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Prevalence and Characterization of Moulds Associated with Fish Feeds Sold 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 and wrote the protocol and the first draft of the manuscript. Authors EM, ROO and JK managed the analysis of the study and literature searches. All authors read and approved the final manuscript.

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ABSTRACT

There is an increase in aquaculture in Kenya due to increased demand for fish as a source of white meat and increased population growth. Most fish farmers use plant-based ingredients such as peanuts, cottonseed, soybeans, maize bran and wheat as sources of protein for the fish feeds. These ingredients are very susceptible to attack by aflatoxigenic fungi. In humid climatic conditions like those found in Kisii County, growth of such fungi on fish feeds is accelerated due to absorption of moisture from the environment as a result of poor storage and sometimes improper drying. This study was conducted to determine the moulds associated with fish feeds sold in Kisii. Commercial fish feeds from five main outlets in Kisii County were sampled and analysed. Home-made fish feeds were obtained from three groups. Fungi were isolated using various media and percentage isolation

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determined. The results show that fifteen fungal species were associated with fish feeds sold in Kisii County. They include *Mucor* spp, *Penicillium glabrum*, *Fusarium oxysporium*, *Aspergillus oryzae*, *Aspergillus flavus*, *Aspergillus parasiticus*, *Alternaria* spp, *Penicillium citrinum*, *Stachybotrys* spp, *Cladosporium* spp, *Aureobasibium* spp, *Eurotium* spp, *Aspergillus versicolor*, *Aspergillus fumigatus* and *Aspergillus niger*. The aflatoxigenic fungi comprising of *A. flavus*, *A. parasiticus* and *A. niger* were most prevalent in fish feeds obtained from Egetuki outlet (29 %) and least prevalent in Dombetty (16.6 %). The mean differences of fungal species were statistically significant (P<0.05) in four outlets. This shows that fish feeds sold in Kisii county are contaminated with aflatoxigenic fungi.

Keywords: Mould; fish feeds; prevalence; aflatoxigenic fungi; home-made.

1. INTRODUCTION

Fish represent an important source of food for human and animal consumption. This has resulted in fast development of aquaculture [1]. In order to provide quality fish from aquaculture, fish nutrition is very important. The fish must be fed on a nutritionally balanced feed free from mycotoxigenic fungi. This will ensure proper growth, good reproductive performance, quality flesh and healthy fish. The common ingredients of commercial fish and home-made feeds commonly used in Kenya are shown in Table 1. Some of the ingredients used in fish feed production such as maize gluten, groundnut oilcake, sunflower oilcake and soy bean meal are substrates for fungal growth [2]. Under favourable conditions toxigenic fungi grow, multiply and produce mycotoxins during post-harvest storage of fish ingredients or during storage of compounded fish feed [3].

Table 1. Common ingredients of commercial and home-made fish feeds in Kenya

Commercial fish feed ingredients	Home-made fish feed ingredients
Wheat bran	Cassava
Omena fish meal	Spinach
Nile perch fish meal	Shrimp
Groundnut oil cake	Omena
Maize gluten meal	Peas
Rice bran	Carrots
Soybean oil cake	Garlic
Molasses	Vitamin mix
Sunflower seed oil cake	Waste blood
Bone meal	Rumen contents
Meat and bone meal	Kales
Cotton seed cake	Groundnuts
Brewers dried yeast	Soybeans
Gelatin	Maize

Source: [4] and [5]

Studies conducted in some countries have confirmed the presence of moulds in fish feeds, some of which are toxigenic. They include [6] who isolated *Fusarium oxysporium* and *Mucor* species from fish feeds in Nigeria, [7] isolated toxigenic *Aspergillus flavus*, *Aspergillus niger*, *Penicillium* species and *Aspergillus niger* from finished fish feeds from farms in Rio de Janeiro in Brazil. In Egypt, [8] isolated *Aspergillus* species, *Penicillium* species, *Fusarium* species and *Alternaria* species from fish feeds, [9] isolated *Fusarium* species, *Mucor* species, *Alternaria* species and nine different species of *Aspergillus* from fish feeds in Iran, [10] isolated *Cladosporium* species, *Eurotium* and four different species of *Penicillium* from rainbow trout feeds in Argentina while [11] isolated *Aspergillus flavus* and *Fusarium* species from tilapia feeds in Mexico. A number of moulds were isolated from finished fish feeds and fish feed ingredients from small holder farms in East Africa [12] while [13] isolated *Aspergillus* species, *Mucor* species, *Rhizopus* species, *Saprolegnia* species and *Penicillium* species from formulated and commercial feeds in three fish farms in humid tropical environments of Kenya.

The presence of aflatoxigenic fungi such as *Aspergillus flavus*, *Aspergillus parasiticus* and *Aspergillus niger* in fish feeds is an indication that fish that consume such feed will accumulate the aflatoxins which will be hazardous to them and humans who consume them [14]. It is therefore important to monitor and do surveillance of such fungi in fish feeds in order to avert negative health effects that could arise from consumption of such contaminated fish feeds. This study was conducted to determine the prevalence and type of moulds associated with fish feeds 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 is located to the South East of Lake Victoria and

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 [16]. 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 month of May has the highest humidity of 76 % while February has the lowest humidity of 61 %. The temperature of Kisii County ranges from 18.5-28 ºC [17] and [18]. It has five main commercial fish feed outlets and three main home-made fish feed producers. The fish feeds in the commercial fish feed outlets are packed in 5, 10, 25 and 50 Kg gunny bags. They are usually place on the floor or wooden stands that are very close to the floor, and staked up. The home-made producers pack the feeds in 1, 2, 5, 10, 25 and 50 Kg gunny bags staked up.

2.2 Materials

The materials that were used during this study include; sterile bags, labels, blender, petri-dishes, Czapek Dox agar, *Aspergillus flavus* and *parasiticus* agar, microscope, microscope slides, microscope slide cover slips, glass rods, droppers, lactophenol cotton blue bye, camera and fish feed samples.

2.3 Methods

2.3.1 Sample collection

Four five-kilogram (Kg) bags of commercial fish feeds were purchased from each of the five main fish feed outlets in Kisii County namely Dombetty enterprises, Egetuki aquashop, Zamo enterprises, Enochem enterprises and Jumbo enterprises. Another set comprising of home-made fish feed samples were obtained from Obomo, JuaKali and Mwanyagetinge self-help groups which are the main producers of home-made fish feeds in the county. Samples of half kilogram were obtained from the top, middle and bottom layers of each bag of commercial and home-made fish feeds, mixed well in separate sterile bags and labelled. These formed composite samples of 6 Kg from each outlet and home-made producer. The samples were transported to the Pathology Laboratory in Kenya Agricultural and Livestock Research Organization (KALRO) Kisii for mycological assay.

2.3.2 Enumeration, isolation and identification of fungal isolates

Mycological assays that were used include; enumeration of fungal colony forming units (CFUs), isolation and identification which largely involved microscopy. Enumeration was done according to the protocol by [19]. Fish feed samples were ground in a blender and 10 grams of each sample was homogenized in 90 ml of distilled water. Serial dilutions of 10^{-2} to 10^{-4} were made and 0.1ml aliquots spread plated in triplicates onto Sabourand Dextrose Agar (SDA) for quantifying and detecting moulds in the ground fish feed samples. The plates were incubated at 25 ºC for 5 to 7 days. Those with colonies between 30 and 300 were enumerated in form of colony forming units (CFU) [20]. 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.

From the fungal growth on primary cultures, fungal isolates were sub-cultured using a plug that was taken from the periphery of fungal cultures and placed onto fresh media of SDA to get distinct colonies. The obtained pure isolates were then stored in the dark at 25 ^{o}C until fruiting structures formed for further identification [21]. Czapak Dox and *Aspergillus flavus* and *Parasiticus* agar (AFPA) were used to differentiate the colonies of *Aspergillus flavus* and *Aspergillus parasiticus*. Taxonomic identification of the various moulds was carried out according to macro and microscopic characteristics of the colonies using identification keys by [22,19,23,24]. Morphological features of *Aspergillus* cultures were studied, the major and remarkable macroscopic features in species identification were the colony diameter, colour (conidia and reverse), exudates and colony texture. Slide culture method for microscopic study of most of the isolates was also carried out. When the mould sporulated, the cover slip was carefully withdrawn from the agar and mounted in a drop of lactophenol cotton blue dye on a microscope slide. Microscopic characteristics used for identification were conidial heads, stipes, colour, vesicles shape and seriation, metula covering, conidia shape and roughness.

2.4 Data Analysis

Percentage isolation of various fungi was calculated and T-test performed.

3. RESULTS AND DISCUSSION

A total of three hundred and thirty-two isolates were obtained from samples purchased from five main fish feed outlets in Kisii County. These comprised of fifteen fungal species namely; *Mucor* spp, *Penicillium glabrum*, *Fusarium oxysporium*, *Aspergillus oryzae*, *Aspergillus flavus*, *Aspergillus parasiticus*, *Alternaria* spp, *Penicillium citrinum*, *Stachybotrys* spp, *Cladosporium* spp, *Aureobasibium* spp, *Eurotium* spp, *Aspergillus versicolor*, *Aspergillus fumigatus* and *Aspergillus niger*. From home-made fish feeds a total of one hundred and twenty-eight fungal isolates comprising of eight different fungal species were obtained. In total four hundred and sixty isolates were obtained from both commercial and home-made fish feeds. Moisture content of commercial fish feeds ranged between 10.2-22.0 % while that of home-made feeds ranged between 14.0-28.6 %.

One hundred and twenty-two isolates were obtained from samples purchased from Egetuki aquashop. These isolates comprised of thirteen fungal species which were *Mucor* spp 12 (9.8 %), *Fusarium oxysporium* 14 (11.5 %), *Aspergillus oryzae* 4 (3.3 %), *Aspergillus flavus* 16 (13.1 %), *Aspergillus parasiticus* 6 (4.9 %), *Alternaria* spp 10 (8.2 %), *Penicillium citrinum* 16 (13.1 %), *Cladosporium* spp 2 (1.6 %), *Aureobasidium* spp 6 (4.9 %), *Eurotium* spp 8 (6.6 %), *Aspergillus versicolor* 10 (8.2 %), *Aspergillus fumigatus* 6 (4.9 %) and *Aspergillus niger* 14 (11.5 %). *Penicillium citrinum* and *Aspergillus flavus* (13.1 %) were the most frequently isolated fungi while *Aspergillus oryzae* (3.3 %) was the least isolated (Fig. 1).

Sixty isolates were obtained from samples purchased from Dombetty enterprises. The samples comprised of nine fungal species which were *Mucor* spp 10 (16.7 %), *Penicillium glabrum* 6 (10 %), *Fusarium oxysporium* 4 (6.7 %), *Aspergillus flavus* 8 (13.3 %), *Aspergillus parasiticus* 2 (3.3 %), *Alternaria* spp 10 (16.7 %), *Penicillium citrinum* 8 (13.3 %), *Stachybotrys* spp 4 (6.7 %) and *Aspergillus versicolor* 8 (13.3 %). *Mucor* spp and *Alternaria* were the most frequently isolated from this outlet while *Aspergillus parasiticus* was the least isolated (Fig. 2).

The isolates obtained from Enochem enterprises were fifty-six in number. They comprised of eleven fungal species which were *Mucor* spp 6 (10.7 %), *Fusarium oxysporium* 4 (7.1 %), *Aspergillus oryzae* 4 (7.1 %), *Aspergillus flavus* 6 (10.7 %), *Alternaria* spp 4 (7.1 %), *Penicillium citrinum* 2 (3.6 %), *Stachybotrys* spp 4 (7.1 %), *Cladosporium* spp 6 (10.7 %), *Aspergillus versicolor* 4 (7.1 %), *Aspergillus fumigatus* 8 (14.3 %) and *Aspergillus niger* 8 (14.3 %). *Aspergillus fumigatus* and *Aspergillus niger* were the most frequently isolated from sample purchased from Enochem enterprises. *Penicillium citrinum* was the least frequently isolated followed by *Fusarium oxysporium*, *Aspergillus oryzae*, *Alternaria* spp, *Stachybotrys* and *Aspergillus versicolor* all of which represented 7.1 % of the total isolates obtained from this outlet (Fig. 3).

Fifty isolates were obtained from samples purchased from Jumbo enterprises. These isolates comprised of eleven fungal species which were *Mucor* 2 (4.0 %), *Penicillium glabrum* 6 (12.0 %), *Fusarium oxysporium* 8 (16.0 %), *Aspergillus flavus* 4 (8.0 %), *Aspergillus parasiticus* 2 (4.0 %), *Penicillium citrinum* 6 (12.0 %), *Cladosporium* spp 4 (8.0 %), *Eurotium* spp 2 (4.0 %), *Aspergillus versicolor* 8 (16.0 %), *Aspergillus fumigatus* 4 (8.0 %) and *Aspergillus niger* 4 (8.0 %). The isolates of *Fusarium oxysporium* and *Aspergillus versicolor* were the most frequently isolated while *Mucor* spp, *Eurotium* spp and *Aspergillus parasiticus* were the least frequently isolated from sample obtained from Jumbo enterprises. *Penicillium glabrum* and *Penicillum citrinum* were the second most frequently isolated (Table 2).

Table 2. Isolation frequency of fungal species obtained from Jumbo enterprises

Fungi	No. of isolates	% isolation frequency
Mucor spp	2	4
Penicillium glabrum	6	12
Fusarium oxysporium	8	16
Aspergillus flavus	4	8
Aspergillus parasiticus	2	4
Penicillium citrinum	6	12
Cladosporium spp	4	8
Eurotium spp	2	4
Aspergillus versicolor	8	16
Aspergillus fumigatus	4	8
Aspergillus niger	4	8
Total isolates	50	100

Fish feed samples purchased from Zamo enterprises had the least number of fungal isolates which was forty-four. The isolates comprised of eight fungal species which were

Mucor spp 6 (13.6 %), *Fusarium oxysporium* 6 (13.6 %), *Aspergillus oryzae* 2 (4.5 %), *Aspergillus flavus* 8 (18.2 %), *Penicillium citrinum* 12 (27.4 %), *Aureobasidium* spp 4 (9.1 %), *Aspergillus fumigatus* 2 (4.5 %) and *Aspergillus niger* 4 (9.1 %). *Penicillium citrinum* (27.4 %) was the most frequently isolated fungus from this outlet while *Aspergillus oryzae* and *Aspergillus fumigatus* (4.5 %) were the least frequently isolated (Fig. 4).

From the five main fish feed outlets *Penicillium citrinum* had the highest percentage isolation frequency of 13.3 % followed by *Aspergillus flavus* with 12.7 %, then *Mucor* spp and *Fusarium oxysporium* which had an isolation frequency of 10.8 % each. *Mucor* spp, *Fusarium oxysporium*, *Penicillium citrinum* and *Aspergillus flavus* were isolated from samples purchased from all the outlets as shown in Table 3. Most fungi were isolated from samples that were purchased from Egetuki aquashop. Thirteen different fungal species out of the fifteen different fungal species isolated from all fish feeds purchased from the five outlets were isolated from Egetuki aquashop samples. Samples from Zamo enterprises recorded the least numbers of both fungal species and fungal isolates (Table 3).

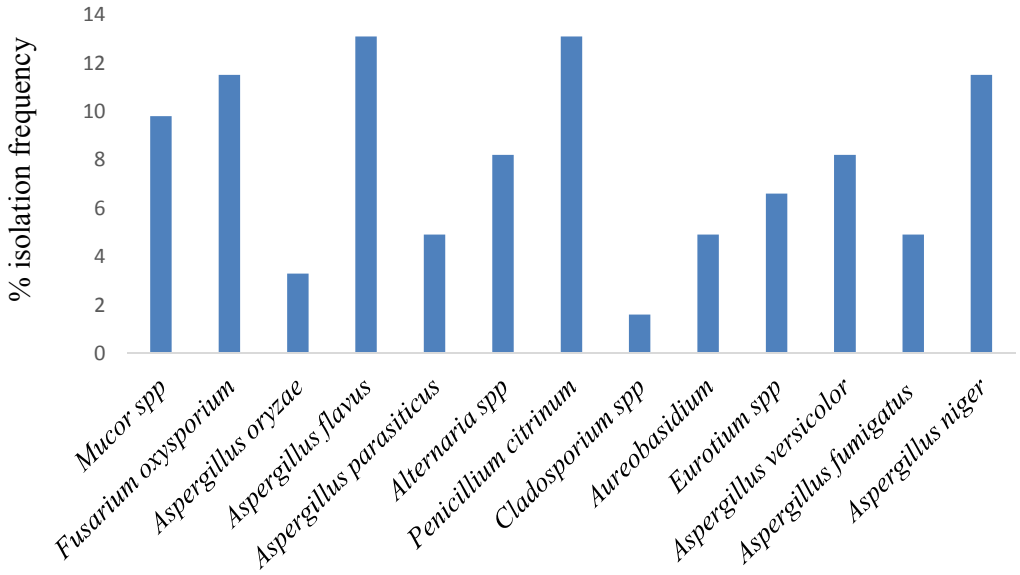

Fig. 1. Isolation frequency of fungal species obtained from Egetuki aquashop

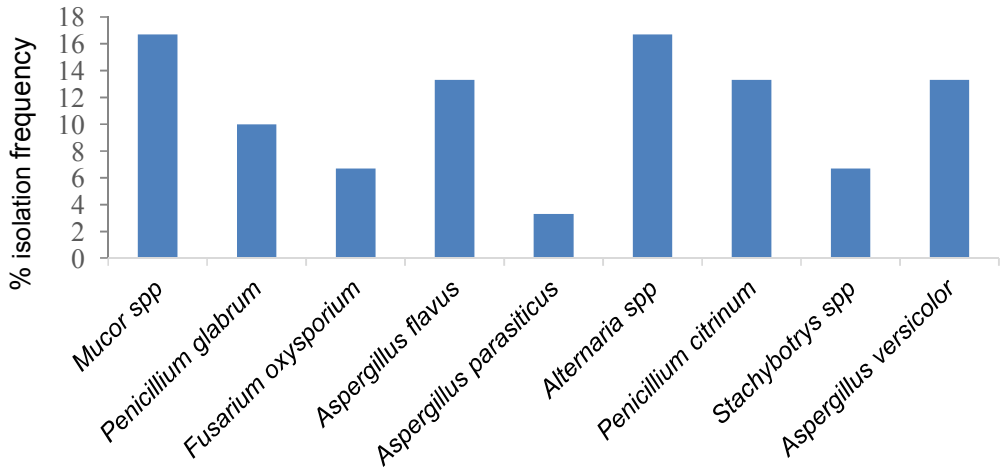

Fig. 2. Isolation frequency of fungal species from Dombetty enterprises

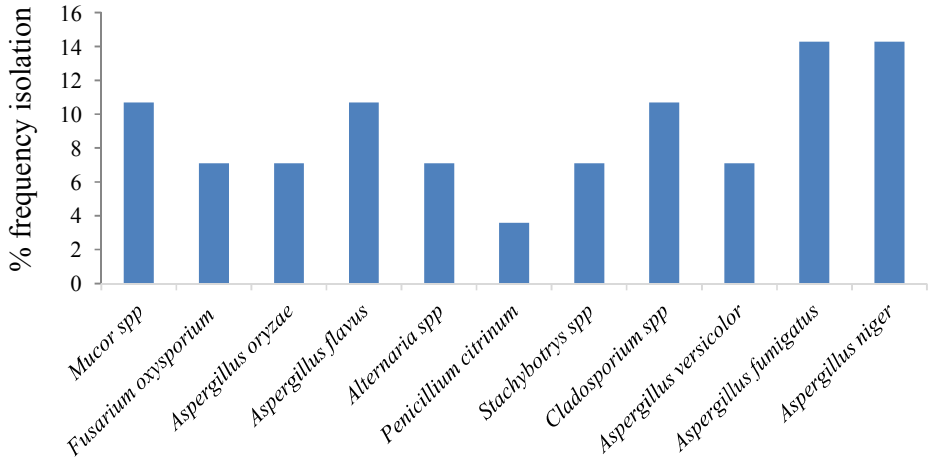

Fig. 3. Isolation frequency of fungal species obtained from Enochem enterprises

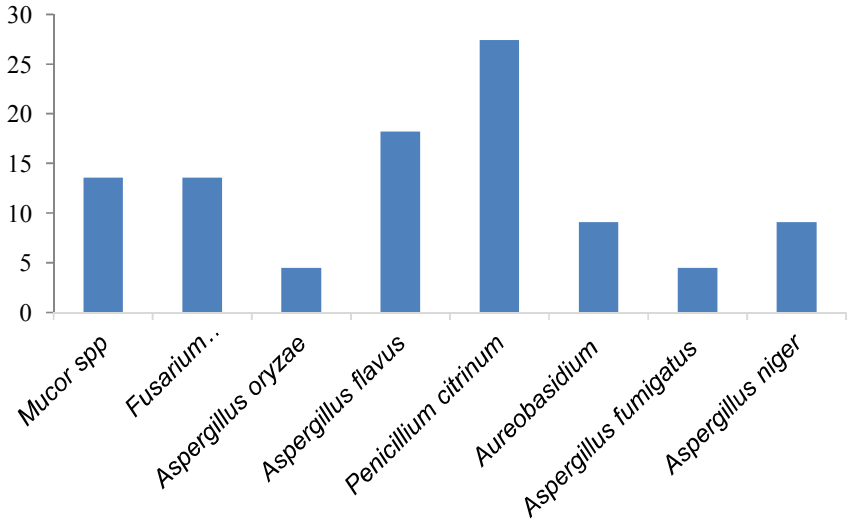

Fig. 4. Isolation frequency of fungal species obtained from Zamo enterprises

The aflatoxigenic fungi comprising of *A. flavus*, *A. parasiticus* and *A. niger* were most prevalent in fish feeds obtained from Egetuki outlet (29.5 %) followed by Zamo (27.3 %), Enochem (25.0 %), Jumbo (20.0 %) while Dombetty had the least prevalence (16.6 %) (Table 4). The mean differences of fungal species were statistically significant in all the outlets except those from Egetuki aquashop (*P*=0.42). The *P*-values for the other outlets were Dombetty enterprise (*P*=0.02), Zamo enterprises (*P*=0.04), Enochem Enterprises (*P*=0.003) and Jumbo (*P*=0.007).

A total of one hundred and twenty-eight fungal isolates were obtained from samples of home-made fish feeds. The samples were obtained from three main home-made fish feed producers (Obomo, JuaKali and Mwanyagetinge self-help group) in Kisii county. The fungal isolates obtained were from eight different fungal species namely, *Trichoderma* species 10 (7.8 %), R*hizopus* species 30 (23.4 %), *Penicillium* species 16 (12.5 %), *Fusarium* species 8 (6.3 %), *Aspergillus niger* 8 (6.3 %), *Aspergillus flavus* 20 (15.6 %), *Cladosporium* species 20 (15.6 %) and *Aureobasidium* spp 16 (12.5 %) (Table 5).

The aflatoxigenic fungi isolated from the home-made feeds were *A. flavus* and *A. niger* while F*usarium* and *Penicillium* species produce

mycotoxins. All these species represented 50 % of all fungal species isolated from home-made feeds. There was a significant difference between the means of the different fungal species isolated from the home-made feeds (P= 0.008). However, there was no significant difference between the percentage isolation frequencies of fungi in home-made and commercial fish feeds (P=0.46).

Fifteen fungal species were isolated from both commercial and home-made fish feeds. The most frequently isolated fungus from the commercial fish feeds was *Penicillium citrinum* (13.3 %), followed by *Aspergillus flavus* which had a frequency of 12.7 %. The least isolated were *Stachybotrys* spp and *Aspergillus parasiticus*. The most isolated fungus from home-made feeds was *Rhizopus* spp (23.4 %) while the least isolated were *Fusarium* spp and *Aspergillus niger* (6.3 %). *Rhizopus* spp was most frequently isolated probably due to their ubiquitous and saprophytic nature. They are commonly found in soil, rotting vegetation and excrement of animals. Some species are plant pathogens and agents of diseases in humans and animals as observed by [25] and [26]. This finding is not in agreement with that reported by

Table 3. Isolation frequency of fungal species from commercial fish feeds

Fungi	Egetuki	Dombetty	Zamo	Enochem	Jumbo	% frequency
Mucor spp	12	10	6	6	2	10.8
P. glabrum	0	6	0	0	6	3.6
F. oxysporium	14	4	6	4	8	10.8
A. oryzae	4	0	2	4	0	3.0
A. flavus	16	8	8	6	4	12.7
A. parasiticus	6	2	0	0	2	2.5
Alternaria sp	10	10	0	4	0	7.2
P. citrinum	16	8	12	2	6	13.3
Stachybotrys sp	0	4	0	4	0	2.5
Cladosporium sp	2	0	0	6	4	3.6
Aureobasidium sp	6	0	4	0	0	3.0
Eurotium sp	8	0	0	0	2	3.0
A. versicolor	10	8	0	4	8	9.0
A. fumigatus	6	0	2	8	4	6.0
A. niger	14	0	4	8	4	9.0
Total	**124**	**60**	**44**	**56**	**50**	**100**

Table 4. Isolation frequency of aflatoxigenic fungi from commercial fish feed outlets

Commercial fish feed outlet	Mould			% isolation frequency
	A. flavus	***A. parasiticus***	***A. niger***	
Egetuki Aquashop	13.1	4.9	11.5	29.5
Dombetty Enterprises	13.3	3.3	-	16.6
Zamo Enterprises	18.2	-	9.1	27.3
Enochem Enterprises	10.7	14.3	-	25.0
Jumbo Enterprises	8.0	4.0	8.0	20.0

Table 5. Percentage frequency of fungal isolates from home-made fish feeds

Fungal species	Occurrence	% frequency
Trichoderma spp	10	7.8
Rhizopus spp	30	23.4
Penicillium spp	16	12.5
Fusarium spp	8	6.3
Aspergillus niger	8	6.3
Aspergillus flavus	20	15.6
Cladosporium spp	20	15.6
Aureobasidium spp	16	12.5
Total isolates	**128**	**100**

[27] who found out that the most frequently isolated fungus from trout feed from the province of Rio Negro and Neuquen in Argentina was *Eurotium* (25 %) followed by *Penicillium* spp (21.4 %) while the least isolated was *Aspergillus* spp (3.6 %). Furthermore, [7] found out that *Cladosporium* species (85 %) were the most frequently isolated while *Aspergillus* and *Penicillium* species had an isolation frequency of 68 % and 60 % respectively from finished fish feeds from farms in Rio de Janeiro state in Brazil. This also did not concur with the findings of this study. The contamination of fish feeds by fungi could be due to the use of plant-based ingredients such as grains, tubers and leaves contaminated with fungi as was observed by [8]. [27] also observed that raw materials used in production of animal feed are usually the source of fungi and mycotoxins in feeds. Another possible cause of contamination of the fish feeds could be exposure to high humidity level of more than 65 %. This accelerates fungal growth in the feeds as observed by [28]. Such humidity is characteristic of Kisii County in most of the months of the year.

The isolation frequency of *Aspergillus flavus* was predominantly higher in most samples. This was also reported by [7] who observed that the most frequently isolated fungus from trout fish feeds was *A. flavus* (60.66 %) followed by *Penicillium* spp. This high prevalence of toxigenic fungi raises a lot of concern on the safety of both humans and animals consuming the feed contaminated with such fungi directly for the fish and indirectly for humans. [14] have observed that fungal contamination is commonly caused by use of infected ingredients, improper drying and storage of feed and fish. [14] further adds that food and feed contamination is usually due to poor quality of raw materials and poor manufacturing practices or both. The growth of fungi in raw materials for feed manufacturing affect the feed's nutritional quality. Lack of proper feed preservation can also cause fungal contamination. Feed should therefore be properly stored and preserved to minimize contamination. Proper drying of feed should also be encouraged as it lowers the water activity in the feed thus inhibiting fungal growth. As observed by [29], improper drying, poor storage conditions such as high moisture content, make stored food and feed susceptible to fungal and consequently aflatoxin contamination. This could be the reason why the fish feed samples investigated in this study were contaminated with fungi.

All fish feeds (100 %) had moisture content of above 10 %, had high CFUs and were not properly stored. This concurs with the findings by [30] who found out that moisture levels in feeds above 14 % and improper storage favoured the growth of aflatoxin producing moulds. When such feeds are stored improperly and for long, the growth of fungi in them is accelerated. The high moisture content could be due to absorption of moisture from the atmosphere during the two rainy seasons of the year when atmospheric humidity increases to 76 %. As observed by [30], such humidity levels that are greater than 62 % favour growth of moulds and aflatoxin production. When exposed to the atmosphere for long, the feeds absorb moisture from the surrounding affirms [31]. This is probably why the sampled fish feed had high moisture content and presence of fungi.

Proper feed storage is important in ensuring both feed quality and safety. This is because improperly stored feed can lead to spoilage causing huge economic losses. It is important that feed safety be ensured by maintaining proper storage conditions for fish feeds. [32] have observed that certain environmental factors such as high humidity, temperature and poor aeration result in increased contamination of stored feeds by fungi. The extent of contamination by fungi will also differ with geographic location and the susceptibility of commodities 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, observed [25]. Moreover, many fungi grow more rapidly at temperatures between 15 ºC and 40 ºC. 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, the [33] advised.

Both commercial and home-made fish feeds were packed in gunny bags. This could have contributed to both fungal contamination and high moisture content of the feeds. [34] have observed that the type of storage material used affect the aflatoxin levels in the stored feed especially if they were stored for a long period of time with moisture content above 10 %. Storage materials such as jute bags absorb moisture from the surrounding and this increases the moisture content of the stored feed or food. Other storage

materials such as polypropylene and polyethylene bags retain the moisture in the feed and 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 feed is not properly dried before storage as observed by [35]. If the fish feeds are stored in polypropylene and polyethylene bags, the bags should be airtight and laced in an airy, dry and clean room as reported by [36]. It is therefore important to ensure that stored fish feeds 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 food or feed to discourage fungal growth and reduce aflatoxin contamination. The stored fish feeds should have attained a moisture content of less than 10 % to prevent growth of moulds, production of aflatoxins and formation of off-flavours from fungal lipase action and oxidative rancidity as observed by [37,38], have also observed that sisal bags are better than all the other bags if all the recommended storage conditions are kept and maintained. Aeration of feeds during transportation is also important as reported by [39].

During storage of feeds effort should be made to prevent moisture migration into the stored feed through leaking roofs and condensation resulting from inadequate ventilation as reported by [40]. This will ensure maintenance of the quality of feeds and reduced risk of fungal and consequently aflatoxin contamination as reported by [41]. The government of Kenya should also ensure that the established maximum allowable aflatoxin levels in feeds is enforced both at the national and especially the county level. Cheap and simple aflatoxin analysis methods such as ELISA can be used for frequent surveillance of aflatoxin levels in foods and feeds. Strengthening of policy and adherence to proper packaging and storage should be enforced at all times.

4. CONCLUSION

The fish feeds sold in Kisii County are contaminated with moulds. These moulds include mycotoxin producing species such as *Aspergillus flavus*, *Aspergillus parasiticus*, *Aspergillus niger*, *Fusarium* and *Alternaria*. Other moulds associated with fish feeds sold in kisii County are *Mucor* spp, *P. glabrum*, *F. oxysporium*, *A. oryzae*, *P. citrinum*, *Stachybotrys* spp, *Cladosporium* spp, *Aureobasidium* spp, *Eurotium* spp, *A. versicolor* and *A. fumigatus*. This contamination could be due to use of mould contaminated ingredients. The presence of mycotoxigenic moulds in the fish feeds poses a health risk to both fish and consumers of fish fed on the contaminated feeds. There is therefore need for frequent detection of mycotoxigenic moulds in fish feeds and sensitization on ways of minimizing mould contamination and proper storage of fish feeds.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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