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Quality assessment and hazard analysis in the small-scale production of poultry feeds in Ogbomoso, Southwest Nigeria

A. Lateef[1] and E.B Gueguim-Kana[2]

[1]Ladoke Akintola University of Technology, Department of Pure and Applied Biology, Microbiology Unit, PMB 4000, Ogbomoso, Nigeria; [2]University of KwaZulu-Natal, School of Biochemistry, Genetics and Microbiology, Private Bag X01, Scottsville, Pietermaritzburg 3209, South Africa; agbaje72@yahoo.com

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RESEARCH ARTICLE

Abstract

We evaluated the microbiological and nutritional qualities of poultry feeds in Ogbomoso, Southwest Nigeria, and determined the incidence of aflatoxins in the samples. Feed samples from five small-scale enterprises were analysed twice a month for five months. The feeds were examined for heterotrophic bacteria, coliforms, and fungi. Similarly, proximate analyses of the feeds, and the incidence of aflatoxin were carried out. The production outfits and processes were critically examined for the identification of hazards associated with the production of feeds. The results showed that the feeds are enriched, which could meet the nutritional requirements of the birds. However, all the feeds were of poor microbial quality and contaminated with coliform, heterotrophic bacteria and fungi. Also, 36% was contaminated by aflatoxin, all indicating poor feed safety. A hazard analysis and critical control point plan was evolved for the production of feed, with the view of ensuring the safety of the feeds. It was discovered that poor manufacturing practices by these small-scale producers contributed enormously to the level of microbial and aflatoxin contamination.

Keywords: aflatoxins, bacteria, fungi, hazard, poultry feed

1. Introduction

Poultry production is an important aspect of agricultural practice in Nigeria as it dominates activities in the sector, because of its rapid monetary turnover. This among others has made the enterprise attractive and popular among small, medium, as well as large scale poultry farmers. The poultry industry has become a diverse industry with a variety of business interests such as egg production, broiler production, hatchery, and poultry equipment business (Oluyemi and Roberts, 1979). The surge in the rearing of poultry as means of self-employment occasioned by socio-economic problems has also led to the establishment and proliferation of small and medium-scale feed mills, for the processing of poultry feeds among others.

The quality of poultry feeds in terms of nutritional contents, as well as microbial safety is paramount, in not only maintaining the physiological functions of the poultry, which will ultimately determine the productivity, but also the safety of the consumers of poultry products. Therefore, the production and delivery of quality feeds is vital to the success of any animal production operation. Livestock feeds can serve as veritable sources of chemical and microbial contaminants, which can be passed on to the consumers of livestock products. It is therefore pertinent to ensure that livestock feeds are free of such contaminants. Most microbial contaminants in stored feed materials usually arise from infestations that began in the field, although some can directly infest storage grains as well when conditions are right (Vieira, 2003), such as temperature, humidity and cross contamination.

This study was designed to assess the microbiology, proximate composition, physico-chemical properties and incidence of aflatoxin in some selected poultry feeds

produced by small-scale enterprises within Ogbomoso agricultural zone of Southwest Nigeria. Though several workers have studied microflora associated with poultry feeds and poultry feed raw materials from different parts of the country (Arotupin *et al.*, 2007; Okoli *et al.*, 2006, 2007; Osho *et al.*, 2007; Uwaezuoke and Ogbulie, 2008), such studies analysed samples obtained through one to three-time sampling regimes. However, in this work, sampling of three types of poultry feeds was carried out on five different small-scale producers for a period of five months at two-week intervals (totally 10 samplings per feed type), thereby making this work to be the most comprehensive to the best of our knowledge in assessing the quality of feeds produced by these small-scale enterprises.

The study also involved the identification of sources of microbial hazards in the production lines, with the view of correcting them by applying the hazard analysis and critical control point (HACCP) strategy. HACCP strategy identifies hazards associated with different stages of preparation and handling, assesses the relative risk and identifies points where control measures would be effective (Bryan, 1988). This strategy has been employed in the feed industries in several industrialised nations of the World (Blackman *et al.*, 1993; Den Hartog, 2003; Jones and Ricke, 1994) and is also applicable in the cottage food industry (Lateef *et al.*, 2010). However, in developing countries such as Nigeria, and particularly among the small and medium-scale feed producers, there is dearth of information on the application of HACCP to reduce or eliminate microbial hazards towards ensuring the safety of animal feeds. Therefore, this study also aimed to identify the sources of microbial hazards in the production process, with the view of correcting them by applying the HACCP strategy.

2. Materials and methods

Sampling

Feed samples (grower, finisher, and layer mash meant for the feeding of cockerel, broiler and egg-laying birds) were collected in previously sterilised plastic containers from five small-scale feed mills as packed in bags for purchase and taken to the laboratory for analysis within 4 h. This was done twice in a month for a period of five months. The composition of each feed was obtained from the mills. At the point of collection, the temperature of the bulk feed was determined using thermometer.

Descriptive analysis of the production outfits

During the period of conducting the research, visits were made to the five production outfits with the view of collecting data as it relate to the history, manufacturing procedures, sanitation, location, quality control and official licensing of each outfit.

Proximate analysis of the feeds

The crude protein (N×6.25%), ash, crude fibre and moisture contents were determined. The methods 4.2.05, 4.1.10, 4.6.02 and 4.1.06 of AOAC (1995) were used, respectively. The pH was determined by suspending 10 g of feed sample in 90 ml of distilled water for about 15 min, after which the pH was measured.

Microbiological analysis of the feeds

Studies were conducted to enumerate and isolate some important bacterial groups that may be associated with the feeds. 10 g of the feed samples was serially diluted, and 0.2 ml aliquot of appropriate dilutions were used to inoculate nutrient agar (Lab M Ltd, Heywood, UK) and McConkey agar (Lab M Ltd.) using pour plate technique for the isolation of mesophilic aerobic bacteria and the coliforms. The plates were incubated at 37 °C for 24-48 h, after which the microbial loads were obtained. The morphologically distinct bacterial colonies were selected and purified by repeated sub-culturing on fresh agar plates to obtain pure cultures. These cultures were identified by means of taxonomic schemes and descriptions (Buchanan and Gibbons, 1974; Lindbäck and Granum, 2006), which was complemented with the use of API 20E and API CH50 identification kits (API System, bioMérieux, Marcy l'Etoile, France). The mycoflora associated with the feeds were isolated by inoculating 0.1 ml of appropriate dilutions of feed suspension on potato dextrose agar using the surface-spread technique. The plates were incubated at 28±2 °C for 48-96 h, after which the distinct fungal colonies were purified to obtain pure isolates, and subjected to macroscopic and microscopic examination for identification (Nelson *et al.*, 1983; Pitt and Hocking, 1997).

Qualitative analysis of aflatoxins

The occurrence of aflatoxins in the samples was carried out according to the methods of Sadasivam and Manickam (2004). About 50 g of the sample was moistened with 10 ml of distilled water, followed by addition of 200 ml of chloroform. The mouth of the flask was plugged with cotton wool wrapped with aluminium foil. The content was shaken vigorously, after which it was filtered under mild suction. The filtrate was transferred to a separating funnel and shaken with one-half volume of chloroform. After the separation of the phases, the bottom (chloroform) phase was then drained into a flask containing about 10 g of anhydrous sodium sulphate to absorb water. The clear chloroform extract was then concentrated to dryness. The extract was re-suspended in 500 µl of chloroform and then subjected to thin layer chromatography (TLC) analysis. The pre-coated silica gel plates (Merck, Darmstadt, Germany) of dimension 20 cm by 20 cm were activated at 110 °C in a hot air oven for 30 min. The chloroform extract (10

µl) was applied on the plates and developed in a solvent system of chloroform:acetone (9:1, v/v). The aflatoxins spots were visually observed under long-wave ultraviolet (UV) light, and the retention factor (R_f; the distance traveled by a compound divided by the distance traveled by the solvent) values of the spots were determined.

Identification of hazards

Through several visitations to the production outfits, the likely sources of hazards in the production lines were identified. These include the level of sanitation, the mode of grinding/milling, drying, cooling, packaging and storage.

3. Results

Descriptive analysis of the production outfits

The descriptive analysis of the production outfit is presented in Table 1. It is evident that production of feeds was carried out in make-shift buildings, where bungalows and shops were converted to production outlets. Similarly, all the outfits were located within residential areas, usually near main roads where the outfits could be easily accessed by the interested feed buyers. The results showed that the age of the outfits ranged from 2-19 years, while the number of workers who were trained informally varied from 4-12. The level of sanitation within and each outfit was assessed, with two of them just above average (good), while another two depicted very poor level of sanitation. In addition, toilet facilities were present in only two of the outfits. The productivity of the outfits ranged from 4-12 bags per day. The production process was characterised with mechanical milling using milling machines, sun-drying or air-drying and manual packaging. Quality control in these outfits is problematic, as feeds are not subjected to periodic laboratory analysis as expected.

Physicochemical and proximate composition of the feeds

The results of the proximate analysis, as well as temperature and pH of the feed samples are as shown in Table 2. The temperature and pH values of the feeds varied from 18.8-26.4 °C and 5.81-7.20, respectively. Other parameters showed the following range of values: (a) moisture contents, 3.22-6.83%; (b) ash contents, 7.45-9.72%; (c) crude protein contents, 16.26-17.88%; and (d) crude fibre contents, 3.17-4.84%.

Microbiological attributes of the feeds

The evaluation of the feeds showed that all the feeds were contaminated with bacteria as shown in Table 3. While the coliform counts were ranged from 0.068-2.2×10^4 cfu/g, the mesophilic aerobic bacteria counts ranged from 0.5-4.76×10^4 cfu/g. Except sample A1, counts of samples were higher than the counts of coliform. Bacterial isolates were identified as *Escherichia coli*, *Staphylococcus aureus*, *Enterobacter aerogenes*, *Proteus vulgaris*, Micrococcus sp., *Bacillus cereus, Pseudomonas aeruginosa, Serratia marcescens* and *Bacillus subtilis*, with frequency levels of 20-100%. The result of the mycological examination of the feeds is presented in Table 4. All the samples were found contaminated by fungi, which were identified as Aspergillus fumigatus, *Aspergillus flavus, Aspergillus nidulans, Aspergillus parasiticus, Rhizopus nigricans, Fusarium compacticum*, and *Saccharomyces cerevisiae*.

Table 1. The descriptive analysis of the production outfits.

Parameters/Production outfits	A	B	C	D	E
Type of building	2-room bungalow	bungalow with shops	bungalow	bungalow	bungalow with shops
Location	near main road	residential area	near market	near main road	residential area
Number of workers	10	04	12	07	05
Toilet facilities	water closet	none	none	water closet	none
Level of sanitation	good	very poor	fair	good	very poor
Year of establishment	2009	2005	1992	2008	1992
Training of workers	informal	informal	informal	informal	informal
Milling	mechanical	mechanical	mechanical	mechanical	mechanical
Drying technique	sun drying	sun drying	sun drying	air drying	sun drying
Packaging	manual	manual	manual	manual	manual
Productivity (×50 kg bags per day)	10	04	12	07	05
Official license	none	none	none	none	none
Laboratory analysis of feeds	no	no	no	no	no

Table 2. Physicochemical and proximate composition of the feed samples[1].

Samples	Temp (°C)	pH	Moisture content (%)	Ash content (%)	Crude protein content (%)	Crude fibre content (%)
A1	21.3	6.34	3.31	9.52	17.28	4.32
B1	21.4	6.28	4.43	9.55	17.88	4.34
C1	23.0	6.18	6.83	9.19	16.71	3.55
D1	23.9	6.54	4.19	9.47	17.25	4.42
E1	23.7	6.44	3.22	9.59	17.36	4.45
A2	24.9	6.60	5.68	9.62	17.31	4.21
B2	22.8	6.48	5.59	9.64	17.26	4.32
C2	18.8	5.81	3.68	7.45	16.26	3.17
D2	21.7	6.50	3.60	9.52	17.28	4.34
E2	26.4	6.66	6.55	9.72	17.31	4.40
A3	22.1	6.18	4.83	9.57	17.24	4.42
B3	21.2	6.24	3.95	9.51	17.30	4.35
C3	22.6	7.20	5.77	8.93	17.41	4.56
D3	22.8	6.62	4.09	9.41	17.31	4.22
E3	20.5	6.22	4.55	9.35	17.26	4.84

[1] Values are means of 10 measurements.
A, B, C, D and E = feeds obtained from different mills; 1, 2 and 3 = layer/starter, finisher and grower feed, respectively.

Table 3. The bacteriological attributes of the feed samples.

Samples	Coliform count[1] ($\times 10^4$ cfu/g)	Mesophilic aerobic bacteria count[1] ($\times 10^4$ cfu/g)	Bacterial isolates[2]
A1	2.20	1.94	*Staphylococcus aureus* (100), *Bacillus cereus* (100), *Pseudomonas aeruginosa* (100), *Escherichia coli* (100) *Serratia marcescens* (20), *Enterobacter aerogenes* (20)
B1	0.17	1.13	*E. coli* (100), *Bacillus subtilis* (100), *P. aeruginosa* (100), *Proteus vulgaris* (20), *Micrococcus* sp. (20)
C1	0.14	0.50	*E. coli* (20), *Micrococcus* sp. (40), *B. subtilis* (100), *P. aeruginosa* (100), *P. vulgaris* (100)
D1	2.20	4.10	*S. aureus* (100), *B. cereus* (100), *P. aeruginosa* (100), *E. coli* (100), *S. marcescens* (20), *E. aerogenes* (20)
E1	0.9	3.4	*S. aureus* (100), *B. cereus* (100), *P. aeruginosa* (100), *E. coli* (100), *P. vulgaris* (20), *B. subtilis* (100), *E. aerogenes* (20)
A2	0.39	4.76	*S. aureus* (100), *B. cereus* (100), *P. aeruginosa* (100), *E. coli* (100), *P. vulgaris* (20), *S. marcescens* (40), *E. aerogenes* (40)
B2	0.12	1.37	*E. coli* (100), *B. subtilis* (100), *P. aeruginosa* (40), *P. vulgaris* (40), *Micrococcus* sp. (40), *E. aerogenes* (40)
C2	0.068	1.27	*E. coli* (20), *B. subtilis* (100), *P. aeruginosa* (100), *P. vulgaris* (100)
D2	1.35	4.76	*S. aureus* (100), *B. cereus* (100), *P. aeruginosa* (100), *E. coli* (100), *P. vulgaris* (40), *S. marcescens* (20), *E. aerogenes* (40)
E2	2.2	4.2	*S. aureus* (100), *B. cereus* (100), *P. aeruginosa* (100), *E. coli* (100), *B. subtilis* (100), *E. aerogenes* (20)
A3	0.63	3.12	*S. aureus* (100), *B. cereus* (100), *P. aeruginosa* (100), *E. coli* (100), *P. vulgaris* (20), *S. marcescens* (40), *E. aerogenes* (20)
B3	0.22	1.05	*E. coli* (100), *B. subtilis* (100), *P. aeruginosa* (40), *Micrococcus* sp (80)
C3	0.17	0.8	*E. coli* (20), *B. subtilis* (100), *P. aeruginosa* (100), *P. vulgaris* (100)
D3	0.63	3.24	*S. aureus* (100), *B. cereus* (100), *P. aeruginosa* (100), *E. coli* (100), *P. vulgaris* (60), *S. marcescens* (60), *E. aerogenes* (40)
E3	1.38	4.72	*S. aureus* (100), *B. cereus* (100), *P. aeruginosa* (100), *E. coli* (100), *P. vulgaris* (20), *B. subtilis* (100), *E. aerogenes* (60)

[1] Numbers in parenthesis are the frequency of isolation.
[2] Values are means of 10 measurements.
A, B, C, D and E = feeds obtained from different mills.

Table 4. The mycology of the feed samples.

Samples	Yeast/mould count[1] (×10^4 cfu/g)	Fungal isolates[2]
A1	5.5	*Fusarium compactum* (20), *Aspergillus parasiticus* (40), *Rhizopus nigricans* (40)
B1	6.5	*Aspergillus fumigatus* (40), *R. nigricans* (40), *F. compactum* (20)
C1	5.8	*Aspergillus flavus* (40), *A. fumigatus* (60)
D1	4.3	*Aspergillus nidulans* (40), *A. parasiticus* (40), *F. compactum* (40)
E1	4.5	*F. compactum* (40), *A. nidulans* (60)
A2	6.2	*A. flavus* (40), *A. parasiticus* (60)
B2	5.8	*A. nidulans* (40), *A. parasiticus* (40), *F. compactum* (20), *Saccharomyces cerevisiae* (20)
C2	4.3	*A. fumigatus* (20), *F. compactum* (40), *R. nigricans* (40)
D2	4.2	*A. flavus* (20), *R. nigricans* (40), *A. nidulans* (40)
E2	5.5	*A. nidulans* (40), *A. fumigatus* (20), *R. nigricans* (40)
A3	2.8	*A. flavus* (20), *A. nidulans* (40), *F. compactum* (40)
B3	7.3	*S. cerevisiae* (20), *A. fumigatus* (20), *A. flavus* (20), *R. nigricans* (40)
C3	5.4	*A. flavus* (20), *A. fumigatus* (20), *R. nigricans* (60)
D3	3.1	*A. flavus* (40), *A. parasiticus* (60)
E3	2.9	*A. flavus* (40), *A. fumigatus* (60)

[1] Average of ten measurements.
[2] numbers in parenthesis are the frequency of isolation.
A, B, C, D and E = feeds obtained from different mills.

Table 5. The incidence of aflatoxins in the feed samples.

Samples	R_f of spots[1]	% occurrence
A1	0.87	20 (2/10)
B1	0.87	20 (2/10)
C1	0.88	60 (6/10)
D1	0.95	40 (4/10)
E1	ND	0 (0/10)
A2	0.88	100 (10/10)
B2	0.87	60 (6/10)
C2	ND	0 (0/10)
D2	0.96	40 (4/10)
E2	0.96	20 (2/10)
A3	0.87	20 (2/10)
B3	ND	0 (0/10)
C3	0.88	60 (6/10)
D3	0.88	20 (2/10)
E3	0.96; 0.87	80 (8/10)

[1] Average values of 10 measurements.
[2] Number in parenthesis indicates positive samples.
A, B, C, D and E = feeds obtained from different mills; ND = not detected; R_f = retention factor.

Qualitative analysis of aflatoxins

The TLC analysis of the feeds showed that 36% (54 out of 150) of the feeds examined were contaminated with aflatoxin, though the frequency of occurrence varied among the feeds 0-100% (Table 5). Two types of aflatoxin producing green fluorescence under long wave UV light were encountered with average R_f values of 0.88 and 0.96. None of the layer feeds obtained from outfit E, finisher feeds from outfit C and grower feeds from outfit B showed evidence of aflatoxin contamination. However, the two types of aflatoxins were found in eight samples of grower mash from outfit E.

Identification of hazards associated with the production of the feeds

The examination of the production process in all the outfits enabled the identification of hazards that may be associated with the production of the feeds as shown in Table 6. Several hazards, including pesticides, heavy metals, stones and pebbles, vegetative pathogenic organisms and spores were identified with the production process. Practices such as sun-drying, cooling in uncontrolled environments, manual packaging using bare hands, and storage in uncontrolled environments of ambient temperature and high humidity are particularly sources of microbial contaminants. The critical control points were identified as procurement of raw materials, drying, cooling, packaging and storage. At any of these points, inefficient or defective procedure will lead to the contamination of the feeds.

Table 6. Processing steps, sources of hazard and control measures in the production of feeds.

Processing steps	Sources of hazard	Hazard	Control parameters and critical limit	Monitoring	Corrective measures
Procurement of raw materials	raw materials	chemicals (pesticides, heavy metals), and stones, mould infestation, mycotoxin	critical moisture contents of 8-12.5%; rejection of grains with mould growth (>10%); 20 µg/kg of aflatoxin	moisture content by devices; detection of mould growth by visual examination, mycotoxin detection using ELISA and UV	use of high quality material/ quality assurance and inspection; reduction of moisture content; rejection of raw materials with high contents of aflatoxin
Milling/mixing	milling and mixing machines	heavy metals, increased mycotoxin levels, pathogenic organisms	related to mixer cleaning and mycotoxin level	mycotoxin detection using ELISA and UV	personal hygiene/GMP, changing the method and time of cleaning; restriction of unauthorised persons
Sun-drying	dust, rainfall	pathogenic organisms, spores and rise in moisture content	heating to temperature of 60-80 °C in a dryer	measurement of temperature using thermometer	GMP/use of cabinet dryer
Cooling	air	vegetative pathogenic organisms and spores; increased level of mycotoxin	temperature of feed should at least 5 °C rise more than surrounding temperature	measurement of temperature using thermometer	cooling under controlled environment; mixing of hot feed with cold feed
Packaging	human	pathogenic organisms (mould and bacteria)	ensuring healthy labour force	occasional medical examination	GMP/wearing of gloves; good personal hygiene; disinfection
Storage	pathogens, vermins	pathogenic organisms (mould and bacteria)	low humidity (<60%); storage at low temperature (<20 °C)	measurement using devices (thermo-hygrometer)	GMP, storage in controlled environment of low temperature and humidity; use of dehumidifiers, fumigation

GMP = good manufacturing practices.

4. Discussion

This study assessed poultry feeds produced by small-scale feed mills that are rapidly increasing in number due to the affordability of their products. These mills are often not located in separate factory settings, but within residential areas and commercial centres. The locations of the mills may expose the products to contamination through domestic animals that are often reared within or around the facilities. The sanitation level of the facilities was just about average, with some of them lacking toilet facilities for the factory workers. It was observed that the level of training obtained by the workers was largely informal and not even adequate in ensuring good manufacturing practice to produce safe feeds. The operations were dominated by manual processes, which increase the likelihood of microbial contamination, particularly when there are poor sanitary practices. There were no resident quality control laboratories to monitor the quality of the products. It has been reported that practices such as packaging, packaging materials, environment and handling circumstances, including the nature and extent of quality control measures can greatly influence the source and degree of contamination (Hancock *et al.*, 1998).

The temperature and pH values of the feeds varied from 18.8-26.4 °C and 5.81-7.20, respectively. The temperature reflected the ambient temperature of the tropics in which the facilities were located, while the variation in the pH may be attributed to the variation in the constituents of the feeds. The proximate composition of the feeds fell within values reported for some poultry feeds in Nigeria (Arotupin *et al.*, 2007). The variation in the values obtained reflects the qualities of the feeds in meeting the nutritional requirements of the poultry which depend on age, purpose and nature of the birds.

The incidence of bacteria in the feeds was high (10^2-10^4 cfu/g), and all the samples were contaminated with coliform and mesophilic aerobic bacteria. The loads and types of bacterial isolates are similar to those previously reported for some poultry feeds in Nigeria (Arotupin *et al.*, 2007; Uwaezuoke and Ogbulie, 2008). The contamination could have arisen from different sources including low-quality raw materials, poor manufacturing and low sanitary practices, as well as contamination by the handlers. The presence of *E. coli* suggests feacal contamination, most probably from houseflies gaining access to the exposed feeds, while the presence of *Pseudomonas, Enterobacter, Serratia* and *Proteus* in the feeds suggests recent contamination most

probably from the millers or buyers. This is because, these organisms are non-spore formers, and their presence in such samples like poultry feeds that are of very low water activity is an indication of recent contamination especially as potential buyers at the milling centres often have a feel of the texture of the feeds with bare hands, thus exposing the feeds to microbial contamination. Similarly, the spore-forming bacilli, which could have contaminated the grains used for the production of the feeds from the farm, are able to perpetuate in the feeds despite the low water activity, because of their tolerant abilities. The presence of these isolates in the feeds is of public health concern. Apart from the fact that these bacteria can deplete the nutritional value of the feeds through biodegradation (Arotupin *et al.*, 2007); they can also pose enormous health risks to the handlers and the poultry. Contamination of animal feed before arrival at and while on the farm contributes to infection and colonisation of food producing animals with these pathogens. Pathogens can then be transmitted through the food chain to humans and cause human foodborne illness (Crump *et al.*, 2002).

All the samples were also contaminated by fungi and similar fungal isolates have been reported in poultry feeds (Arotupin *et al.*, 2007; Okoli *et al.*, 2007; Saleemi *et al.*, 2010; Uwaezuoke and Ogbulie, 2008). Large numbers of these isolates belong to the toxigenic fungi involved in the human and animal food chains (Santin, 2005; Sweeney and Dobson, 1998). Mould contamination is wide spread in tropical countries where poultry production and processing are expanding rapidly (Okoli *et al.*, 2006; Van den Bergh *et al.*, 1990), where their growth poses the health risk of aflatoxicoses. The fungal contamination can arise from the ingredients, particularly grains that are used in compounding the feeds, and also as environmental contaminants from production facilities. The moulds are able to survive in the feeds because they are able to tolerate the low water activity either as vegetative forms or spores. The growth of fungi is further enhanced by the ineffective drying method, sun drying in this instance which may take longer time during cloudy weather. This can facilitate the production of mycotoxins by the toxigenic strains of fungi.

The incidence of aflatoxin in the feeds was obtained as 36%, showing that the potential problem of aflatoxicoses is high. It is important to be able to detect and quantify the mycotoxin concentration in foods and feeds destined for human and animal consumption (Whitaker *et al.*, 2005). Certain studies have established the ability of toxigenic fungal strains to produce mycotoxins (Campos *et al.*, 2008; Fraga *et al.*, 2007; Rashid *et al.*, 2008). In this study, the green fluorescence emitted by the aflatoxin spots on TLC is presumptive of the production of aflatoxins G1 and G2, which is known to be produced by *A. parasiticus*. The difficulty of removing mycotoxin makes prevention the best of control. However, many measures have been studied in an attempt to reduce infection by moulds, including the development of mould resistant species, alternative methods of soil cultivation, drying and storage techniques and so on. Recently, a HACCP like approach was evaluated as a means to provide a management tool to reduce or eliminate the hazards caused by fungal contamination (Scudamore, 2005). Avoiding mycotoxin accumulation in stored grains and oilseeds depends primarily on moisture control. If the product is too dry to allow fungal growth and it is kept dry, no further deterioration will occur. However, if there is insect or rodent activity, moisture migration, condensation, or water leaks, fungal growth that could lead to mycotoxin contamination will occur (Degirmencioğlu *et al.*, 2005). The risk of contamination by mycotoxins is an important food safety concern for grains and other field crops. Foods contaminated with mycotoxins, can cause illness and are associated with increased cancer risk (Degirmencioğlu *et al.*, 2005). In addition, there are indirect health risks to those who consume animal products containing residues of carcinogenic mycotoxins. Mycotoxins can be detected in meat, milk and eggs from animals that have consumed feed ingredients containing mycotoxins, and many countries have tolerance standards for mycotoxin residues in milk and meat products. Another concern is the potential economic losses from animal health and productivity problems (Dohlman, 2005). There is also the possibility of occupational exposure to aflatoxins through inhalation by the workers and the farmers who make use of the feeds. In a similar study, Viegas *et al.* (2013) reported detectable levels of AFB_1 in blood serum of workers of poultry and swine farms in Portugal. The study showed the possibility of occupational exposure to AFB_1 through inhalation.

The physical, chemical and microbiological properties of feeds have a great importance in the quality of feed, the health of the animals which consume the feeds and also the quality and safety of the food products obtained from them (Degirmencioğlu *et al.*, 2005). Therefore, to prevent the diseases which can affect the performance of the livestock and maintain the safety of the product; feed factories should have critical control and control points according to HACCP system. Several practices employed by the small-scale outfits are particularly sources of microbial contaminants. In this study, efforts were made to evolve HACCP system that can be adapted for implementation towards ensuring the safety of the poultry feeds. To the best of our knowledge, there is dearth of information on the application of HACCP in this sector (small-scale feed-producing enterprises) in the country. It is expected that a number of monitoring and corrective measures are achievable in this sector. The implementation of the system calls for proper training of the factory workers on good manufacturing and hygienic practices, and investment in infrastructure such as storage facilities, cabinet dryers, dehumidifiers, cooling systems and equipment such as

thermo-hygrometer, gloves, aprons, personal protective equipment, and portable UV lamp. It is important that feed ingredients are sourced from reliable agents, who also adopt good agricultural practices to eliminate the procurement of infested grains. However, in every case, true representative of bulk samples should be examined.

In conclusion, it has been shown in this study that poultry feeds obtained from small-scale producers were of low microbial quality as all of them were contaminated with both bacteria and fungi. It was also observed that about 36% of the samples showed evidence of contamination with aflatoxin, all indicating poor feed safety. However, the feeds appeared to contain enough nutrients to support the growth of different types of poultry as revealed by their proximate compositions. It was discovered that poor manufacturing practices by these small-scale producers contributed enormously to the level of microbial and aflatoxin contamination. Since the poultry sector is witnessing rapid expansion in the country, the surge in the establishment of these small-scale enterprises has also been an upward trend. The socio-economic factors surrounding the establishment of such outfits, and the relative affordability and availability of the feeds compared with established local and imported brands make it imperative for the concerned regulatory authorities to take steps to improve the quality of feeds churned out by these outfits.

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