the microorganisms attack the immune system of the consumer, usually man, thereby, giving room for the invasion of disease. *Escherichia coli* and *Staphylococcus aureus* were reported as the predominant microorganisms present in smoked fish in Asaba area of Delta State of Nigeria (Okonta and Ekelemu, 2005). Outbreak of Listerosis in different parts of the world in the last three decades as a result of eating smoked fish has been a major public health concern.

This study is therefore to evaluate the microbiological quality and safety of traditional smoked bonga shad fish from Lagos State and by so doing, identify bacterial and fungal species prevalent in smoked fish, their distribution, effects and possible public health implications of the presence of such microorganisms.

MATERIALS AND METHODS

Fish Used

Fresh bonga shad fish (100 samples) were collected from 20 different fishing/processing centres of Badagry and Epe Local Government Areas of Lagos State, Nigeria and the fresh bonga shad fish samples were divided into two batches. One batch was smoked with local drum kiln at processing centres and the second batch was smoked with convective smoking kiln as control at the IFSERAR laboratory at Federal University of Agriculture, Abeokuta.

Culture Media

The following culture media were used Peptone water (PW; Oxoid): Plate Count Agar (PCA; Oxoid): Eosine Methylene Blue Agar (EMBA; Oxoid): Baird-Parker (Difco) agar: Salmonella-shigella agar (Oxoid): Brilliant Listeria Agar (Oxoid): Sabouraud dextrose agar (Oxoid).

Chemicals

All chemicals used in this study were of the analytical grade unless stated otherwise.

Area of Study

Using a current geopolitical map of Nigeria, Lagos State lies to the south-western part of Nigeria and has boundaries with Ogun State both in the north and east. It is bordered on the west by the Republic of Benin and in the south, stretches for 180 km. along the coast of the Atlantic Ocean. It therefore has 22.5% of Nigeria's coastline and occupies an area of 3,577 sq km land mass with about 786.94 sq. km. (22%) of it being lagoons and creeks. The state is endowed with marine, brackish andfresh water ecological zones with varying fish species that provide productive fishing opportunity for fishermen. Two local government areas (Badagry and Epe Local Government) were covered because they are highly densed fish processing centers. They were selected for the study and hazard analyses of the products.

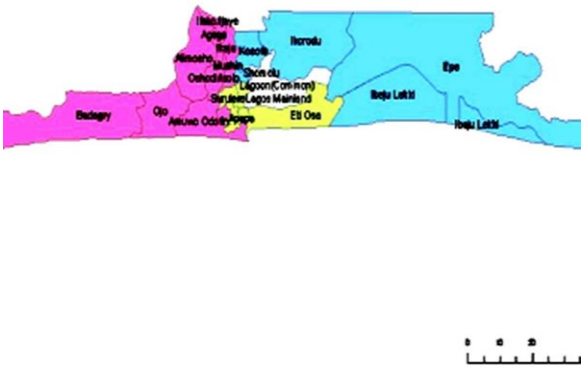

Figure 1: Map of Lagos State Showing the 20 LGA.

Sampling Procedure

'Fresh silver catfish' (100 samples) and smoked silver catfish (100 samples) were collected from 20 different processing centers from two local government areas by purposive sampling in sterile containers (Ziploc).

All freshly harvested silver catfish samples were kept on ice during transportation to the laboratory and smoked on the same day. Smoked fish samples were analyzed immediately.

Fish Smoking Process

Smoked fish was prepared following the method (Figure 2) as described by Crapo (2011) with modifications. Fish were carefully cleaned to remove slime, blood and harmful bacteria. The fish were eviscerated, leaving the skin on the fish. The fish were cut into uniform pieces (fillet) so that no parts will get overheated.

The fish were smoked to 80°C internal temperature (with a thermometer) for at least 24hours. The kiln temperature was adjusted as needed throughout this smoking period to maintain the 80°C internal temperature. Hands, utensils and work surfaces were cleaned when transferring fish from smoker to oven to cool down to avoid cross-contamination. Smoking was done for 24 hours until the fish is fully dried.

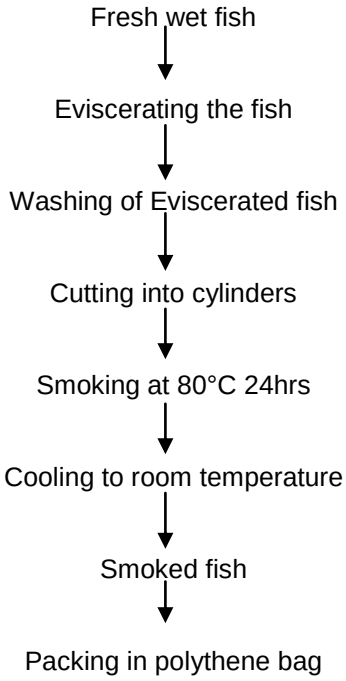

Figure 2: Traditional fish smoking (Crapo, 2011).

Physico-Chemical Analysis

A Kent pH meter (Kent Ind. Measurement Ltd., survey) model 7020 equipped with a glass electrode was used to measure the pH of the flesh, employing 10 g of fish homogenized in 10 ml of distilled water. Triplicate determinations were made in all cases. The pH meter was calibrated using pH 4.0 and pH 7.0 buffers. The total volatile base- nitrogen, trimethylamine value

(TMA), thio-barbituric acid value, peroxide value and free fatty acid value of the fresh fish and smoked fish were determined by AOAC method (2000). All chemicals used in this study were of the analytical grade unless stated otherwise.

Microbiological Studies

The presence of pathogens in fresh and smoked fish samples were investigated. These include: *Listeria monocytogenes, Salmonella paratyphi*, *Escherichia coli*, *Staphylococcus aureus* and *Fungal count.:* Fish samples (fresh and smoked) obtained from the identified processing centres were analyzed microbiologically. The microbiological procedures recommended in the International Commission on Microbiological Specification for Foods (ICMSF, 1996) were applied. Culture media were those of Oxoid, Biolife and Difco. For each sample, 25 g were weighed out and transferred to a sterile blender with 225 ml of 0.1% peptone and mixed thoroughly for 2 minutes to prepare fish homogenate. These were then analyzed as follows:

Total Viable Bacterial Counts: Appropriate dilutions of the fish homogenate were prepared and inoculated on to sterile Petri dishes. Plate count agar (Oxoid) media were then poured. Plates were incubated at 35–37 °C for 48 hours and colonies were then counted and reported as total colony count/ml. A second set of plates was incubated at 35–37 °C for 48 hours in a carbon dioxide incubator or under anaerobic conditions using a gas pack anaerobic jar. Colonies were then counted and reported as anaerobic total bacterial count. In case of spore formers count, the food homogenate was boiled first at 75–80 °C and then rapidly cooled. Appropriate serial dilutions were prepared and inoculated onto the surface of sterile and dried plate count agar media. These were incubated finally at 35–37 °C for 48 hours.

Detection of *Escherichia coli:* One ml of each of the decimal dilutions of the fresh and smoked fish homogenate was plated on poured Eosine Methylene Blue Agar (Oxoid) and then incubated at 35–37 °C for 24 hours. Counts were calculated from the number of growth on the plates. The colonies with green metallic sheen were counted as *Escherichia coli*.

Detection of *Staphylococcus aureus:* A sample of 0.1 ml of the fresh and smoked fish homogenate and dilutions was inoculated on Baird-Parker (Difco) agar plates and incubated at 35–37 °C for 48 hours. Colonies appearing to be black and shiny with narrow white margins and surrounded by clear zones were identified by coagulase test reactions. The coagulase test was carried out by first inoculating typical colonies in brain heart infusion broth (Difco) and incubating at 37 °C for 24 hours. From the resulting cultures, 0.1 ml was then added to 0.3 ml of rabbit plasma in sterile tubes and incubated at 37 °C for 4 hours. The formation of a distinct clot was evidence of coagulase activity.

Detection of *Salmonella paratyphi*: Samples of fresh and smoked fish homogenate and dilutions were inoculated in Salmonella-shigella agar (Oxoid) and incubated at 35–37 °C for 24 hours. For identification, 2–3 suspected colonies were inoculated into tryptone broth for indole test, triple sugar iron agar slant (Oxoid), urea broth and lysine iron agar. These were incubated at 37 °C for 24 hours. Salmonella species is indole negative, on triple sugar iron it produces acid (yellow) and alkaline (red) with or without gas and hydrogen sulfide, is urea negative, and on lysine iron agar shows an alkaline (purple) reaction throughout the medium. Serological tests were then carried out.

Detection of *Listeria monocytogenes*: A sample of 0.1 ml of the fresh and smoked fish homogenate and dilutions was inoculated on Brilliant Listeria Agar (Oxoid) plates and incubated at 35–37 °C for 24 hours. Colonies appearing were counted and reported as *Listeria monocytogenes*.

Enumeration of fungi: Appropriate dilutions of Sabouraud dextrose agar plates (Oxoid) were poured over 1 ml of the fish homogenate and dilutions. Plates were incubated at 22–25 °C for 3 days and then colonies were counted and reported as fungal count/ml.

RESULTS AND DISCUSION

The results showed the predominance of *Listeria monocytogenes, Staphyloccoccus aureus*, *Salmonella paratyphi* and *Escherichia coli* in the fresh unsmoked and smoked spotted tilapia fish samples. Total plate count (TVC) of fresh unsmoked bonga shad samples was 6.8×10^6 - 8.7×10^8 cfu/g and TVC of smoked bonga shad fish samples and control samples were 2.0×10^4 – 6.3×10^4 cfu/g and 1.0×10^3 – 1.8×10^3 cfu/g respectively. The TVC values obtained for the smoked spotted bonga shad fish samples and control samples were within the range of specified microbiological limits recommended by ICMSF (1986) for fish and fishery products, the maximum recommended bacterial counts for good quality products (m) is 5×10^5 (5.7 log10 CFU/g).

Listeria monocytogenes count of fresh unsmoked spotted tilapia samples was 1.4×10^2 - 2.7×10^2 cfu/g and that of samples of smoked spotted tilapia fish from different processing centres ranged from 1.3×10^1 – 18.3×10^1 cfu/g. Although the *Listeria monocytogenes* count values obtained for the smoked spotted tilapia fish samples were low, the range of specified microbiological limits recommended by ICMSF (1986) for *Listeria monocytogenes* for fish and fishery products is the presence of the organism, that is zero tolerance so most of the smoked samples from processing centres do not meet the ICMSF recommended microbial specification. Therefore, the smoked spotted tilapia samples from all processing centres need to be cooked before consumption in order to destroy *Listeria monocytogenes* that is present in the samples to prevent possibility of food poison by listeriosis.

All the control samples tested negative for *Listeria monocytogenes* while the fresh unsmoked spotted tilapia fish samples contained *L. monocytogenes. Staphylococcal* count of fresh unsmoked spotted tilapia fish samples ranged from 6.3×10^2 - 8.4×10^2 cfu/g and that of samples of smoked bonga shad fish from different processing centres and control samples ranged from 16.3×10^2 – 87.3×10^2 cfu/g and 1.1×10^2 – 2.2×10^2 cfu/g. The *Staphylococcal* count values obtained for the smoked bonga shad fish were low and below the specified recommended value for all fish (FDA, 2001).

Table 1: Microbial Quality (cfu/g) and pH of fresh Bonga shad (*Ethmalosa frimbriata*) from 20 Different Processing Centers.

Locations	*Listeria Monocytogenes*	*Salmonela paratyphi*	*E.coli*	Staphylococcal count	Fungal count	T.V.C.	pH
Agbalata	$2.0 \times 10^{2}_{bc}$	$1.5 \times 10^{2}_{bc}$	$1.3 \times 10^{2}_{ab}$	$8.1 \times 10^{2}_{c}$	-	$8.7 \times 10^{8}_{e}$	6.96abcd
Ajido	$1.9 \times 10^{2}_{ab}$	$1.1 \times 10^{2}_{a}$	$1.1 \times 10^{2}_{a}$	$6.5 \times 10^{2}_{a}$	-	$8.0 \times 10^{8}_{d}$	7.03cdef
Asakpo	$1.4 \times 10^{2}_{a}$	$1.3 \times 10^{2}_{ab}$	$1.4 \times 10^{2}_{ab}$	$7.8 \times 10^{2}_{bc}$	-	$7.6 \times 10^{8}_{c}$	7.18fgh
Boguru	$1.9 \times 10^{2}_{ab}$	$1.5 \times 10^{2}_{bc}$	$1.3 \times 10^{2}_{a}$	$7.1 \times 10^{2}_{ab}$	-	$7.9 \times 10^{8}_{d}$	6.91ab
Fvanoveh	$2.2 \times 10^{2}_{bc}$	$1.0 \times 10^{2}_{a}$	$1.4 \times 10^{2}_{ab}$	$8.0 \times 10^{2}_{c}$	-	$8.2 \times 10^{8}_{d}$	6.93abc
Gberefun	$2.1 \times 10^{2}_{bc}$	$1.3 \times 10^{2}_{ab}$	$1.0 \times 10^{2}_{a}$	$7.3 \times 10^{2}_{ab}$	-	$6.3 \times 10^{6}_{a}$	7.11efgh
Gbetrome	$2.6 \times 10^{2}_{d}$	$1.0 \times 10^{2}_{a}$	$1.2 \times 10^{2}_{a}$	$7.1 \times 10^{2}_{ab}$	-	$7.8 \times 10^{6}_{c}$	6.93abc
Ilaje	$2.3 \times 10^{2}_{cd}$	$1.1 \times 10^{2}_{a}$	$1.3 \times 10^{2}_{ab}$	$8.4 \times 10^{2}_{a}$	-	$8.4 \times 10^{8}_{d}$	6.82a
Kofegameh	$2.0 \times 10^{2}_{bc}$	$1.3 \times 10^{2}_{ab}$	$1.1 \times 10^{2}_{a}$	$7.6 \times 10^{2}_{bc}$	-	$6.7 \times 10^{6}_{ab}$	6.86a
Pako	$2.7 \times 10^{2}_{d}$	$1.5 \times 10^{2}_{bc}$	$1.0 \times 10^{2}_{a}$	$8.2 \times 10^{2}_{c}$	-	$8.3 \times 10^{8}_{d}$	7.07cdefg
Afuye	$2.3 \times 10^{2}_{cd}$	$1.0 \times 10^{2}_{a}$	$1.4 \times 10^{2}_{a}$	$7.4 \times 10^{2}_{a}$	-	$6.8 \times 10^{6}_{ab}$	7.10defgh
BodinYawa	$1.8 \times 10^{2}_{ab}$	$1.2 \times 10^{2}_{a}$	$1.0 \times 10^{2}_{a}$	$8.1 \times 10^{2}_{c}$	-	$7.6 \times 10^{8}_{c}$	7.13efgh
Idale	$2.0 \times 10^{2}_{bc}$	$1.0 \times 10^{2}_{a}$	$1.4 \times 10^{2}_{ab}$	$7.7 \times 10^{2}_{bc}$	-	$7.9 \times 10^{8}_{d}$	7.24h
Igbodun	$1.7 \times 10^{2}_{ab}$	$1.3 \times 10^{2}_{ab}$	$1.2 \times 10^{2}_{a}$	$7.4 \times 10^{2}_{bc}$	-	$8.0 \times 10^{8}_{d}$	7.00bcde
Ilogun	$1.5 \times 10^{2}_{a}$	$1.1 \times 10^{2}_{a}$	$1.0 \times 10^{2}_{a}$	$6.3 \times 10^{2}_{a}$	-	$7.5 \times 10^{8}_{c}$	7.14efgh
Mejona	$2.0 \times 10^{2}_{bc}$	$1.4 \times 10^{2}_{bc}$	$1.1 \times 10^{2}_{a}$	$6.9 \times 10^{2}_{ab}$	-	$8.0 \times 10^{8}_{d}$	6.81a
Oluwo	$2.4 \times 10^{2}_{cd}$	$1.2 \times 10^{2}_{a}$	$1.3 \times 10^{2}_{a}$	$8.3 \times 10^{2}_{c}$	-	$8.3 \times 10^{8}_{d}$	7.20gh
Okorisan	$2.1 \times 10^{2}_{bc}$	$1.1 \times 10^{2}_{a}$	$1.0 \times 10^{2}_{a}$	$6.5 \times 10^{2}_{a}$	-	$8.0 \times 10^{8}_{d}$	7.09defgh
Orita	$2.0 \times 10^{2}_{bc}$	$1.4 \times 10^{2}_{ab}$	$1.3 \times 10^{2}_{ab}$	$6.8 \times 10^{2}_{ab}$	-	$6.7 \times 10^{8}_{ab}$	7.01bcdef
Orogoro	$2.3 \times 10^{2}_{cd}$	$1.1 \times 10^{2}_{a}$	$1.1 \times 10^{2}_{a}$	$7.3 \times 10^{2}_{ab}$	-	$8.3 \times 10^{8}_{d}$	7.13efgh

Data are means of 3 replicates. Data with different subscripts in the same column indicate significant difference at $p<0.05$. T.V.C = Total viable count - = no count

Table 2: Microbial Quality (cfu/g) and pH of Bonga shad (*Ethmalosa frimbriata*) from 20 Different Processing Centers using Local Drum Kiln and Conventional Smoke Kiln.

Locations	*Listeria monocytogenes*		*Salmonella paratyphi*		*E.coli*		Staphylococcal count		Fungal count		T.V.C.		pH	
	Local	Convect	Local	Convect	Local	Convect	Local	Convect	Local	Convect	Local	Convect	Local	Convect
Agbalata	$6.0 \times 10^{1}_{e}$	-	-	-	-	-	$49.0 \times 10^{2}_{f}$	-	$1.0 \times 10^{1}_{a}$	-	$6.0 \times 10^{4}_{ef}$	$1.4 \times 10^{3}_{ab}$	6.41_{defg}	6.56_{a}
Ajido	$8.2 \times 10^{1}_{g}$	-	-	-	-	-	$63.2 \times 10^{2}_{g}$	$1.5 \times 10^{2}_{ab}$	-	-	$4.1 \times 10^{4}_{cd}$	$1.3 \times 10^{3}_{ab}$	6.38_{cdef}	6.72_{bcde}
Asakpo	$2.1 \times 10^{1}_{b}$	-	-	-	-	-	$18.5 \times 10^{2}_{c}$	-	-	-	$2.4 \times 10^{4}_{ab}$	$1.0 \times 10^{3}_{a}$	6.62_{ij}	6.93_{i}
Boguru	$10.0 \times 10^{1}_{h}$	-	-	-	-	-	$16.3 \times 10^{2}_{b}$	-	-	-	$5.0 \times 10^{4}_{d}$	$1.1 \times 10^{3}_{a}$	6.29_{abcd}	6.65_{abc}
Fvanoveh	$7.4 \times 10^{1}_{f}$	-	-	-	-	-	$34.5 \times 10^{2}_{e}$	$1.1 \times 10^{2}_{a}$	$4.0 \times 10^{1}_{b}$	-	$3.5 \times 10^{4}_{bc}$	$1.8 \times 10^{3}_{cd}$	6.58_{hij}	6.90_{hi}
Gberefun	$2.5 \times 10^{1}_{b}$	-	-	-	-	-	$22.4 \times 10^{2}_{d}$	-	-	-	$2.3 \times 10^{4}_{a}$	$1.5 \times 10^{3}_{bc}$	6.53_{fghi}	6.61_{ab}
Gbetrome	$1.3 \times 10^{1}_{a}$	-	-	-	-	-	$29.1 \times 10^{2}_{ab}$	-	-	-	$2.1 \times 10^{4}_{a}$	$1.0 \times 10^{3}_{a}$	6.37_{bcde}	6.72_{def}
Ilaje	$3.1 \times 10^{1}_{bc}$	-	-	-	-	-	$41.6 \times 10^{2}_{f}$	$1.2 \times 10^{2}_{a}$	-	-	$4.4 \times 10^{4}_{cd}$	$1.2 \times 10^{3}_{a}$	6.43_{defgh}	6.84_{ghi}
Kofegameh	$4.6 \times 10^{1}_{c}$	-	-	-	-	-	$45.0 \times 10^{2}_{f}$	-	$1.7 \times 10^{1}_{a}$	-	$2.1 \times 10^{4}_{a}$	$1.3 \times 10^{3}_{ab}$	6.71_{j}	6.63_{abc}
Pako	$6.0 \times 10^{1}_{e}$	-	-	-	-	-	$37.4 \times 10^{2}_{e}$	$2.1 \times 10^{2}_{bc}$	-	-	$5.3 \times 10^{4}_{de}$	$1.1 \times 10^{3}_{a}$	6.24_{abc}	6.91_{i}
Afuye	$12.1 \times 10^{1}_{i}$	-	-	-	-	-	$80.1 \times 10^{2}_{h}$	-	-	-	$2.1 \times 10^{4}_{a}$	$1.0 \times 10^{3}_{a}$	6.32_{abcde}	6.65_{abc}
Bodin Yawa	$6.3 \times 10^{1}_{e}$	-	-	-	-	-	$84.0 \times 10^{2}_{h}$	$2.2 \times 10^{2}_{bc}$	-	-	$5.4 \times 10^{4}_{de}$	$1.5 \times 10^{3}_{bc}$	6.42_{defgh}	6.71_{bcde}
Idale	$6.0 \times 10^{1}_{e}$	-	-	-	-	-	$12.4 \times 10^{1}_{a}$	-	$10.0 \times 10^{1}_{e}$	-	$4.3 \times 10^{4}_{cd}$	$1.4 \times 10^{3}_{ab}$	6.21_{a}	6.64_{abc}
Igbodun	$12.4 \times 10^{1}_{i}$	-	-	-	-	-	$87.3 \times 10^{2}_{h}$	-	$6.2 \times 10^{1}_{c}$	-	$2.0 \times 10^{4}_{a}$	$1.2 \times 10^{3}_{a}$	6.58_{hij}	6.77_{def}
Ilogun	$6.2 \times 10^{1}_{e}$	-	-	-	-	-	$27.5 \times 10^{2}_{d}$	$1.1 \times 10^{2}_{a}$	$3.1 \times 10^{1}_{b}$	-	$5.1 \times 10^{4}_{d}$	$1.3 \times 10^{3}_{ab}$	6.41_{defg}	6.93_{i}
Mejona	$3.1 \times 10^{1}_{bc}$	-	-	-	-	-	$23.4 \times 10^{2}_{d}$	$1.2 \times 10^{2}_{a}$	$1.4 \times 10^{1}_{a}$	-	$2.5 \times 10^{4}_{ab}$	$1.4 \times 10^{3}_{ab}$	6.22_{ab}	6.72_{bcde}
Oluwo	$3.3 \times 10^{1}_{bc}$	-	-	-	-	-	$48.1 \times 10^{2}_{f}$	-	-	-	$6.3 \times 10^{4}_{f}$	$1.1 \times 10^{3}_{a}$	6.56_{ghij}	6.80_{efg}
Okorisan	$4.0 \times 10^{1}_{c}$	-	-	-	-	-	$28.4 \times 10^{2}_{d}$	$1.5 \times 10^{2}_{ab}$	-	-	$3.1 \times 10^{4}_{bc}$	$1.4 \times 10^{3}_{ab}$	6.23_{abc}	6.68_{bcd}
Orita	$5.0 \times 10^{1}_{d}$	-	-	-	-	-	$16.3 \times 10^{2}_{b}$	-	-	-	$4.3 \times 10^{4}_{cd}$	$1.0 \times 10^{3}_{a}$	6.20_{a}	6.74_{cdef}
Orogoro	$18.3 \times 10^{1}_{j}$	-	-	-	-	-	$31.0 \times 10^{2}_{e}$	-	$8.0 \times 10^{1}_{d}$	-	$2.0 \times 10^{4}_{a}$	$1.2 \times 10^{3}_{a}$	6.46_{efgh}	6.92_{i}

Data are means of 3 replicates. Data with different subscripts in the same column indicate significant difference at $p<0.05$. T.V.C = Total viable count - = no count

In addition, smoking also reduced *Staphylococci*, and fungal counts. The isolation of *Staphylococcus* in smoked samples can be attributed to post processing contamination. *Salmonella paratyphi* was not detected in smoked bonga shad fish samples and control samples and this conformed with the specified microbiological limits recommended by ICMSF (1986). In this study, *fungal count* of samples of smoked bonga shad fish from different processing centres ranged from 1.0×10^{1} – 8.0×10^{1} cfu/g. The population of fungi in the samples were all below 5×10^{5} CFU/g specified microbiological limits recommended by ICMSF (1986) for fungi, except for the samples control samples that had no fungi count.

CONCLUSION

From this study, smoking significantly ($p<0.05$) reduced the pH and total viable count in all samples of smoked bonga shad fish using local drum kiln; however, the samples of smoked fish using conventional smoke kiln showed no count for *Listeria monocytogenes. Salmonella paratyphi*

and Escherichia coli. *Salmonella paratyphi and Escherichia coli* were not detected in all smoked spotted tilapia fish samples and control samples and this conformed with the specified microbiological limits recommended by ICMSF (1986) for *Salmonella paratyphi and Escherichia coli* count for fish and fishery products which is the presence of the organisms, that is zero tolerance.

In all cases, fecal contamination of the products was not detected as *Salmonella paratyphi* and *Escherichia coli* which serve as indicator organisms for fecal contamination of foods are absent and this suggests Good Manufacturing Practices (GMP). The study concluded that the traditional smoked bonga shad fish from Lagos State needs further cooking or heat treatment before consumption.

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