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PREVALENCE AND STAKEHOLDERS' PERCEPTION OF MYCOTOXINS IN THE GHANAIAN POULTRY FEED VALUE CHAIN

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ABSTRACT

The poultry sector in Ghana has the potential to contribute significantly to domestic food and nutrition security. There is limited information regarding the knowledge of feed industry stakeholders on the presence of mycotoxins in poultry feed. This work was aimed at assessing the prevalence of aflatoxin and fumonisin in poultry feed, and mycotoxins awareness among stakeholders of the poultry feed value chain in Ghana. Three hundred and fifty (350) respondents consisting of 255 commercial poultry farmers, 85 feed processors and 16 feed vendors were involved in the study. AgraStrip® Quantitative test from RomerLab, USA was used to quantify total fumonisin and aflatoxin levels in the prepared feed samples. The study revealed that commercial feed producers, feed mills operators and on-farm feed processors are the three main sources of feed and ingredients for commercial poultry farmers in Ghana. The study identified a high level of mycotoxin contamination of feed and ingredients. Feed samples from the commercial feed processors recorded significantly lower aflatoxin levels (21.63$\pm$7.05 ppb, $p<0.008$). However, the threshold of 15 ppb for the Ghana Standards Authority, FAO/WHO maximum permissible limit of 30 ppb and EU regulatory limit of 20 ppb for poultry feeds were exceeded by 70% of all the samples. Fumonisin levels were less than the 30mg/kg FDA guidance levels for maize and maize by-products intended for consumption by breeding poultry. From the study, a majority of the farmers (85%), vendors (87.5%) and all of the feed processors have their own feed storage facilities or warehouses. Storage problems identified by these stakeholders included pest infestation and mold development, which usually occur after a few weeks of storage to the end of the storage period. Sanitation was poor along the feed chain, particularly during feed formulation and storage. Awareness of mycotoxins and their effect on animal and human health was low among the respondents. Some of those who have heard about aflatoxins were not aware of what it is and its effect on the health of humans and animals. This threatens the management of mycotoxins in the poultry feed chain.

Key words: aflatoxin, fumonisin, mycotoxin contamination, mycotoxin awareness, sanitation, poultry feed, feed processors

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INTRODUCTION

One of the key Millennium Development Goals for many developing countries is food security. Reports suggest an increase of 70% sustainable food production globally by the year 2050 due to population increase [1]. Poultry production has the greatest potential for addressing shortfalls in supply of high quality animal protein and job creation to the fast-growing human population [2]. It also provides ready cash for emergency needs, contributes significantly to ecologically sound management of natural resources and poverty alleviation [3].

Mycotoxins have seriously contaminated food and feeds worldwide [4], which is a significant problem [5]. Stoev [6] observed that mycotoxin contamination of the animal feed and human food chains presents a unique challenge to food safety. Among the numerous mycotoxins reported, the most commonly found are aflatoxin, deoxynivalenol, fumonisin, ochratoxin and zearalenone [4,7]. Aflatoxin has been identified to be the most important mycotoxin to the poultry industry due to its frequency of occurrence in feedstuffs and toxicity, and is reported as the most important in Africa [7].

In Ghana, various animal feed raw materials are derived from the same sources as human food. The predisposing factors to mycotoxin contamination have been reported to include pre-harvest practices, harvesting, moisture content levels at harvesting, poor hygienic postharvest practices during transportation and storage, marketing and processing, and insect damage [8,9]. These factors may facilitate fungal growth and contribute to the production of mycotoxins [10].

Reports indicate that mycotoxin adversely affect animal productivity and health [11] with severe implications on human health [12]. Reducing mycotoxins concentration in the food and feed value chains will improve human and animal health and productivity, and reduce financial burden on healthcare [13]. There is therefore the need to continuously monitor mycotoxin contamination of feeds on regular basis, to enable the adoption of proper mitigation strategies to reduce the adverse effects of these mycotoxins. This will guarantee that animal products including poultry derived are safer for the consumers [14,15].

Cook [16] observed a substantial increase in feed production in the Ghanaian poultry industry over the years, largely matched by the establishment of on-farm feed mills by

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large-scale poultry farmers. Aflatoxin and fumonisins have been identified in feed samples collected from Ghana [17]. However, information regarding mycotoxins knowledge of stakeholders in the poultry feed value chain in Ghana is limited. This study was aimed at assessing the levels of aflatoxin and fumonisin and mycotoxins awareness among stakeholders in the poultry feed value chain in Ghana.

METHODOLOGY

The Survey

The study was carried out in the Ashanti, Brong Ahafo and Eastern regions of Ghana. The three regions were purposely selected because commercial poultry farms are concentrated in the Ashanti and Brong Ahafo regions [2,18] while the greatest number of semi-commercial farms and the highest number of broilers in the country [2,19] are in the Eastern region. The target population was the registered poultry farmers from the selected regions.

The sample size was estimated based on the formula by Naing et al [20] as:

$$n = \frac{Z^2 P(1-P)}{d^2}$$

Where

- n = sample size,
- Z = Z statistic for a level of confidence,
- P = expected prevalence or proportion, and
- d = precision

Three hundred and fifty (350) commercial poultry farms were select as the target participants using random sampling, with assistance from the Veterinary Services Directorate of the Ministry of Food and Agriculture (MoFA) within the selected regions. A total of 85 commercial feed millers and processors, and sixteen (16) feed vendors available within the selected regions were randomly selected. The on-farm poultry feed processors in the selected regions were identified with the assistance of the Ghana Poultry Farmers Association. The targeted farmers, feed processors and vendors were informed about the nature of the intended study and the purpose of the research was also explained in detail to them. A verbal consent of the participants was obtained and those individuals willing to participate and cooperate with the researcher

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were used. In all, a total of 350 participants made up of 255 commercial poultry farms, 85 commercial feed millers and processors and 16 feed vendors willingly participated in the study as respondents.

Questionnaire and semi-structured interview were used to collect primary data from the respondents. The questionnaires, with both open-ended and closed-ended structured questions, were administered to the research participants. It was designed to gather information on participants' socio-demographics (age, gender, education and marital status), their source of feed or feed ingredients, transportation, feed preparation, handling, storage, feed testing and quality management. It also sought to examine participants' knowledge and awareness of mold contamination of feeds and ingredients, and the perceived risk, human and animal health implications of its ingestion. The number of birds on a farm was used as measured as farm size. The researcher's observation was employed to validate the information from the respondents. Initially, the questionnaire was pre-tested to ascertain its reliability.

Mycotoxin Analysis

The AgraStrip® Total Quantitative test Watex® obtained from the RomerLab, USA was used to quantify the total aflatoxin and fumonisin levels in prepared feed samples. The collection of prepared feed samples, feed sample extraction, extract dilution and test procedure followed the details described by Aboagye-Nuamah *et al.* [17].

The sample extraction was done using distilled water, Filter Whirl-Pak® bags and extraction buffer bags. Ten (10) grams of each ground feed sample were weighed into the filter bags. One extraction buffer bag and 30 ml of distilled water were added to each sample in the Filter bags. The bags with its content were shaken vigorously after which they were allowed to settle by placing in a tray on a laboratory bench for two minutes.

The various feed sample extracts were diluted 1:20 with a dilution buffer. Fifty microlitres (50 µL) of sample extract was mixed with 1000 µL of dilution buffer. This was shaken vigorously with the hand to thoroughly mix it. The conjugate microwells were removed from the conjugate canister and placed inside the heat block of the AgraStrip® Incubator at 45^{o}C.

Each microwell was filled with 100 µL of diluted sample extracts. The conjugates in each well were dissolved completely by pipetting the contents mixed in each microwell

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up and down four (4) times. One test strip was inserted into a microwell, covered with the heat block cover and allowed to develop colour for three (3) minutes. The tip of each test strip was cleaned with an absorbent paper and the strip inserted into the strip holder in the AgraVision for reading.

Data Analysis

SPSS 16.0 statistical software was used to conduct statistical analysis on the data obtained. Analysis of variance (ANOVA) was performed for aflatoxin and fumonisin levels in feed samples from the different sources. Differences in mean values from different feed sources were tested using the Tukey test. Descriptive statistics were employed in the analysis and presentation of the data gathered from the survey.

RESULTS AND DISCUSSION

Ghana Poultry Feed Value Chain

The study revealed three main sources of feed and ingredients for commercial poultry farmers in Ghana. These are commercial feed producers, feed mills operators and on-farm feed processors. The poultry feed value chain in Ghana is presented in Figure 1:

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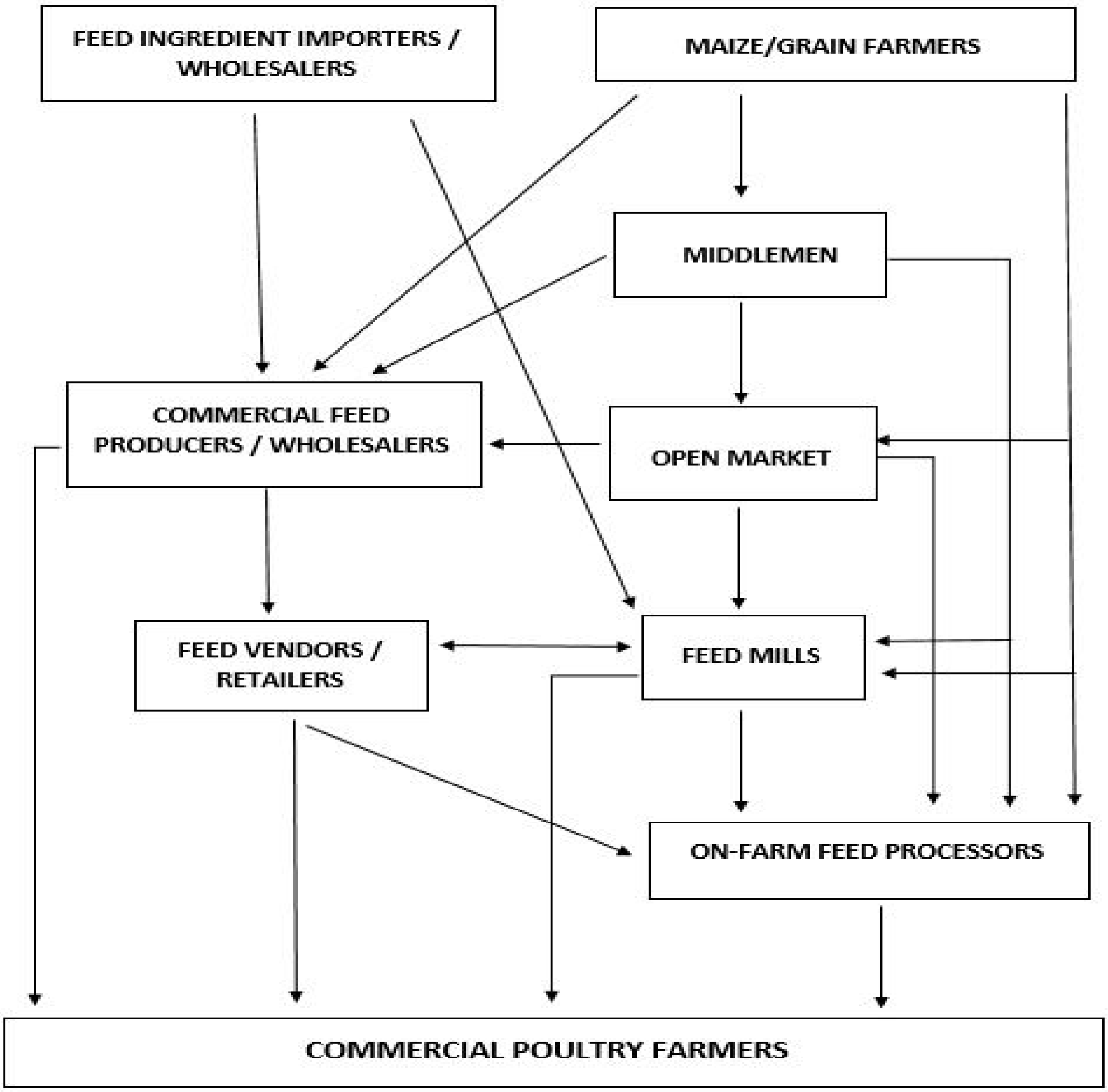

Figure 1: The Ghanaian Poultry feed value chain (Source: Field data)

The main ingredients for poultry feed formulation identified from this study were maize (45-65%), wheat (10-20%), soyabean cake (5-15%), sunflower cake (1-5%), fish meal (5-10%), oyster shell (2-9%) and nutrient supplements usually referred to as concentrates (5-10%). The percentage composition of each ingredient in a given ration depends on the type of feed ration being prepared.

These ingredients are mostly obtained either from the open market or the feed vendors. The ingredients are transported from the suppliers to the processors mainly through the use of trucks. The feeds and ingredients are transported to their destination within a day. However, big trucks carrying large volumes of feed and feed ingredients may take up to three days. The feeds and ingredients are usually packaged in plastic sacks during transportation and storage.

Feed handling during transportation could be a source of contamination by mycotoxigenic fungi. Transportation is one of the handling processes during which proper sanitation should be taken seriously to avoid contamination of feeds and ingredients. Typically, concentrates delivered directly from a commercial feed mill (or more likely from an importer/distributor to their mills) are likely to reduce the risk of contamination by molds. Battilani [7] cautioned that beneficial impact of operating proper sanitation of load compartment for transporting harvested crop should not be overlooked. There is the risk of new load being contaminated by residues of contaminated feed and ingredients from dirty trucks.

Feed Processing and Storage

From the study, a majority of the farmers (85%), vendors (87.5%) and all of the feed processors have their own storage facilities or warehouses (Table 1). A majority (80%) of these warehouses are buildings constructed with concrete blocks but some (19.7%) are sheds constructed with wood.

The study revealed that about 40% of the respondents face some storage problems either intermittently or all the time. The storage problems observed include insect infestation, birds and rodents attack, as well as mold development. These problems usually occur after a few weeks of storage to the end of the storage period (Table 1).

Although a majority (85.6%) of the processors clean their processing equipment, some of them (14.4%) do not clean them at all. Among those who clean the equipment, the greater percentage (60.6%) do not have any regular period of cleaning. Cleaning is done when the need arises with a few (6%) cleaning their equipment after every operation.

Sanitation is one of the risk factors that could influence the prevalence of mycotoxins in feeds. Poor hygienic conditions during handling and storage create favorable conditions for mycotoxin production [21]. Correlation has been observed between cleaning stores before loading new produce and reduced mycotoxin levels [22]. The present study revealed that apart from the commercial feed producers, sanitation was

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poor in most cases, particularly at the production floors and during storage. Such poor sanitation within the stores and warehouses will create favorable environment for fungal contamination, growth and subsequent development of mycotoxins.

Pest infestation within the storage environment can facilitate fungal growth and promote the development of mycotoxins. Increased moisture content due to condensation of moisture from respiration during insect activity provides ideal conditions for fungal activity [23]. Mycotoxigenic fungi take advantage of openings caused by insect damage to easily enter and rapidly activate their metabolism. Hence, any appropriate insect pests management strategy would reduce mycotoxin contamination problems.

Levels of Aflatoxin and Fumonisins

The study recorded high aflatoxin levels in poultry feed samples collected from the various sources. The total aflatoxin and fumonisin levels in the feed samples were 0 – 118 parts per billion (ppb) and 0.28 – 15 parts per million (ppm), respectively. The means for aflatoxin and fumonisin were 57.25$\pm$2.55 ppb and 1.54$\pm$0.12 ppm, respectively.

Significant differences were observed in aflatoxin recorded in feed samples from the various sources (Table 2). Significantly lower aflatoxin level was recorded in prepared feeds from commercial feed processors (21.63$\pm$7.05 ppb, $p<0.01$), while feeds from farmers recorded the highest (61.64$\pm$3.70 ppb, $p<0.01$).

The regions significantly influenced both the aflatoxin and fumonisin levels recorded in the feed samples (Tables 3). Feed samples from the Brong Ahafo region recorded significantly higher mean aflatoxin (69.62$\pm$3.06 ppb, $p<0.01$) and fumonisin (1.80$\pm$0.19 ppm, $p<0.01$) levels than those from the other regions.

An earlier report [17] recorded similar aflatoxin and fumonisin levels in feed samples. Generally, aflatoxin levels in 18% of all feed samples exceeded the United States Food and Drug Administration (FDA) recommended average doses of 100 ppm AFB1 in poultry feeds [24]. Apart from feeds from the commercial feed processors, the mean aflatoxin levels in feeds from the other sources exceeded the 20 µg/kg European community regulatory limit, the permissible limit of 30 µg/kg recommended by the Food and Agriculture Organization (FAO)/World Health Organization (WHO) for poultry feeds [25] and the Ghana Standard Authority limit of 15 ppb [26]. Fumonisin levels were less than the 30 mg/kg FDA guidance levels for maize and maize by-products intended for consumption by breeding poultry [24].

Aflatoxin and fumonisins levels recorded in this study could be attributed to the feed ingredients and their sources. The contribution of maize, sorghum, groundnut, rice, and wheat, which were identified as the main ingredients for poultry feed formulation in Ghana, each make more than 10% of the global exposure to aflatoxin [5]. Fungi contaminate these ingredients because of their ubiquitous nature. Maize has been found to be one of the high-risk commodities for mycotoxin contamination around the globe [27] and has been shown to be a good substrate for mold infection and production of aflatoxins [28]. Aflatoxin contamination of maize has been reported in Ghana [8,29-33] and poultry feed samples [17].

High aflatoxin concentrations above the 30 µg/kg maximum permissible limit recommended by FAO/WHO were observed in maize samples stored in warehouses and silos in Ghana [34]. Other studies have reported the use of feed ingredients contaminated with aflatoxin producing fungi such as Mucor and Rhizopus species in preparing poultry feed [35,36].

Feed Quality and Mycotoxin Awareness

According to this study, a majority (75%) of the farmers produce their own feeds. However, more than 57% of farmers and 80% of the feed processors do not have any formal training in animal nutrition or feed formulation (Table 4). They use their experiences acquired through the several years of working on the farm. Only 19.7% of the processors and 47% of the farmers have some exposure through short courses and workshops they attended. This study also revealed that 78% of the farmers and 69% of the feed processors have good collaboration with veterinary officers from the Ministry of Food and Agriculture (MoFA) who assist them with current information on feed formulation and technology transfer.

A majority of the farmers (84%), feed processors (74%) and vendors (87.5%) expressed awareness of moldiness in feeds and that they have experienced moldy ingredients in their feed (Table 4). The results revealed that although the majority (82.3%) of the farmers reject such moldy feedstuffs, some of them (16%) still buy such moldy feeds, sometimes at reduced prices.

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With regard to prepared feeds, all of the respondents indicated checking the feeds at all times before selling them. The odour, cleanliness, moldiness, and in some cases, the moisture content of the feeds are checked. Some farmers and vendors (12.5%) either mix the moldy feeds with fresh feeds or sell such moldy feeds at reduced prices. About 25% of the farmers who detect moldiness in their feeds dry such moldy feeds while others blend them with non-moldy feeds before feeding them to the birds.

The present study revealed inconsistencies among the farmers regarding checking feed ingredients for moldiness and discarding such moldy feedstuffs. Reports indicate that physical sorting of contaminated grains could be useful in reducing the extent of mycotoxin development in feeds [27]. Fandohan *et al.* [9] observed that sorting, winnowing, washing, among other traditional processing of contaminated maize and maize-based foods significantly removed aflatoxins and fumonisins in Benin. Sorting, cleaning and discarding visibly moldy ingredients have helped to reduce the level of mycotoxin contamination of stored cereal produce [7,9,37]. Although sorting and discarding moldy ingredients seem to be a simple practice to adopt, most feed producers find it difficult determining which of the ingredients are contaminated due to inadequate established or non-existent regulatory mechanisms to check aflatoxin contamination of poultry feeds and ingredients. A similar observation was made in Nigeria [35]. Frequent monitoring of the feed for mycotoxin contamination is necessary to ensure that poultry birds are fed with quality feed. Safer animal products will also be guaranteed for the final consumers [15].

Elimination of the contaminated feedstuff, reducing the feeding rate of the contaminated feedstuff, as well as using mycotoxin sequestering agent to decontaminate the feed have been ways of getting clean feedstuff. Although most of the farmers indicated discarding the moldy feeds and ingredients, the challenge is their ability to detect moldiness and the level at which they are convinced that the feed or ingredient is too moldy to warrant discarding it. There is the risk of a high prevalence of aflatoxin in feeds due to the practice where poultry farmers dry the moldy feeds or blend them with non-moldy ones and feed them to the birds. This is a major source of feeding poultry birds with aflatoxin-contaminated feeds because farmers are unable to measure the level of contamination in their feeds.

Results of this study showed that awareness of mycotoxins and its effect on the health of animals and humans was low among stakeholders in the poultry feed chain (Table 5). Some of those who have heard about aflatoxins were not aware of what it is and its

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effect on the health of humans and animals. It was also observed that checking for moldiness of feed ingredients and discarding such moldy feedstuffs were not consistent among the farmers.

The low awareness of mycotoxins among stakeholders in the poultry industry might account for the reason why some poultry farmers and feed processors do not worry about the state of the feed ingredients they use in preparing their feeds. It is interesting to note that the few (4%) on-farm processors who add toxin binders to the prepared feeds do not really understand what it is and how it works.

Increased awareness of the effect of mycotoxins on the health of human and animals will guide feed mills operators to uphold standards that will prevent mycotoxin contamination of feeds and ingredients. It has been observed that establishing limits and regulations for mycotoxins in feed has been motivated by an increased awareness and understanding of mycotoxins and their effects on animal and human health [38]. James *et a.l* [39] concluded that aflatoxin contamination could be reduced through sustained public education. Battilani et al [7] emphasized the importance of increasing the awareness of farmers to the issue of mycotoxins in feed. A focus on the major sources of mycotoxins contamination entering the feed chain is relevant to enhance the avoidance of any possible toxicological issue for the consumer [7].

CONCLUSION

The study has identified mycotoxin contaminated feeds and ingredients in the Ghanaian poultry feed chain. Feed samples from commercial feed processors have lower aflatoxin levels. Most of the feed samples exceeded the 15 ppb threshold of the Ghana Standards Authority, the 30 ppb maximum permissible limit of FAO/WHO and EU regulatory limit of 20 ppb for poultry feeds. Storage problems identified by the stakeholders include pest infestation and mold development. It is recommended that farmers should obtain feed ingredients directly from the producers and store them properly to reduce contamination and mycotoxin development. Feed processors should always monitor, sort, and dispose of visibly moldy feed ingredients before feed formulation. This will help reduce the level of mycotoxins contamination and exposure of poultry birds to contaminated feed. Intensified public education on mycotoxins may guide feed processors and feed mills operators to uphold standards that will reduce the level of feed contamination and its associated effects on animal and human health.

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Credit Author Statement

Francis Aboagye-Nuamah: Methodology, Resources, Investigation, Data curation, Formal analysis, Writing- Original draft preparation. Charles K. Kwoseh: Methodology, Supervision, Writing- Reviewing and Editing. Dirk E. Maier: Conceptualization, Validation, Supervision, Writing- Reviewing and Editing.

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Table 1: Storage of feeds and ingredients by Ghanaian Poultry Feed Stakeholders

Factor		Farmers	Processors	Vendors
Storage facility	Yes	85.4	100.0	87.5
	No	14.6	0.0	12.5
Location of store	Field	41.7	22.7	0.0
	House	47.9	60.6	25.0
	Courtyard	8.3	16.7	0.0
	Town	2.1	0.0	75.0
Type of storage problem	Insects	4.2	7.6	37.5
	Rodents	8.3	22.7	50.0
	Birds	0.0	3.0	0.0
	Mold	85.4	4.5	12.5
	Caking	0.0	37.9	0.0
	Not applicable	2.1	24.2	0.0
Period storage problem is Observed	Beginning of storage	8.3	10.6	12.5
	After few weeks	41.7	19.7	50.0
	End of storage	47.9	4.5	25.0
	Not applicable	2.1	65.2	12.5

Table 2: Aflatoxin and Fumonisin levels as influenced by the Source of Poultry feed in Ghana

Source of Feed	N	Aflatoxin (ppb)			Fumonisin (ppm)		
		Mean	Median	Range	Mean	Median	Range
Commercial	22	21.63 ± 7.05a	11.76	0 - 51.04	0.96 ± 0.23	0.39	0.28 - 2.40
Feed Mills	48	59.01 ± 5.43bc	32.04	0 - 111.10	1.37 ± 0.13	0.48	0.31 - 3.42
On-farm Processors	70	55.64 ± 4.85b	43.71	0 - 115.30	1.61 ± 0.34	0.28	0.32 - 15.0
Farmers' feed	100	61.64 ± 3.70c	53.17	0 - 118.00	1.63 ± 0.12	0.34	0.29 - 6.61

Means with the same letters are not significantly different at 0.05 level according to Tukey Test

Table 3: Aflatoxin and Fumonisin level as influenced by the Region in Ghana

Region	N	Total Aflatoxin level (ppb)			Total fumonisin level (ppm)		
		Mean (ppm)	Median	Range	Mean (ppb)	Median	Range
Ashanti	53	11.83 ± 0.13a	8.32	0 - 11.95	0.47 ± 0.04a	0.08	0 - 0.50
Brong	105	69.62 ± 3.06c	54.68	0 -115.40	1.80 ± 0.19c	0.45	0 - 15.00
Eastern	82	40.67 ± 3.62b	32.17	0 - 118.00	1.19 ± 0.11b	0.28	0 - 6.61

Means with the same letters are not significantly different at 0.05 level according to Tukey Test

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Table 4: Stakeholders' Awareness of Feed Quality in the Ghanaian Poultry Feed Chain

Factor		Farmers	Processors	Vendors
Training in Animal Nutrition	Yes	42.7	19.7	0.0
	No	57.3	80.3	100.0
Awareness of Moldy Feed / ingredients	Yes	84.4	74.2	87.5
	No	15.6	25.8	12.5
Checking for Moldiness	All the time	70.8	83.4	75.0
	Sometimes	22.9	12.1	25.0
	Not at all	6.2	4.5	0.0
Measures on Moldy feed/ingredients	Buy	10.4	7.6	0.0
	Reject	82.3	81.1	100.0
	Buy/Sell at lower price	5.2	8.3	0.0
	Sorting	2.1	3.0	0.0
Handling Moldy Feed	Discard	75.0	84.8	87.5
	Use/sell	10.4	6.6	0.0
	Dry before use/sell	11.5	1.5	0.0
	Blend with non-moldy feeds	3.1	4.5	12.5
Avoiding Moldiness	Avoid long term storage	56.2	6.1	7.5
	Dry before storage	27.1	77.3	88.0
	None	3.1	12.1	4.5
	Others	13.5	4.5	0.0

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Table 5: Stakeholders' Awareness of mycotoxins, feed contamination and its effects on humans and animals in Ghana

Factor		Farmers	Processors	Vendors
Mycotoxin awareness	Yes	47.9	40.9	12.5
	No	52.1	59.1	87.5
Contamination of feed	Yes	41.7	37.9	12.5
	No	58.3	62.1	87.5
Mycotoxin effect on humans	Yes	36.5	34.8	12.5
	No	63.5	65.2	87.5
Mycotoxin effect on animals	Yes	37.5	42.4	12.5
	No	62.5	57.6	87.5
Health risk awareness	Yes	26.0	60.6	87.5
	No	74.0	39.4	12.5
Use of toxin binder in feed	Yes	4.2	2.1	0
	No	95.8	98.9	100

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