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Mycotoxin Contamination Risks Due to Handling Practices of Indigenous Chicken Feeds in Kenya

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Authors' contributions

This work was carried out in collaboration among all authors. Author NOO performed the statistical analysis, wrote the protocol, managed the literature searches and wrote the first draft of the manuscript. Authors HAR, JOO and LSG designed the study, managed the analyses and supervised this work. All authors read and approved the final manuscript.

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ABSTRACT

Aim: Mycotoxins are prevalent in animal feeds and agricultural products. These toxins are produced by fungi and once incorporated in the substrate, are not easy to eradicate. They are associated with morbidity and mortality in both livestock and humans. Avoiding contamination is the preferred way of mitigating mycotoxins in livestock feeds and cereals.
Study Design: A purposive multiple-stage survey design was used in this study.
Place and Duration of Study: Between February and March 2016 to assess factors that exacerbate mycotoxins due to feed type and handling practice by smallholder farmers in farmer groups keeping indigenous chicken in Western Kenya.
Methodology: Three counties Siaya, Busia and Kakamega of Kenya were selected based on the population of indigenous chicken. Semi-structured questionnaires were used in gathering data on feed types, handling practices and mycotoxins awareness from 180 farmers in women and youth groups.
Results: Common feed types identified included maize (96%), sorghum (54%), cassava (42%), millet (40%), homemade rations (16%), while 44% used commercial feeds. It was noted that 38%

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use rotten, insect-infested, unsorted and broken cereals and 62% clean cereals as feeds. For storage, 85% and 7% of farmers were using polypropylene and hermetic bags, respectively; 97% dried their grains/feeds on a platform; 21% were not sorting their grains and 17% were not using grain preservatives during storage. Mycotoxin awareness levels were assessed among farmers. Approximately 44% of farmers were unaware of feed safety while 71% were aware of mycotoxins; however, 73% of participants were unaware of dangers posed by mycotoxin contamination in feeds.

Conclusion: Information to farmers on mycotoxin and proper feed and cereals handling and storage practices is necessary for mycotoxin management. Therefore, avoiding contamination is a preferred method of mitigating mycotoxins in indigenous chicken feeds and cereals.

Keywords: Mycotoxins; indigenous chicken feeds; feed handling practices; mycotoxins awareness.

1. INTRODUCTION

Smallholder indigenous chicken farmers depend primarily on plant-based feeds in their production. However, indigenous chicken production is characterized by inadequate and poor quality feeds [1], that may be associated with poor handling practices and storage practices [2]. The feeds may contain pathogenic fungal species that compromise quality by reducing nutrient content, dry matter and causing a sour flavor. These pathogenic fungal species may produce mycotoxins that can lead to mortality of animals that ingest these feeds [3]. Some of these toxins, for example, aflatoxins and fumonisins as well as fungi responsible for their production have been reported in cereals from several parts of Kenya [4].

Mycotoxins are low molecular weight secondary metabolites of saprophytic fungi that grow on substrates [5]. Mycotoxin production can take place when conducive conditions are in place for fungal growth in crops or crop products in the field, at harvest, during transportation, processing stages or storage [3]. The favourable conditions that govern the formation of mycotoxins in feeds include temperature, humidity, nutrient status, hydrogen ion concentration, among others [6]. The hot and humid climatic conditions experienced in Eastern Africa favor mycotoxin production [7].

Among mycotoxins, aflatoxin is the most important from a public health perspective, and produced mainly by toxigenic strains of *Aspergillus* and other related species [8]. Aflatoxins exposure to human beings and animals is mainly through food and feed intake. In human, they cause chronic and acute toxicity, mutagenicity, teratogenicity, carcinogenicity, genotoxicity and immune-suppression [9]. Among animals, poultry is known to be the most sensitive to aflatoxin B_1 even in small amounts [10]. Even though poultry does not have a longer life span to allow for the development of cancer, disorders related to aflatoxin B_1 can negatively affect their health [11].

Mitigation of mycotoxins contamination of feeds and cereals can be done at farm level. Proper handling and storage practices can assist in the prevention of mycotoxin accumulation in feeds and agricultural products. Other mitigation measures include awareness creation on sources of mycotoxins contamination and health risks associated with mycotoxins [12]. This study explored the extent to which indigenous chicken farmers were adopting proper chicken feed handling and management practices that are known to prevent mycotoxins contamination challenge in chicken feed in the counties of Busia, Kakamega and Busia, Kenya. This study will be of value to farmers in the sense that it will alert them on mycotoxins contamination risk areas, leading to better management practices.

2. MATERIALS AND METHODS

2.1 Study Location

This study was conducted between February and March of 2016, covering three counties in Kenya namely; Busia (Teso South, Matoyos and Nambale sub-counties), Kakamega (Lurambi, Navakholo and Lugari sub-counties) and Siaya (Gem, Alego and Ugenya sub-counties), their geo climatic patterns are presented in Table 1.

2.2 Study Design

A survey involved 180 indigenous chicken farmers from three counties. In each county, 60 farmers were selected; in each of the nine sub-counties, 20 farmers were selected for this study.

Table 1. Geo-climatic locations, rainfall patterns and altitudes where chicken feed samples were collected in a regional survey of Kenya in 2016

County	Sub-county	AEZ	Sampling hub	Altitude (masl)	Rainfall (mm)
Busia	Matayos	Sub-humid	Bosibwabo	1200-1440	1650-2000
Busia	Matayos	Sub-humid	Nang'oma	1200-1440	1650-2000
Busia	Nambale	Humid	Bukhayo Central	1200-1440	1650-2000
Busia	Nambale	Humid	Bukhayo East	1200-1440	1650-2000
Busia	Teso South	Sub-humid	Amakura Central	1200-1350	1550-1800
Busia	Teso South	Sub-humid	Amakura East	1200-1350	1550-1800
Kakamega	Lugari	Sub-humid	Chevaywa	1300-1500	1500-1850
Kakamega	Lugari	Sub-humid	Mautuma	1500-1900	1000-1600
Kakamega	Lurambi	Humid	East Butsotso	1300-1500	1800-2000
Kakamega	Lurambi	Humid	South Butsotso	1300-1500	1800-2000
Kakamega	Navakholo	Humid	Bunyala East	1300-1500	1800-2000
Kakamega	Navakholo	Humid	Ingotse Matiha	1300-1500	1650-1850
Siaya	Alego Usonga	Sub-humid	Karemo	1200-1350	1450-1600
Siaya	Alego Usonga	Sub-humid	Usonga	1200-1350	1450-1600
Siaya	Gem	Humid	Yala	1300-1500	1300-1500
Siaya	Gem	Sub-humid	Wagai	1200-1350	1450-1600
Siaya	Ugenya	Sub-humid	Ukwala	1200-1350	1450-1600
Siaya	Ugenya	Humid	Sihayi	1300-1500	1300-1500

Meters above sea level (masl)
All regions experience two rainfall/crop seasons per year (bimodal)
Source: [16,17]

The three-point multiple-stage sampling design was used in the study [13]. First, purposively selecting counties because they are within agro-ecological zones experiencing warm and humid weather conditions that promote mould growth and subsequent mycotoxins production [14]. Secondly, three sub-counties were purposively selected based on the number of farmer groups involved in indigenous chicken production and activity of the groups. Third, random sampling was used in selecting indigenous chicken farmers in the four selected farmer groups per sub-county with the guidance of county front-line extension officers. Only youth and women groups keeping indigenous chicken were sampled for this survey because chicken are mainly reared by youths and women [15]. In each group, five farmers were randomly selected for an interview. Together with trained enumerators and county front-line extension officers, semi-structured questionnaires were used in the survey on indigenous chicken feeds. Data were collected on the following: Types of feeds, feed handling practices and knowledge on mycotoxins.

2.3 Data Analysis

Data obtained were analyzed using general descriptive statistics using Statistical Package for Social Sciences (SPSS) version 20 and MS Excel 2016.

3. RESULTS

3.1 Types of Feeds

Farmers from the three counties used plant-based feeds such as maize (96%), sorghum (54%), cassava (42%), millet (40%), homemade rations (16%) while some used commercial feeds (44%) as feeds for their indigenous chicken (Table 2). Other types of feeds used to a lesser extent common proportion (less than 10% of farmers) included brewers' waste, sweet potato, *posho* mill waste, sesame, cotton seed cake, eggshell, rice bran, wheat bran, maize bran, flour, sunflower seed cake, wheat pollard and pellets.

3.2 Feed Handling and Storage Practices

3.2.1 Grain health/condition

Even though most farmers were using either clean grains as feed, some were using insect-infested or rotten grains. For instance, 38% of farmers used rotten, insect-infested, unsorted and broken maize grain as feeds, while 62% used clean maize as feeds (Table 3).

Table 2. Chicken feeds used by indigenous chicken farmers in three counties of Kenya

Feed types (%)	Total (N=180)	Counties		
		Siaya (N=60)	Busia (N=60)	Kakamega (N=60)
Maize	96	98	92	98
Sorghum	54	88	45	28
Millet	40	25	53	42
Cassava	42	45	68	11
Peanuts	18	38	8	8
Ugali (corn bread)	96	92	98	97
Soya bean	10	10	8	11
Beans	4	8	5	0
Home-made ration	16	23	18	7
Brewers waste	6	8	7	3
Vegetables	17	15	10	27
Sweet potatoes	7	0	0	22
Posho mill waste	5	2	8	5
Cotton seed cake	1	0	2	0
Sunflower seed cake	1	2	0	2
Rice bran	8	17	3	5
Wheat bran	8	17	3	5
Flour	1	2	2	0
Wheat pollard	1	2	0	0
Commercial	44	48	27	57

N represents the number of farmers interviewed. The values represent the proportion of interviewed farmers in percentages and multiple responses were allowed

3.2.2 Feed storage methods

Feed storage in all three counties was almost comparable; the commonly used storage method across the three counties was polypropylene bags in the houses with 85% of the farmers using this method while 7% used hermetic (airtight) bags. Only a few farmers used buckets (2%), traditional granaries (1%) and polythene bags (1%) for storage (Table 3).

3.2.3 Sorting

Sorting was another postharvest handling activity practiced by farmers in all three counties. Sorting of maize was done manually by picking out infected and physically damaged grains mainly based on physical damage, size, coloration and mould infestation. While sorting of grains such as millet and sorghum was done by winnowing. Farmers sorted their produce (79%) before shelling, after which they were adequately dried (Table 3).

3.2.4 Drying of grains

Drying of plant-based feed materials under the sun was mainly done on polythene or mat in the three counties as opposed to bare ground and on cemented floors. Most of the farmers who used plant-based feeds dried their farm threshed grains on either mat or polythene paper (97%) and 3% dry the plant-based feeds on the bare ground (Table 3). However, some farmers dried maize cobs on bare ground where they would do the sorting.

3.2.5 Grain preservation methods against storage pests

Grains ready for storage, mostly maize and sorghum, were treated against storage pests before introduction into the storage facilities; in contrast, cassava and millet were notably stored without any preservatives. Among the farmers, most common preservatives used were chemical pesticides, specifically actelic (pirimiphos-methyl) at 48% (Table 3) and in most cases; it was applied once during the storage period. Furthermore, 14% of the farmers applied ash as traditional protectants, while 4% of farmers applied a combination of preservative methods during the maize grains storage, for instance, re-drying and ash, actelic and hermetic bags. Despite the various methods of preservation at the disposal of the farmers, 17% of the farmers used no preservatives during the storage periods.

Table 3. Feed handling practices used by 180 indigenous chicken farmers in the three counties of Kenya

Characteristics	Overall (N=180)	Counties		
		Siaya (N=60)	Busia (N=60)	Kakamega (N=60)
Storage (%)				
Polypropylene bag	88	95	78	90
Hermetic	7	3	11	7
Traditional granary	1	0	2	2
Bucket	2	2	5	0
Polythene bag	1	0	2	0
Modern store	1	0	0	2
No packaging	1	0	2	0
Grain health (%)				
Clean	62	58	62	68
Rotten/broken/ insect infested	38	42	38	32
Drying (%)				
Dry on a mat/polythene	97	93	100	100
Dry on ground	3	7	0	0
Sorting (%)				
Sorting prior to storage	79	88	76	73
No sorting prior to storage	21	12	24	27
Preservation (%)				
Actelic	48	32	47	64
Hermetic bag	6	3	9	9
Ash	8	22	2	0
Actelic/ash	2	5	0	0
Hermetic bag/ actelic	1	0		2
Hermetic bag/ ash	1	0	2	0
Re-drying	1	0	4	0
Airtight bucket	1	0	2	2
From the market	17	8	15	27
No preservation	17	29	20	2

N represents the number of participating farmers while percentage represent the ratio of participants

3.3 Mycotoxins Awareness

According to the collected data, 56% the interviewed farmers were aware of feed safety while 71% were had heard of mycotoxins; however, 73% of the participants were unaware of the dangers mycotoxins imposed on them or their chicken (Table 4).

Table 4. Mycotoxins awareness among indigenous chicken farmers across three counties in Kenya

Mycotoxins awareness (%)	Total (n=180)	Overall and specific counties		
		Siaya (n=60)	Busia (n=60)	Kakamega (n=60)
Aware of feed safety	56	58	48	62
Unaware of feed safety	44	42	52	38
Aware of mycotoxin / aflatoxins	71	73	70	70
Unaware of aflatoxins	29	27	30	30
Aware of dangers of mycotoxins/aflatoxins	43	47	38	43
Unaware of the dangers of mycotoxins	57	53	62	57
Aware of mycotoxins control methods	62	63	55	67
Unaware of mycotoxins control methods	38	37	45	33

N represents the number of participating farmers

4. DISCUSSION

4.1 Feed Types

Most indigenous chicken farmers (96%) from the three counties in Kenya used cereal feeds than commercially (44%) available chicken feeds. This is primarily because grains are more readily accessible and affordable to these resource-limited farmers [15]. These findings were similar to those of another study done in Western Kenya where, 6.8% of indigenous chicken farmers used commercial feeds; 18.6% used both local and commercial feeds, while the majority (74.6%) were using locally available feeds [1]. Similar observations were made in Makueni County, Kenya where 39.3% of indigenous chicken used grains as feeds while only 10% used commercially available chicken feeds due to their high cost [18].

4.2 Drying of Grains

After harvest, grains should be taken off the soil and dried to a safe moisture level to curb fungal growth during storage. Mycotoxigenic fungal growth and mycotoxin production take place in improperly dried grains before storage [19]. Therefore, rapid drying of agricultural products on mats/polythene to appropriate moisture levels is highly recommended [20]. Of the farmers interviewed in Western Kenya, 97% of them were sun-drying maize on mats, but a few were drying their agricultural produce directly on the ground or along the road. The practice of drying grains off the ground reduces the risk of picking up potential toxigenic mould spores from the soil during drying, thus reducing the possibility of mycotoxins production and accumulation. This is because the soil is an essential habitat for mycotoxigenic fungi species such as *Aspergillus* and *Fusarium* spp. [21]. A similar study [20] reported that 37.6% and 39.1% of the farmers in Nandi and Makueni counties, respectively, were not drying maize on a canvas instead they were drying their unshelled maize directly on the ground. Drying maize in direct contact with the ground risked picking up of fungal spores from the soil, hence the risk of mycotoxins production and accumulation. Well-ventilated enclosures are recommended for drying grains to avoid contamination with fungi spores carried by wind.

4.3 Preservation

Application of chemical pesticides and ash pesticides to control insect pests during storage was commonly practiced among indigenous chicken farmers from the three counties. However, 29% of farmers in the three counties, with the majority (29%) from Siaya County were not adding any preservatives to their grains during storage. Insects play a crucial role in mycotoxins contamination in crops both in storage and in the field. They transmit fungal spores from other infected crops or grains to inoculate defective kernels [22]. Moreover, insects predispose crops/grains to fungal infection through disruption of the seed coat and the creation of wounds that facilitates fungal inoculum penetration and subsequent mycotoxins production [23]. Insect pest creates a favourable microclimate within storage bags through their metabolic activities that release heat and water that are essential for mould [22]. Therefore, the use of insecticides is essential in managing fungal contamination and subsequent mycotoxin contamination. Findings from this study were consistent with recent reports that indicated that farmers apply insecticides to grains (maize) before storage to manage insect pests [23]. This was in agreement with a study carried out in Makueni and Nandi Counties who reported that about 25% of farmers were not using any pesticides during storage [20].

4.4 Storage Methods

Storage methods are equally vital to the fungal growth and mycotoxins contamination of grains under storage. The method of grain storage or type of bag could favour or mitigate mycotoxins accumulation. Most indigenous chicken farmers (88%) were using polypropylene bags to store their agricultural produce in their living houses with only 7% using hermetic bags, while some left their maize on cobs on the floor. Even though widely used in the polypropylene bags are neither insect nor moisture resistant and they also allow air circulation; as a result, they predispose stored grains to moisture and insect infestation [24]. This encourages mould growth and accumulation of mycotoxins [25]. Fungi are aerobic microorganisms, for this reason, technologies in hermetic bags [26] and metal silos [27] have been developed to increase carbon dioxide content and reduce oxygen content in storage to limit the growth of mycotoxigenic fungi and subsequent aflatoxins production as well as to curb insect pest infestation.

4.5 Sorting

Mycotoxins distribution in grains is highly heterogeneous with large amounts of the toxin concentration in a small fraction or just a few of the kernels [28]. Traditional food and feed processing methods such as sorting form a practical, inexpensive and sustainable post-harvest handling practices that reduce mycotoxin levels and exposure risks [29]. Hand sorting was typical (79%) before storage of grains among indigenous chicken farmers from the three counties. They sorted out infected and physically damaged grains based on odd shaped, coloration, reduced sizes and shriveled. This is one of mycotoxins reduction strategy since it allows manual separation of mould-infested kernels/nuts from the intact and seemingly non-contaminated kernels. It is known that sorting out of infected and mechanically damaged grains can reduce aflatoxins contents in grains by 40%-80% [30], however, some kernels maybe contaminated but invisible to the eye. The beauty of sorting is that it reduces levels of mycotoxins in agricultural products without either compromising their nutritional value or leaving behind toxin products in food/feeds [20]. In a study carried out in Brazil, reported that sorting of wheat grains significantly decreased mycotoxins contents in wheat grains and products [31].

In this study, some indigenous chicken farmers used mouldy and discoloured grains as chicken feeds; however, most farmers argued that their chicken only fed on these mouldy, discoloured grains during scarcity and drought seasons since there is little to share between man and chicken. Furthermore, farmers sort out grains intended for human consumption as opposed to those intended for use as chicken feeds. Consuming these mycotoxins contaminated feeds intensifies the toxicity to the chicken; resulting in reduced performance and/or compromised health status [32]. Other studies have reported that heavily damaged and moulded grains contain the highest concentrations of fumonisins and aflatoxins [33].

4.6 Mycotoxins Awareness

This study investigated mycotoxins awareness levels and health risk among indigenous chicken farmers in the three counties. The study showed that, although 71% of the local chicken farmers were aware of mycotoxins/aflatoxins, only 43% were aware of their health effects in both human and animals. A feedback workshop on mycotoxins contamination in Western Kenya, which was held at Agricultural Training Centre (ATC) Busia County Kenya in July 2018, a farmer indicated that all along they knew that a virus in food caused cancer and not mycotoxin contaminated in food as they were informed. Famers' lack of adequate knowledge on health risks associated with mycotoxin exposes farmers and the general population them together with poultry to consuming contaminated foods and feeds, respectively. Hence, mycotoxin awareness needs to be raised and broadened to mitigate this challenge. Farmers and consumers need to become more aware of health risk associated with mycotoxin-contaminated feed/ food so that they are in a position to demand safe and quality food/ feed on a routine basis.

Other studies showed even higher levels of unawareness among farmers, for instance, awareness levels of 26.7% among traders, 20.8% among farmers, 25.2% among consumers and 60% among poultry farmers had been reported in Ghana, Benin and Togo [34]. In Kilosa District, Tanzania, 92% of the peanut and maize framers were not aware of mould/aflatoxin contamination [35]. The findings further indicated that age, gender and education level were positively correlated to awareness levels.

Other studies on awareness study in Nigerian revealed that 98% of respondents were not aware of mycotoxin contamination and that this slightly correlated to the level of education [36]. In most African countries, knowledge of mycotoxins awareness levels are higher in high-risk areas that have experienced outbreaks in the past and contingent on education levels [37]. Surveys in Kenya and Mali indicate that majority of the farmers who had heard of mycotoxins obtained that information from extension workers or local language radio station, and lack of proper of mycotoxins contamination contributed to the poor control of mycotoxin in these areas [38]. Empowering farmers with mycotoxins knowledge will help them and population to demand safe food and feeds their general well-being [39].

5. CONCLUSION

Most of indigenous chicken farmers are not conversant with health risks associated with mycotoxins contamination. It is therefore, important that the authorities in charge of food and feed safety sensitize indigenous chicken farmers and the general population on mycotoxins/aflatoxins, preferably through extension services so at to safeguard the public from mycotoxins exposure through contaminated chicken feeds and food. The promotion of safe appropriate agricultural produce handling and storage practices to lower the risks of mycotoxins contamination is essential in mycotoxins management.

CONSENT

As per international standard informed and written participant consent has been collected and preserved by the authors.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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