Sources of Fungal Contamination of Fresh and Dried Fish in Kisii County, Kenya

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Authors' contributions

This work was carried out in collaboration among all authors. Author ISN designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors EM, OO and JK managed the analyses of the study. Author ISN managed the literature searches. All authors read and approved the final manuscript.

Original Research Article

ABSTRACT

Aflatoxins are toxic secondary metabolites produced by *Aspergillus flavus* and *Aspergillus parasiticus* that frequently invade foods and feedstuffs. In humid climatic conditions like those found in Kisii County, growth of fungi on dried fish and fish feeds is accelerated due to absorption of moisture from the environment as a result of poor storage and sometimes improper drying. This can lead to creation of favourable conditions for the growth of the toxigenic fungi and consequently production of aflatoxins. This study was conducted to determine the main sources of fungal contamination of selected fresh and dried fish sold in Kisii county, Kenya. Samples of fish were randomly obtained from four main markets in the county. A structured questionnaire was used to determine the sources of fish, mode and hygiene of transportation, handling of fish, duration of storage, hygiene of packaging materials and display environment of fish. Levels of fish contamination were expressed in form of colony forming units per gram (CFU/g) of fish. One-way analysis of variance was used to determine mean differences in parameters analysed. The results

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revealed that CFU/g of fish from control samples were significantly less than those from fresh and dried fish samples from the various sources (p<0.05). There was generally no significant difference between CFU/g from both fresh and dried fish from the various sources. The study found out that fresh and dried fish sold in Kisii county are contaminated with fungi. There is therefore need for frequent surveillance on the sources of fish contamination and public sensitization of all those involved in fish supply chain. This will help reduce possible aflatoxin contamination thus promoting consumers' healthy living.

1. INTRODUCTION

Fish supplies a balance of protein, vitamins and minerals. Fish and fish products such as fish fillets, fish balls, fish samosa and fish soup are considered a source of high-quality animal protein available both in urban and rural areas for human consumption. In addition, they are exceptionally rich in calcium, phosphorus and supply of ß- complex vitamins [1,2,3]. Interest in fish consumption has increased over the years, due to health benefits it imparts being a rich source of omega-3 fatty acids that reduces cholesterol levels and the incidence of heart and pre-term birth [4]. Dried fish are a very important part of the traditionally accepted diet for many in developing countries. They are often enjoyed for their characteristic flavour and are commonly used as raw material for season's foods. This is why fish and fish products constitute more than 60% of the total protein intake in adults especially in the rural areas [2]. When poorly handled, fish meat gets spoilt quickly due to bacterial and fungal attack. It has been estimated that up to 30% of landed fish get spoilt through microbial activity [5]. Contamination of fish by bacteria and fungi is mostly due to a polluted environment [6,7].

In Kisii County, there are over 3000 fish farmers, operating 3,129 fish ponds, courtesy of the economic stimulus program [8]. Despite the big number of fish ponds in Kisii County, fish supply from the ponds does not meet the demand due to preference of white meat from fish because of health benefits associated with it. Therefore, more fish is imported from the neighboring counties of Homabay, Migori and from the republic of Tanzania to meet the demand. If the fish imported by both wholesalers and retailers, is not hygienically transported, handled, stored and failure to meet the required moisture content of 10%, can result in fungal contamination. Such contamination can involve aflatoxin producing strains such as *Aspergillus flavus* and *Aspergillus parasiticus* [7] which can consequently produce aflatoxins in the fish. Aflatoxin have serious negative implications on human health. They are immunosuppressive, carcinogenic, teratogenic and hepatogenic [9,10].

Improperly stored fish absorbs moisture, create a conducive environment for the growth of the aflatoxigenic fungi and other moulds. Identifying sources of fish fungal contamination is important in putting up measures to prevent or reduce such contamination. This is vital in improving its nutritional status and safety [11,12]. Therefore, there is need to determine the sources of fish contamination for proper surveillance and sensitization of all stakeholders in the fish supply chain. This study was conducted to determine the sources of contamination in fish sold in Kisii County, Kenya.

2. MATERIALS AND METHODS

2.1 Study Area

The study was conducted in Kenya in Kisii County which lies between latitude 0º 30´ and 10´South and longitude 34º 38´and 35º 0´ East. It has humidity of 61-76% due to heavy rainfall (over 1,500 mm per annum) in September to December and March to June. The temperature range of Kisii County is 18.5-28 ºC [13,14]. It is bordered by six counties with Narok to the South, Migori to the West, Homabay to the North West, Kisumu to the North, Bomet to the South East and Nyamira to the East. It has a population of 1,266,860 according to Kenya National Census of 2019 [15]. The county has over 3000 fish farmers, operating 3,129 fish ponds, courtesy of the economic stimulus program [8]. Most of the fish sold in this county is imported from Migori, Homabay, Kendubay and Mbita.

2.2 Administration of Questionnaires

Handling of fish, fish sources, transportation and storage conditions of fresh and sun-dried fish was determined by observation and use of

structured interviews guided by questionnaires during sample collection. Ten randomly selected fish sellers from each market and fish sources were interviewed. The markets were Keroka, Daraja Mbili, Nyakoe and Riosiri while the fish sources were Migori, Mbita, Homabay, Kendubay and Kisii. The responses obtained were used to evaluate fish sources, how fish was handled, transported, displayed and stored. In the questionnaire, the hygiene standards of the means of transport, display environment and packaging materials were rated using a Likert type scale ranging from 1-4, where 1 represented very good, 2 represented good, 3 represented poor and 4 represented very poor.

2.3 Sample Collection

Four hundred grams of sun dried were sampled by the systematic random design from ten retailers in four different marketing sites; Keroka, Riosiri, Daraja Mbili and Nyakoe. Another set of four hundred-gram of fresh fish samples were obtained from ten fish farmers in Kisii County and from the shores of Lake Victoria in Migori, Homabay, Mbita and Kendubay which are the main sources of fish sold in Kisii County. These samples from the shores were used as control samples. All the samples were packed in sterile bags and tagged accordingly. They were taken to the Kenya Agricultural and Livestock Research Organisation (KALRO) Kisii pathology laboratory for mycological analysis. The level of contamination was expressed in form of colony forming units per gram of sample (CFU/g). Moisture content was determined by crushing and weighing five grams of the sun-dried fish samples. The samples were then dried in an oven at a temperature of 102 $^\circ$C until a constant weight was attained. They were then cooled in a desiccator. The final weight of the sample was subtracted from the initial weight and the loss in weight expressed as a percentage.

2.4 Mycological Assay

Enumeration technique of fungal colony forming units (CFUs) was done according to the protocol by Pitt and Hocking 1997. Fifteen grams of each sun-dried fish sample were ground in a blender, ten grams of each sample was homogenized in 90 ml of distilled water for 20 minutes in a shaker and serial dilutions made (10^{-2} to 10^{-4}). Aliquots of 0.1ml were spread plated in triplicates onto Sabouraud Dextrose Agar (SDA). The plates were incubated at 25 ^{0}C for 5 to 7 days. The plates with colonies between 30 and 300 were enumerated in form of CFU. Those with less than 30 colonies were considered too few while those with more than 300 were categorized as numerous [16]. The abundance of fungi was determined in form of the CFU. The colonies were counted and the CFU per gram of sample determined through calculations by taking into account the dilution factor.

2.5 Data Analysis

Data on CFU were transformed using the logarithmical function $\log_{10}$. One-Way ANOVA test was then performed to compare the means in colony forming units per gram (CFU/g) of fish obtained from fresh and dried fish samples from various fish sources using Tukey's test by Statistical Package for Social Sciences (SPSS) for windows 20.0. A confidence level of 95% with a P value of <0.05 was considered significant. Responses from questionnaire items were computed into percentages.

3. RESULTS

3.1 Sources of Contamination of Fish Samples

3.1.1 Transportation, packaging and environment of displaying fish

Most of the fish sellers transported the fish they sell to the market using public service vehicles. An average number did so by motorbikes while a small number by using carts. In Daraja Mbili, Nyakoe and Keroka markets 60% of the fish sellers transport the fish they sell to the market using public service vehicles, while 30% in Daraja Mbili, 40% in Nyakoe, 60% in Riosiri and 30% in Keroka used motorbikes. Its only 10% of fish sellers in Daraja Mbili and Keroka that used carts. None of the sampled fish sellers in Riosiri and Nyakoe used a cart. The hygiene condition of the means of transport used was rated as good by 30% of the fish sellers in Riosiri, 10% in Daraja Mbili and Nyakoe and 70% in Keroka. Those that rated the means of transport as poor hygienically were 70% in Riosiri, 90% in Daraja Mbili, 80% in Nyakoe and 30% in Keroka. None of the fish sellers rated the means of transport as very poor in all the markets except 10% from Nyakoe market.

Most of the fish sellers (90%) acknowledged that the materials they used for packaging the fish from where they buy it were hygienically poor. This was said by 70% of the sellers in Riosiri,

80% in Daraja Mbili, 60% in Nyakoe and 10% in Keroka. Those who rated the packaging materials as good were 30% in Riosiri, 20% in Daraja Mbili and Nyakoe and 80% in Keroka. Its only 20% of fish sellers in Nyakoe and 10% in Keroka who rated the materials as very poor hygienically.

In terms of the environmental hygiene around and where the fish was displayed, the sampled fish sellers generally rated it as poor (45%) with 17.5% rating it as very poor. This gave a total percentage of 62.5%. It is only 10% of fish sellers from Riosiri who rated the environmental hygiene as very good, 50% rated it as good, 40% as poor and none rated it as very poor. In Daraja Mbili 60% rated it as good, 20% as poor and another 20% as very poor. In Nyakoe, 20% rated it as good, 60% as poor and 20% as very poor. In Keroka 50% rated it as good, 20% as poor and 30% as very poor (Fig. 1).

Generally, in most markets, fish was displayed in a hygienically poor environment (70%), fish seller often wore dirty aprons (82%), displayed their fish on materials that were washed once a week (95%) or twice a week (5%) and the fish was either displayed on wooden stands (85%) or on the ground (15%) using gunny bags (70%) or polythene bags (30%).

Gunny bags were the commonly used materials for displaying the fish sold in the market both on the ground and wooden stands. In Riosiri, Daraja Mbili and Nyakoe markets, 90% of the fish sellers used gunny bags. In Keroka gunny bags were used by 80% while polythene was used by 10% of the fish sellers in Riosiri, Daraja Mbili and Nyakoe. In Keroka polythene was used by only 20% of the fish sellers.

3.1.2 Storage, handling and hygiene of fish samples

Fish was stored in dirty gunny bags and stores. The hygiene conditions were very poor and fish was stored for more than a week. Most of the fish samples had moisture content above 10%. Fish samples that had moisture content of 10% and below and were stored hygienically had very low CFU even after being stored for a long time (more than 4 weeks). Those that had moisture content of 10% and below but were not hygienically stored had more CFUs. Samples that had moisture content of more than 10% and were stored hygienically had fewer CFUs compared to those that had moisture content of more than 10% and were not stored hygienically. The number of CFUs for all the fish samples increased with increase in the duration of storage and moisture content of the samples. Rats and cockroaches were common storage pests as reported by all fish sellers (100%) in all the markets.

In Riosiri market 90% of the fish sellers were not aware of any precautionary measures necessary to keep fish safe from contamination and absorption of moisture while only 10% were aware. In Daraja Mbili 30% were aware while 70% were not. In Nyakoe 90% were not aware while 10% were aware. In Keroka 20% were aware while the majority 80% were not aware.

In terms of materials used for storage of fish 92.5% of fish sellers from all the markets used gunny bags. The percentage distribution per market was 100% in both Riosiri and Daraja Mbili markets, 90% in Nyakoe market and 80% in Keroka market. It is only 10% of fish sellers in Nyakoe and 20% in Keroka who stored their fish in polythene bags. It was also observed that 90% of the fish sellers in Riosiri market stored their fish for 0-1 week before exhausting their stock while 10% stored their fish for over one week but sold it before 2 weeks were over. In Daraja Mbili market, 50% of fish sellers stored their fish for 0-1 before exhausting their stock, 40% for 1-2 weeks and 10% for more than 2 weeks. For those in Nyakoe, 30% stored their fish for less than a week, 70% for more than a week but less than 2 weeks while in Keroka 60% stored their fish for less than a week, 30% for more than a week but less than 2 weeks while 10% stored it for more than 2 weeks (Fig. 2).

Most of the fish sellers in all the markets did not frequently dry the fish that has not been sold in order to reduce their moisture content. In Riosiri market 80% of the fish sellers did not dry their fish at all. They only displayed a small amount of the fish while the bulk of it was left in gunny bags in the market place and some in the store. Twenty percent of the fish sellers dried their fish once a week while none dried it daily, twice or even thrice a week. In Daraja Mbili market 70% of the sellers did not dry their fish at all, 30% dried it once a week while none dried their fish twice or even thrice a week. In Nyakoe 10% dried their fish daily, 30% did it 2-3 times a week, 50% did it once while 10% did not dry it at all. In Keroka none of the fish sellers dried their fish daily, 10% did it 2-3 times a week, none of them dried them once a week while 90% did not dry the fish (Fig. 3).

It was also observed that in all the markets, fish buyers did not observe simple hygiene practices such as refraining from touching the displayed fish in the market (Plate 1). In Riosiri market 70% very oftenly touched the displayed fish with only 30% refraining from touching the displayed fish. Daraja Mbili market had the highest number of fish buyers touching the displayed fish (90%) while in Nyakoe and Keroka markets 80% of the fish buyers touched the displayed fish very oftenly (Fig. 4).

All the fish sellers in all the markets handle money with their bare hands and used the same hands to pack fish for their customers (Plate 2). Most of the fish sellers displayed their fish on wooden stands (Plate 3) while a few did so on the ground (Plate 4). It was observed that 50% of fish sellers in Riosiri and Keroka markets displayed their fish on the ground while another 50% did so on wooded stands. In Daraja Mbili market, 30% of the fish sellers displayed their fish on the ground while a majority (70%) did so on wooden stands. In Nyakoe 20% displayed fish for sale on the ground while 80% did so on wooded stands. Averagely 62.5% of fish sellers displayed fish on wooden stands while 37.2% on the ground.

A majority of the fish sellers in all the markets did not frequently clean the materials they used for buying and displaying fish. In all the markets except Nyakoe none of the fish sellers washed their packaging and displaying materials weekly. In Daraja Mbili and Nyakoe 100% of the fish sellers sampled washed their packaging and displaying materials once a month. In Riosiri, 70% washed once a month while the remaining 30% washed them twice a month. This was not the case for Nyakoe as 40% of them washed them once while 50% washed them twice a month. Generally, a majority of the fish sellers (77.5%) in all the markets washed their packaging and displaying materials once a month. Only 2.5% did so weekly while 20% did so twice a month.

It was observed that Daraja Mbili attended to the largest number of fish buyers each market day as compared to the other three markets. All the fish sellers sampled attended to either 101- 150 (20%) or more than 150 (80%) fish buyers every market day. The second was Riosiri market where its fish sellers attended to either 51-100 (20%), 101-150 (40%) or above 150 (40%) fish buyers every market day. Sixty percent of fish sellers in Nyakoe attended to 1-50 fish buyers while 40% of them attended to 51-100 fish buyers every market day. In Keroka 10% of fish sellers attended to 1-50 buyers, 60% attended to 51-100 buyers while 30% attended to 101-150 buyers every market day (Fig. 6).

Plate 1. Fish seller handling money

Plate 2. Fish buyer touching dried fish

Plate 3. Fish displayed on wooden stands
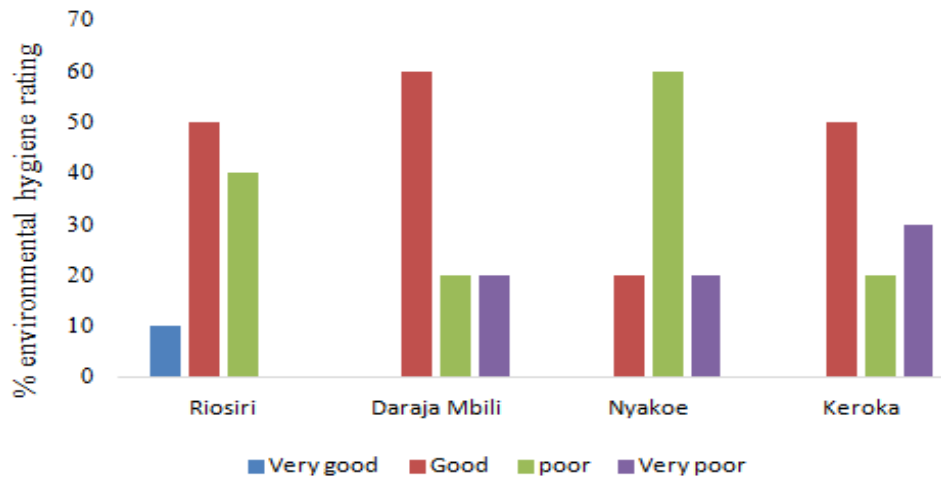

Plate 4. Fish displayed on the ground

Fig. 1. Percentage environmental hygiene rating of where fish is displayed
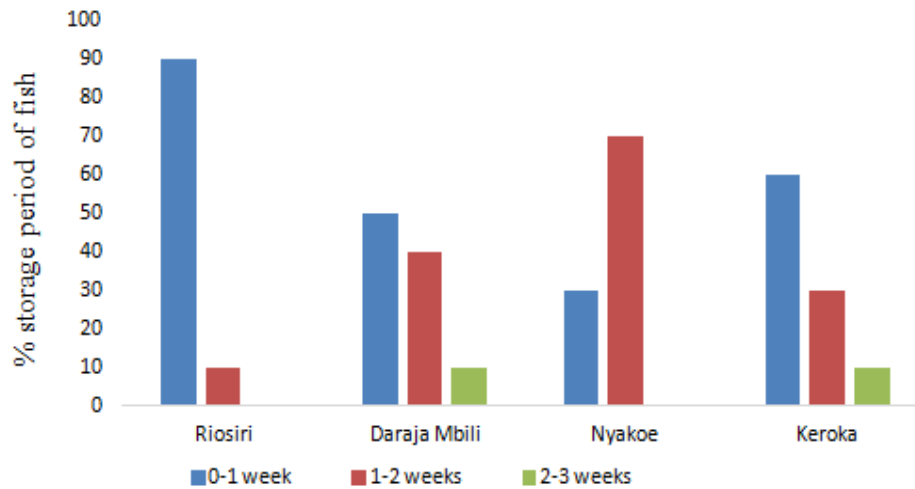

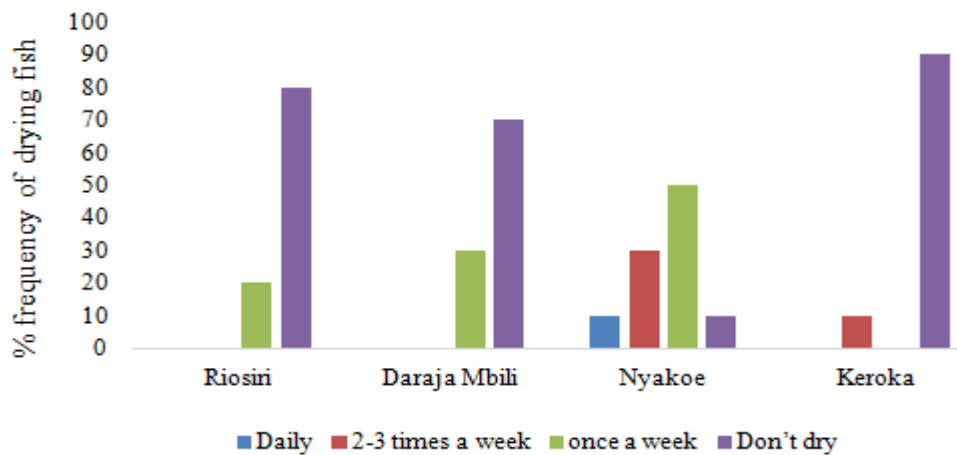
Fig. 2. Storage period of fish

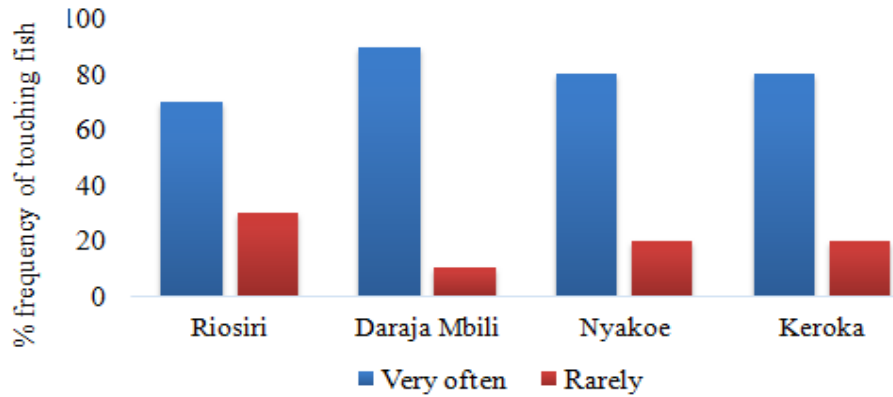**Fig. 3. Percentage frequency of drying fish**

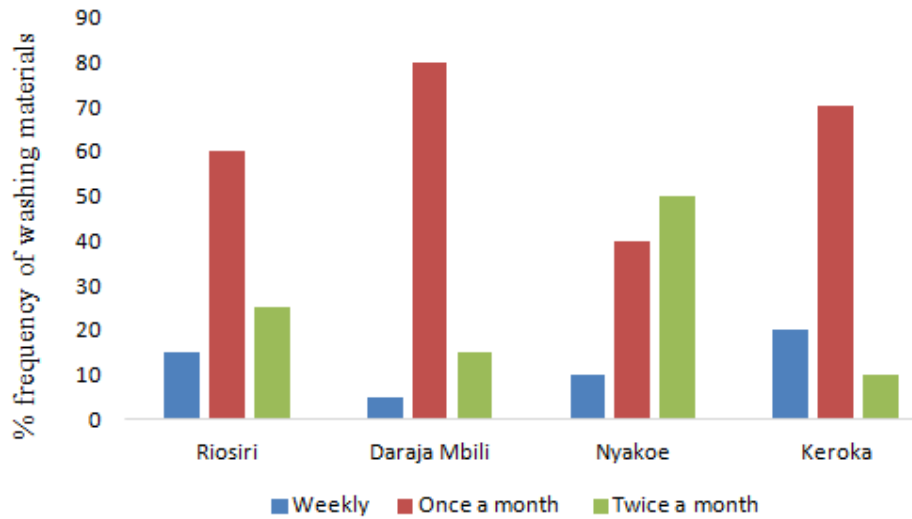**Fig. 4. Percentage frequency of number of fish buyers touching displayed fish**

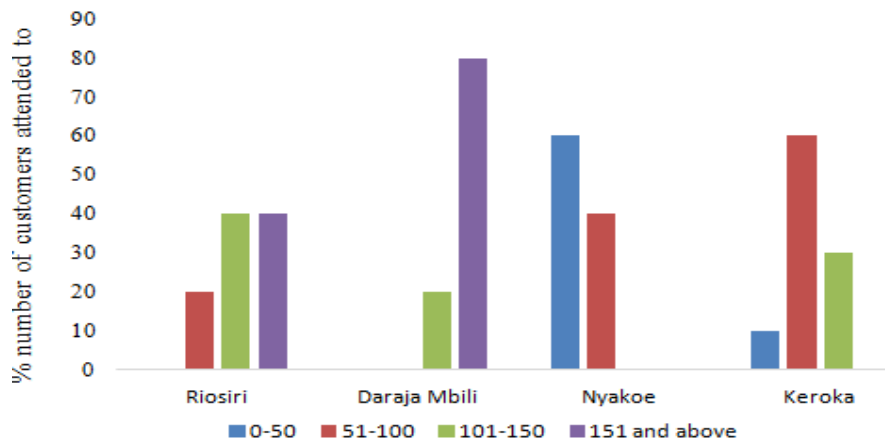**Fig. 5. Percentage frequency of washing packaging and displaying materials**

Fig. 6. Percentage number of customers attended to each market day

3.2 CFU from Fish Samples

CFU obtained from fresh and dried fish were from twenty fungal species identified as *Cunninghamella*, *Rhizopus*, *Penicillium*, *Candida*, *Phoma*, *Trichoderma*, *Aspergillus*, *Mucor*, *Trichophyton*, *Alternaria*, *Cladosporium*, *Acremonium*, *Fusarium*, *Mycosporum*, *Geotricum*, *Cladophialophora*, *Scopulariopsis*, *Verticillium*, *Clamydosporum* and *Microsporum*. Samples of both fresh and sun-dried fish that were purchased from the shores and around the shores of Lake Victoria in the four main sources (Mbita, Migori, Homabay and Kendubay) and Kisii ponds, handled and transported hygienically (control samples) had fewer (1.6165 ± 0.05011 for fresh fish and 2.4291 ± 0.18244 for dried fish) $\log_{10}$ colony forming units per gram (CFU/g) of fish. Those that were purchased from fish sellers in different markets had more (3.0333 ± 0.17616 for fresh fish and 4.7365 ± 0.25126 for dried fish) CFU/g of fish. Samples of sun-dried *R. argentea* had the highest CFU/g, followed by sun-dried Nile perch, sun dried catfish and sun-dried tilapia respectively. The CFU/g per source for fresh and dried samples were as shown in Tables 1 and 2.

3.2.1 CFU from fresh fish samples

Samples of fresh *Rastrineobola argentae* from Mbita had the highest mean fungal count ($\log_{10}$ CFU/g) (2.8807 ± 0.07203) followed by samples from Migori (2.8754 ± 0.6767), then those from Kendubay (2.7487 ± 0.08374). Samples from Homabay had the least fungal count (2.7148 ± 0.12287) among the four main sources of fresh fish sold in Kisii County. The control samples had a lower mean CFU/g (1.6595 ± 0.18242) compared to all the other sources (Table 1). There was no significant CFU/g mean difference between samples from the four markets (p=0.564). There were no samples of fresh *Rastrineobola argentea* from Kisii County as farmers do not farm this type of fish. The results revealed that there was a significant CFU/g mean difference between the control samples and other samples obtained from the various sources (p<0.001).

Fresh fish samples of Nile perch from Homabay had the highest CFU/g mean (2.7690 ± .09749), followed by samples from Kendubay (2.6704 ± 0.13741), Migori (2.6041 ± 0.11882), Mbita (2.5755 ± 0.16441) and Kisii (2.3201 ± 0.07421) respectively. The control samples had a lower mean CFU/g (1.7996 ± 0.07791) compared to all the other sources (Table 1). There was no

significant CFU/g mean difference between samples of Nile perch obtained from Mbita, Migori, Homabay and Kendubay (p>0.05). However, there was a significant CFU mean difference between Kisii and Homabay (p= 0.012), Kisii and Kendubay (p= 0.044) and between the control and all the four sources (p<0.001).

Fresh fish samples of Tilapia from Kendubay had the highest mean $\log_{10}$ CFU/g (3.0333 ± 0.17252), while those from Kisii had the lowest (2.6746 ± 0.17616). The means from the other sources were Mbita (2.9510 ± 0.1105), Homabay (2.8383 ± 0.11608) and Migori (2.7945 ± 0.31698). The control samples had a lower mean CFU/g (1.6165 ± 0.05011) compared to all the other sources (Table 1). There was no significant mean difference between CFU/g of samples from the different sources (p=0.437). However, there was a significant mean difference between the control samples and samples from all the five fish sources (p<0.001).

Samples of fresh catfish from Kendubay had the highest mean $\log_{10}$ CFU/g (3.0144 ± 0.16898) followed by Migori (2.9255 ± 0.10833), Homabay (2.6606 ± 0.07158), Mbita (2.5856 ± 0.14146) and Kisii (2.5169 ± 0.07759). The control samples had a lower mean CFU/g (1.6795 ± 0.15356) compared to all the other sources (Table 1). There was no significant mean difference in CFU of samples from Mbita, Migori and Homabay (p>0.05). However, there was a significant mean difference between samples from Mbita and Kendubay (p=0.024), Migori and Kisii (p=0.031) and between Kendubay and Kisii (P=0.010). There was also a significant mean difference in CFU/g between control samples and samples from all other sources of catfish (p<0.001).

3.2.2 CFU from dried fish samples

Sun dried samples of *R. argentea* from Migori had the highest mean $\log_{10}$ CFU/g (4.7365 ± 0.25126) compared to the other three sources. They were followed by samples from Kendubay (4.5066 ± 0.32360), Mbita (4.3260 ± 0.28514) and Homabay (4.2172 ± 0.40125) respectively. Control samples had a lower mean CFU/g (2.4291 ± 0.18244) compared to all the other fish sources (Table 2). There was no significant mean difference between CFU of samples from the various fish sources (p=0.733). However, there was a significant mean difference between CFU of control samples and the samples of *R. argentea* from various sources (p<0.001).

Table 1. Mean CFU from fresh fish from different sources

Source of fish	Mean fungal count ($\log_{10}$ CFU/g)			
	Rastrineobola argentea (Omena)	*Lates niloticus* (Nile perch)	*Oreochromis niloticus L* (tilapia)	*Clarius gariepinus* (catfish)
Mbita	2.8807[b] ± 0.07203	2.5755[bc] ± 0.16441	2.9510[b] ± 0.11053	2.5856[b] ± 0.14146
Migori	2.8754[b] ± 0.6767	2.6041[bc] ± 0.11882	2.7945[b] ± 0.31698	2.9255[c] ± 0.10833
Homabay	2.7148[c] ± 0.12287	2.7690[c] ± 0.09749	2.8383[b] ± 0.11608	2.6606[bc] ± 0.07158
Kendubay	2.7487[b] ± 0.08374	2.6704[c] ± 0.13741	3.0333[b] ± 0.17252	3.0144[c] ± 0.16898
Kisii	-	2.3201[b] ± 0.07421	2.6746[b] ± 0.17616	2.5169[b] ± 0.07759
Control	1.6595[a] ± 0.18242	1.7996[a] ± 0.07791	1.6165[a] ± 0.05011	1.6795[a] ± 0.15356

Mean values with different superscripts differ significantly (p<0.05)
Mean value expressed as mean ± SE by Tukey's test.
-no this type of fish

Table 2. Mean CFU from sundried fish from different sources

	Rastrineobola argentea (omena)	*Lates niloticus* (Nile perch)	*Oreochromis niloticus L* (tilapia)	*Clarius gariepinus* (catfish)
Mbita		4.2121[c] ± 0.20297	3.6601 ± 0.39313	3.8532[b] ± 0.32809
Migori	4.7365[b] ± 0.25126	4.0887[bc] ± 0.25578	3.6578 ± 0.32365	4.1933[b] ± 0.27496
Homabay	4.3260[b] ± 0.28514	3.9423[bc] ± 0.18301	3.9198 ± 0.41679	3.8129[b] ±0. 19200
Kendubay	4.5066[b] ± 0.32360	4.2570[c] ± 0.30420	3.8501 ± 0. 28352	3.8913[b] ± 0.43488
Kisii	-	3.5808[b] ± 0.17103	3.0084 ± 0.32398	3.4501[b] ± 0. 19099
Control	2.4291[a] ± 0.18244	2.6399[a] ± 0.09623	2.6995 ± 0.04711	2.5444[a] ± 0.15051

Mean values with different superscripts differ significantly (p<0.05)
Mean value expressed as mean ± SE by Tukey's test.
-no fish

Samples of dried Nile perch from Kendubay had the highest mean $\log_{10}$ CFU/g (4.2570 ± 0.30420). Those from Mbita had the second highest mean CFU/g (4.2121 ± 0.20297), those from Migori had the third highest mean CFU/g (4.0887 ± 0.25578). Samples from Homabay had the fourth highest mean CFU/g (3.9423 ± 0.18301) while samples from Kisii had the lowest mean CFU/g (3.5808 ± 0.17103). Control samples had a lower mean CFU/g (2.6399 ± 0.09623) compared to all the other fish sources (Table 2). There was no significant mean difference between CFU/g of samples obtained from Mbita, Migori, Homabay and Kendubay (p>0.05). However, there was a significant mean difference between mean CFU/g of samples from Mbita and Kisii (p=0.046), Kendubay and Kisii (p=0.034) and between control samples and the samples of Nile perch from the various sources (p<0.001).

Samples of sundried tilapia from Homabay had the highest mean $\log_{10}$ CFU/g (3.9198 ± 0.41679) while those from Kisii had the lowest mean CFU/g (3.0084 ± 0.32398). Samples from Kendubay had the second highest mean CFU/g (3.8501 ± 0. 28352), those from Mbita had the third highest mean CFU/g (3.6601 ± 0.39313) while those from Migori had the fourth highest mean CFU/g (3.6578 ± 0.32365). Control samples had a lower mean CFU/g (2.6995 ± 0.04711) compared to all the other fish sources (Table 2). There was no significant mean difference between CFU/g of samples obtained from different markets (p>0.05). However, there was a significant mean difference between CFU/g of control samples and the samples from different sources (p<0.05).

Sun dried samples of catfish from Migori had the highest mean $\log_{10}$ CFU/g (4.1933 ± 0.27496), samples from Kendubay had the second highest (3.8913 ± 0.43488), Mbita had the third highest (3.8532 ± 0.32809), Homabay had the fourth highest (3.8129 ±0. 19200) while samples from Kisii had the lowest (3.4501 ± 0.19099) mean CFU /g. Control samples had a lower mean CFU/g (2.5444 ± 0.15051) compared to all the other fish sources (Table 2). There was no significant mean difference between CFU/g of samples obtained from different markets (p>0.05). However, there was a significant mean difference between CFU/g of control and the other samples obtained from different sources (p<0.05).

4. DISCUSSION

During this study it was observed that fish for sale was not properly stored and handled. Furthermore, pests such as rats and cockroaches were common in stores where the fish was stored. This could have led to fungal contamination of the fish as reported by [17] and [18] who found out that good storage practices were not observed by most wholesalers of smoked and smoke-dried fish in Nigeria causing fungal contamination. Access to the stored fish by rats and cockroaches could have contributed to fungal fish contamination as reported by [18]. These pests carry fungal spores and hyphae on their bodies from elsewhere into the stores were fish is kept. This is why proper food storage is important in ensuring both food quality and safety. Such contamination during storage can lead to fish spoilage causing huge economic losses and possible illness due to consumption of aflatoxin contaminated fish. It is important for food safety to be ensured by maintaining proper storage conditions for fish and other foods by preventing pests from accessing the storage environment. In this study most fish sellers did not properly dry their fish for sale. High moisture content (above 10%) promotes rapid growth of fungi in food. This can be hazardous if the food is contaminated with mycotoxigenic fungi. [19] have observed that the production of mycotoxins is stimulated by certain environmental factors such as high humidity, temperature, poor aeration and improper drying as was observed during this study. The extent of fish contamination by toxigenic and nontoxigenic fungi differ with geographic location and their susceptibility to the penetration of fungi during storage and processing periods in different weather conditions. This is because fungi are found everywhere and may be transmitted by humans, rodents, insects and animals, resulting in contamination. Moreover, many toxigenic fungi grow more rapidly at temperatures between 15 ºC and 40 ºC and the highest toxin production occurs between 15 ºC and 25 ºC [20] which is characteristic of Kisii county throughout the year. This temperature range is termed as temperature danger zone. Foods and feeds should be handled so that the amount of time the food is in the temperature danger zone is kept to a minimum to minimize multiplication of the fungi [21]. This could be the reason why fish which was not properly dried, handled and was stored for more than a week had more CFU/g of fish.

Most fish sellers displayed and stored their fish using gunny bags. These bags can allow penetration of moisture and easy access of pests into the stored fish. [22] have observed that the type of storage material used affect the aflatoxin levels in stored food especially if stored for a long period of time. Storage materials such as jute bags absorb moisture from the surrounding and this increases the moisture content of the stored food. Other storage materials such as polypropylene and polyethylene bags retain the moisture in the food stored due to poor air circulation within the bags. Since the bags are non-absorbent, they tend to trap heat inside thus encouraging growth of fungi and aflatoxin production specially if the fish are not properly dried before storage [23]. If the fish are stored in polypropylene and polyethylene bags, the bags should be airtight and laced in an airy, dry and clean room [24]. It is therefore important to ensure that stored fish for consumption are kept in storage facilities where moisture content is adequately regulated. The storage room should be maintained dry to minimize absorption of moisture from the surrounding by the stored fish or other foods to discourage fungal growth and reduce aflatoxin contamination. The stored fish should have attained a moisture content of less than 10% to prevent growth of moulds, production of aflatoxins and formation of off-flavors from fungal lipase action and oxidative rancidity [25,26]. Fish sellers should therefore dry their fish as frequently as possible as this will remove any moisture absorbed during storage thus reducing possibility of fungal growth. [27] have observed that sisal bags are better than all the other bags if all the recommended storage conditions are kept and maintained. [28] added that aeration of fish during transportation is also important. During storage effort should be made to prevent moisture migration into the stored fish through leaking roofs and condensation resulting from inadequate ventilation [29,28] as the moisture content of all dried fish samples reported in this study was higher than the recommended 10%. This will ensure maintenance of the quality of fish [30].

The environment where fish was displayed was unhygienic. Furthermore, the packaging materials, means of transportation and materials for displaying fish were all unhygienic. This could have contributed to fish contamination as was also observed by [31] who reported that bad handling conditions during selling and displaying fish on dirty tables was the source of fish contamination. Similar observations were made

by [32] and [33]. Lack of information of good hygiene practices and precautionary measures to observe especially during fish storage could have contributed to fish fungal contamination. [31] also reported that lack of training and low instruction level resulted to non-compliance with good hygiene practices among fish sellers in Ouagadougau markets. Control samples from all the five fish sources in Kisii county had very low CFU/g of fish compared to those that were purchased from the main markets. This was because the control samples were handled and stored hygienically and this resulted in low CFU/g. Fresh fish samples had lower CFU/g compared to dried fish. This concurs with the observation made by [34] who reported lower CFU/g on fresh fish compared to smoke dried fish sold in Oba and Koko markets in Edo and Delta states in different seasons.

The display environment and fish stores should be dry, clean, free from pests and well aerated [35]. They should also ensure that maximum allowable moisture content in dried fish is not exceeded. Strengthening of policy and adherence to proper packaging and storage should also be enforced at all times.

5. CONCLUSION AND RECOMMENDA-TION

Dried and fresh fish sold in Kisii County in Kenya are contaminated with fungi. Transportation, handling, display environment and storage of fish are sources of fungal contamination in fish sold in Kisii County. However, fish transported, handled, displayed and stored hygienically was less contaminated with fungi. This implies that proper transportation, handling, display and storage of fish are very important in reducing fish contamination in Kisii County. The government of Kisii county through the ministry of public health should ensure that the recommended sanitation standard operating procedures (SSOPS) and good hygiene practices (GHP) such as wearing of clean aprons, displaying fish on wooden stands and hygiene of the display environment are maintained at all times through surveillance and constant sensitization.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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