Original Article

Biosecurity practices in commercial and house hold poultry farms in the Delta region, Egypt: I- Correlation between level of biosecurity and prevalence of poultry mites

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Abstract

The risk of parasitic disease outbreaks among commercial poultry farms can result in significant economic loss for the farmer and the integration. These diseases can be reduced by the proper application of biosecurity measures. This study primarily aimed at assessing the current biosecurity practices applied in different kinds of poultry farm (broiler, layer, duck and mixed farms) in Kafrelshiekh Governorate (Delta region), Egypt. Correlating the compliance of the studied biosecurity measures with the prevalence of poultry mites in the surveyed farms was the second aim. For achieving these aims, on-farm questionnaire surveys and observational studies were conducted from January 2017 to August 2018 in 74 poultry farms (46 broiler chicken ,8 layer ,6 duck and 14 mixed) from both farm systems: commercial farm based (CFB) (representing 56.7%) and house hold based (HHB) (43.24 %). A total of 148 samples (74 litter and 74 dust samples) were taken for mite isolation. The results showed that Commercial based (CFB) broiler farms have a higher level of biosecurity than house hold based (HHB) farms and the only biosecurity program clearly known to most farm owners is cleaning and disinfection. *Ornithonyssus bursa*, known as the "tropical fowl mite" was isolated from both farm types with a higher prevalence in HHB farms (75%), and there was a positive correlation between bad hygiene and the prevalence of mites in the surveyed farms. The current survey results can give stake holders and policy makers an idea about the current situation of the level of biosecurity application in both HHB and CFB farms in the studied area.

Keywords: Biosecurity practices, Poultry farms, Egypt, *Ornithonyssus bursa*, Prevalence

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Introduction

Poultry production is an important and diverse component since eggs and meat are part of the health and diet for the large population all over the world. The world has over 23 billion poultry birds - about three per person on the planet (Faostat, 2016),- and about 5 times more than 50 years ago. Poultry are kept and raised in a wide range of production systems and provide mainly high-quality meat, eggs and manure for crop fertilization.

Egypt's annual consumption of poultry is around 1.2 billion birds, the equivalent of around 1125 million tons of poultry meat. The total volume of poultry meat consumed in 2026 will be 14% more than the volume consumed in 2017 (FAO, 2017). Furthermore, poultry production systems in Egypt are quite diverse, ranging from rural very small-scale extensive poultry production to highly intensive systems with over 70,000 birds per house in industrial commercial systems. Commercial poultry farms of various sizes provide about 90 percent of the chicken produced in Egypt with the remaining 10 percent provided by the small-scale household poultry farms that are abundant in villages and cities (FAO, 2017; Hosny, 2006; Geerlings *et al.*, 2007; Fasina *et al.*, 2012) and is considered a very important sector in Egypt.

Bio-security means security against infectious biological agents including bacteria, viruses, protozoa, fungi, parasites and any other agents capable of introducing an infectious disease into poultry flocks (Permin and Detmer, 2007; Fasina *et al.*, 2012; Scott *et al.*, 2018). Such infectious agents, whether they cause clinical or subclinical disease, significantly reduce the productivity, profitability and financial viability of the poultry industry (Steenwinkel *et. al.*, 2011). Biosecurity considered a fundamental part of any successful poultry manufacture system.

Biosecurity measures are structural or operational, internal or external. The external schemes are those measures applied to prevent the entry of new diseases into a flocks or production groups, while internal biosecurity measures on the other hand, are those procedures taken to prevent the spread of a disease already in the flocks (Ajewole and Akinwumi, 2014). Furthermore, recurrent global disease outbreaks in poultry farms have made the practice of biosecurity an important tool to protect poultry farms from the intentional and unintentional threat of any disease producing agents on the farms (Ajewole and Akinwumi, 2014).

In Egyptian small-scale poultry units, there are many technical difficulties in the application of some biosecurity practices to reduce the chance of occupational Zoonoses of poultry origin (Fasina *et al.*, 2007; Hogerwerf *et al.*, 2010, Yitbarek *et al.*, 2016), which it is recommended should be applied in large-scale commercial units (Hosny, 2006; Guerne-Bleich *et al.*, 2009; Newell *et al.*, 2011).

The economics of poultry farming may be hindered by frequent outbreaks of disease due to defects in the biosecurity programs of the poultry farms. Of these infectious diseases, parasitic contagions may cause considerable damage and great economic loss to the poultry industry due to malnutrition, decreased feed conversion, weight loss, lowered egg production and the death of young birds.

Mites [*Dermanyssus* (De Geer, 1778) and *Ornithonyssus* (Berless,1888)] are one of the most important avian ectoparasites which are found on bird species in different rearing systems worldwide. Their presence is problematical for the producers either through the direct potential effects on weight gain, egg production or as nuisance insects to workers handling hens and eggs (Hogsette *et al.*, 1991). Furthermore, the poultry mite is increasingly being suspected as a disease vector and reports indicating that attacks on alternative hosts, including humans, are becoming more public on a worldwide basis (Sparagano *et al.*, 2014).

A lot of previous studies have focused on the relationship between biosecurity practices and bacterial or viral disease causing agents (Negro-Calduch *et al.*, 2013; Newell *et al.*, 2011); however, there is still a deficiency in data concerning the relationship with parasitic disease-causing agents. Therefore, the present study primarily aimed at assessing the current biosecurity practices applied in different kinds of poultry farms (broiler, layer, duck and mixed farms), in Kafrelshiekh Governorate (Delta region), Egypt. To the author's knowledge there have been no previous studies investigating the correlation between the biosecurity practices applied in poultry farms and the prevalence of some parasites, which are of public health importance. So the secondary aim of the current study is to investigate the role of applying biosecurity practices in controlling some ectoparasites, particularly mite species on poultry farms.

Materials and Methods

This study was conducted in 74 poultry farms in the Delta region from January 2017 until August 2018, to evaluate the level of biosecurity practices compliance and to quantify the likelihood of mite prevalence in these farms in relation to the level of application of theses biosecurity measures. Likewise, finally to address the most effective biosecurity items correlating with prevalence of this parasite and effecting its control.

Assessment of the biosecurity practice in examined farms:

a. Selection and description of poultry premises: The current study was applied in poultry farms in and around Kafrelshiekh Governorate, Egypt, which is about 134 km north of Cairo in the Nile Delta of lower Egypt (Latitude: 31° 06' 25.20" N Longitude: 30° 56' 26.99" E). The selected farms in this study were of two scale systems which vary in production level and size. CFB either defined as farms stocking 1000 or more birds (East, 2007) or those housed separately in designed farms with one or more barn (Scott *et al.*, 2018). Usually this type contains 1-4 sheds, producing 1–7 cycles per year. However, the other scale HHB, refers to birds that are housed in human houses on the roof top of the house or in an empty room inside the human house (Fasina *et al.*, 2016) and numbers range approximately from one to five hundred birds per production cycle. Different types of poultry species of both production systems were chosen in this survey (broiler chicken, layer chicken, duck and mixed) as detailed in Table 1.

b. Farm survey: Questionnaire surveys and observational study were conducted to collect data on bio security measures and problems associated with selected poultry farms in and around Kafrelshiekh Governorate. The current survey was conducted from January 2017 to August 2018 in a total of 74 poultry farms (46 broiler chicken, 8 layer ,6 duck and 14 mixed) in order to describe the biosecurity practices being implemented on these farms.

For each type of poultry scale system, a structured questionnaire was designed, both in Arabic and English. The questionnaire was divided into four parts and included both standardized closed and semi-closed questions, in total consisting of 6 pages: 1. General farm data: location; system scale; capacity; bird species and presence of other species or other animals. 2. Restricted access to the birds: restrictions on visitors; multiple species rearing; isolation and quarantine of new birds; sheds or contact with birds; presence of fence around premises. 3. utilization of borrowed equipment/sprayers and entrance order. 4. cleaning and disinfection: all-in-all-out pest control; access of wild birds to fresh litter and manure; access of rodents and wild birds to feed storage; feeding outside; type of drinking and cleaning water; visitors. 5. Other biosecurity practices: method of disposal of farm waste; allocation of waste water; disposal of dead birds; presence of ponds around the farm; presence of grass around the farm; keeping different age groups together; isolation pens for diseased birds and rodent control. 6. socio-economic profiles of the respondent: occupation in the farm; age; sex; the experienced of symptoms of ill health that lasted 2–5 days or more within 6 months and personal hygiene: utilization of on-farm clothes and footwear; wearing of gloves or washing hands after handling; using respirators and using face masks.

Isolation of mites from dust & litter samples of surveyed poultry farms: A total of 74 dust samples from the surveyed farms' air, windows and suction fans, as well as litter samples were gathered individually in polyethylene plastic bags and taken to the laboratory for mite isolation. The collected specimens were processed by floatation technique. The recovered mites were stored in 70% ethanol for a few days, followed by overnight incubation in 10 % NaOH solution and then clearing was done by keeping the mites for 1–2 hours in lactophenol. The mites were then gently washed with distilled water and transferred on to a small drop of Hoyer's medium on microscope slides. The prepared specimens were observed and photographed using an Olympus light microscope. The recovered mites were identified with the aid of the key developed by to Baker (1999) and Stoll and Verlag (2000).

Data analysis: Data was collected, coded, revised and entered on the Statistical Package for Social Science (IBM SPSS) version 20. The data was presented as number and percentages for the qualitative data, mean, standard deviations and ranges for the quantitative data with parametric distribution and median with inter quartile range (IQR) for the quantitative data with non-parametric distribution.

Chi-square test was used in the comparison between two groups with qualitative data and Fisher exact test was used instead of the Chi-square test when the expected count in any cell found less than 5.

The confidence interval was set to 95% and the margin of error accepted was set to 5%. So, the p-value was considered significant (P < 0.05).

Results

Assessment of the biosecurity practice in examined farms:

a. Farm survey: Of the total surveyed poultry farms, 62.2% (46) were broiler, 10.8% (8) were layer, 8.1% (6) duck and 18.9% (14) were mixed). The examined farms were classified according to the housing scale system for commercial farm based (representing 56.7%) and house hold based (43.24 %).43.5% of broiler farms housed 5000 bird /farm while 100% of surveyed layer, duck and mixed farms were housed with less than 1000 bird /farm. Description of poultry farms according to species, system type, no. of birds per farm, stocking density and no. of cycles per year are summarized in Table (1).

b. Level of compliance with biosecurity practices in different types of poultry farms:

I- Restricted access to birds: Restriction of visitors: in farms varied significantly from 69.6% in broiler to only 12.5 % on layer farms (P = 0.002) (Table.2), while there was no significant difference between CFB and HHB (Table.4). Multiple species rearing occurred more commonly in mixed type farms (71.4%) than other types (P = 0.00001), and in HHB (37.5 %) than CFB (4.76%) with marked significant difference (P = 0.0003) (Tables 2 and 4). Table.4 shows that utilization of borrowed equipment/sprayers occurred mostly in CFB (21.4%) rather than HHB (3.125%) with significant difference (P= 0.022). Other practices such as isolation and quarantining of new birds, the presence of fences around premises and contact with birds insignificantly differed between bird species and between the CFB and HHB systems (P > 0.05) as shown in Table. 2 and 4.

II- Cleaning and sanitation: Table. 2 shows that cleaning and disinfection of farm equipment was common in all farm types, with the highest proportion of farms conducting this practice being reported among broiler farms (95.6%), with the lowest being among layer farms (50%). Additionally, this practice was applied more in CBF than HHB system with significant difference (P= 0.0003) (Table.4). Cleaning and disinfection of poultry houses was applied in all the studied farms with significant difference among farm types (P< 0.05). Table.4 shows that cleaning and disinfection was applied more in CFB than in the HHB system with significant difference (P= 0.003). Spraying as a method of disinfection was used more in all types of farms and in both farm systems (CFB and HBB) rather than fumigation (table.2 and 4). There is a significant difference between different types of farms in the application of spraying (p= 0.0008) (Table.2)

III- Personnel hygiene: The result of the utilization of on-farm clothes and footwear was more commonly applied in broiler farms 69.6% as compared to the other farm types (12.5 %,16.7% and 14.3% on layer, duck and mixed farms, respectively), with marked significant difference (P<0.05). The wearing of gloves or washing hands after handling less commonly occurred in all farm types (17.4 %, 12.5%, 16.7% and 14.3% in broiler, layer, duck and mixed farms, respectively). Utilization of on farm clothes and footwear was more highly applied in CFB than HHB farms with great significant difference (P= 0.00001) as clarified in Table (4). Furthermore, the presence of foot baths on farms varied significantly from 56.5% in broiler farm types to only 12.5% of layer farms (P< 0.05).

IV- Disposal of waste and dead carcasses: Disposal of farm waste to fish farms varied significantly from 73.9% in broiler farms to 12.5%, 16.7% and 14.3% in layer, duck and mixed farms respectively (P<0.05). 83.3% of duck farms dispose of their waste as land fertilizer compared to 30.4% in broiler farms (P<0.05). Disposal of farm waste to domestic rubbish applied more in layer (87.5%) and duck farms (83.3 %) than other farm types as described in Table (3). Likewise, the same table indicates that the application of burying for the disposal of dead birds was uncommon in all farm types. About 30.4% of broiler farms throw dead birds in the canal, while this is less common in other farm types. The majority of layer farms (87.5%) dispose of dead birds by throwing them into domestic rubbish followed by mixed farms (57%) then broiler farms (34.7%); the lowest proportion of farms that apply this practice was recorded in duck farms (33%) (P<0.05). Feeding dead birds to pets in order to get rid of them was uncommon in all farm types. Burning dead birds occurred mostly in duck farms (66.7%) compared to other farm types as described in Table (3). Disposal of farm waste to fish farms was applied more frequently in CFB than HHB farms with marked significant difference (P=0.00001) (Table.5). Whereas disposal to domestic rubbish was applied more in HHB than CFB farms, also with marked significant difference (P=0.00001). Disposal of dead birds by throwing them into canals was used more in CFB (33.3%) than HHB farms (6.25%) (P=0.005) as detailed in Table. 5.

V- Managemental and structural biosecurity items: The presence of neighboring farms within 500 m was reportedly high across all farm types; however, it differed among farm types; 100% of duck farms have neighboring farm but the percentage in other farm types was 95.7 %, 87.5% and 85.7% on broiler, layer and mixed farms respectively. The presence of trees around the farm was found in 91.3%,12.5%, 66.7% and 57.1% of broiler, layer, duck and mixed farms, respectively (P<0.05) (Table.3). 73.9 % of broiler farms reported the presence of ponds around them with 57.1% of mixed farms and 50% of layer farms and finally 33.3 % on duck farms (P= 0.05). The presence of stray dogs and /or cats was recorded in 73.9% ,12.5%, 16.7% and 57.7% of broiler, layer, duck and mixed farms respectively (P=0.001). Table. 3 shows that rodents were detected most in 87.5% of layer farms while they were present in 43.5 %, 33.3% and 42.8 of broiler, duck and mixed farms respectively. Access of wild birds was uncommon in all farm types; however, it was present on 42.9 % of mixed farms (P<0.05). Keeping different age groups together occurred significantly in all duck farms (100%) and 87.5%, 57.1% and 17.39% of layers, mixed and broiler farms, respectively (P<0.05). Isolation pens for diseased chickens existed on 78.3%, 50%, 66.7% and 71.4% of broiler, layer, duck and mixed farms, respectively. A deep litter system was the most used system in all surveyed farms (100 %,97.8%, 87.5% and 85.7 %of duck, broiler, layer and mixed farms respectively). Wood shavings as a bedding material were found mostly on broiler farms (60.9%) (P <0.05). Straw was used as a bedding material in 50% of layer farms. All duck farms (100%) used hay as bedding material and about half of layer farms were recorded to use the same material (P<0.05). Cage systems rarely existed in all farm types (p<0.05).An All in All out system was applied more in broiler farms (65.2%) than other farm types (P= 0.001) as shown in Table (3).

Table.5 shows that the presence of trees, grasses and ponds with higher frequency in CFB than HHB farms (p<0.05). Stray dogs and cats were observed more in CFB than HHB farm (P = 0.004). On the other hand, access of wild birds, keeping different age groups together and using hay as a bedding material were applied higher in HHB than CFB farms (P > 0.05). In contrast wood shavings were used as a bedding material more frequently in CFB than HHB farms and the All in All out system was also applied more in CFB than HHB farms (p< 0.05).

Correlation between biosecurity measures and prevalence of Ornithonyssus bursa:

I- Prevalence of Ornithonyssus bursa in surveyed farms with different rearing systems: Out of 74 poultry farms examined, 62 were found to be infected with mites, reflecting that a total percentage of infection reached 83.8%. Concerning the distribution of infection in surveyed farms, the present study discovered that 70.96% of the HHB farms were afflicted, whereas 35.48% of the commercial based farms on the other hand, were found to be positive. This marked difference was found to be statistically significant ($\chi2$= 8.121, p<0.004) as depicted in Table .6. The same table also summarizes the relationship between the prevalence rate and the sample type. From this table it is evident that the dust samples had a higher infection rate (75.7%) than the litter samples (48.6%). This marked difference was found to be statistically significant ($\chi2$= 11.49, p<0.0006). Additionally, the same table demonstrates that the dust samples showed highest prevalence (71.42 and 81.28%) in both types of surveyed farms, as compared to the litter samples (33.33% and 68.75%), with marked statistical significance (P<0.05).

Considering the intensity of infestation, the obtained results demonstrated that the number of recovered mites was 100 and ranged between 1 and 150 per farm. All inspected farms were found to be infested with *Ornithonyssus bursa*. *Ornithonyssus bursa* is a Dermanyssoid mite but it is placed in the family

Macronyssidae. *O. bursa* can be distinguished from other mite species as follows: the chelicera of females is elongated but with well-developed, distinct fixed and movable digits and anus present on the anterior half of anal plate. (Fig. 1, a-d)

II- Prevalence of O. bursa in relation to the application of restricted access to the birds and cleaning and disinfection: Table. 7, Visitors were not allowed to enter poultry sheds in 58 farms (78.3%) and this restriction was found to be associated with the prevalence of *Ornithonyssus bursa*. Higher prevalence (89.6%) was observed in farms that restricted visitors than those that allowed visitors to enter (62.5%) with a significant difference between them (P = 0.009). Housing of multiple species was applied in 13.5% of surveyed farms, 100% of these farms were positive for *Ornithonyssus bursa*, while 81.3% only in farms which housed only one species.

Most of the farms did not have fence around them (97.2%) Only two farms, in which no *Ornithonyssus bursa* was detected, had a fence compared with 86.1% prevalence in farms without fence. Contact with external birds was found in 18.9% of examined farms and it increased the prevalence of *Ornithonyssus bursa* (85.7%). Utilization of borrowed equipment/sprayers was found to be related with a reduced occurrence of *Ornithonyssus bursa*.

Table. 7 also revealed that the absence of cleaning and disinfection of farm buildings and farm equipment, together with the absence of foot baths and spraying as a method of disinfection, were linked with a higher prospect of *Ornithonyssus bursa* occurrence (100%,100%, 95.45% and 100% respectively).

III- Prevalence of Ornithonyssus bursa in relation to methods used for waste and carcass disposal: Table. 8 shows that disposal of farm litter and / or manure to fish farms or as land fertilizer was associated with a lower prevalence of *Ornithonyssus bursa*. However, throwing of it into domestic rubbish was significantly associated with a higher prevalence of *O. bursa* (P=0.01). Disposal of dead birds through burning, burying or feeding to dogs was associated with a lower prevalence of *O. bursa* than disposing of it into domestic rubbish or into canals.

Table 1 Description of poultry premises

Farm type	No of farms/ type	No of birds /Farm					No of cycles/year						Stocking density Bird/m2					Scale system	
		<5000 (12)			5000 (20)	>5000 (14)	1	2-3	3-4	4-5	5-7	Not fixed	5	8-10	10-15	20	Not deter mined	Comm ercial farm	House hold
		500-1000	100-200	50															
Broiler	46	6	2	4			-	6	4	4	24	8	-	34	4	4	4	40	6
Layer	8	8			-	-	4	4	-	-	-	-	-	-	-	-	8	-	8
Duck	6	6			-	-		2	-	-	4	-	-	-	-	-	6	-	6
Mixed	14	14			-	-	8	-	-	-	2	4	2	-	-	-	12	2	12

Table 2 Biosecurity practices information related to restricted access to the birds, cleaning and sanitation, and personal biosecurity practices in surveyed farms with different species (broiler, layer, duck and mixed farms).

Biosecurity practices	Type of poultry farm				
	Broiler farm (n=46)	Layer farm (n=8)	Duck farm (n=6)	Mixed farm (n=14)	P value
Restricted access to the birds (%)					
Restriction to visitors	69.6 (n= 32)	12.5(n =1)	83.3(n= 5)	85.7(n= 12)	0.002
Multiple Species rearing	2.2 (n= 1)	87.5 (n= 7)	16.7 (n= 1)	71.4(n= 10)	0.00001
Isolation and quarantine of new birds	17.4(n= 8)	12.5(n= 1)	16.7 (n= 1)	28.6(n= 4)	0.76
Presence of fence around premises	2.2 (n= 1)	12.5(n= 1)	16.7 (n= 1)	14.3(n= 2)	0.24
sheds or contact with birds	17.4(n= 8)	12.5(n= 1)	16.7 (n= 1)	42.8(n= 6)	0.19
Utilization of borrowed equipment / sprayers	21.7(n= 10)	12.5(n= 1)	16.7 (n= 1)	7.1 (n=1)	0.626
Cleaning and Sanitation (%)					
Cleaning and disinfection of farm equipment	95.6 (n= 44)	50 (n= 4)	66.7(n= 4)	57 (n= 8)	0.0005
Cleaning and disinfection of poultry houses	97.8 (n= 45)	87.5 (n= 7)	83.3 (n=5)	42.8 (n= 6)	0.00001
Method of disinfection (spraying)	91.3 (n= 42)	87.5 (n= 7)	83.3 (n=5)	42.8 (n= 6)	0.0008
Method of disinfection (Fumigation)	8.7 (n= 4)	12.5(n= 1)	16.7 (n= 1)	7.1 (n=1)	0.5693
Personnel biosecurity practices (%)					
Utilization of on-farm cloths and footwear	69.6 (n= 32)	12.5(n= 1)	16.7 (n= 1)	14.3(n= 2)	0.00009
Wearing of gloves or washing hands after handling	17.4(n= 8)	12.5(n= 1)	16.7 (n= 1)	14.3(n= 2)	0.98
Presence of foot bath	26 (56.5)	12.5(n= 1)	16.7 (n= 1)	28.6(n= 4)	0.02

Table 3 Biosecurity practices information related to disposal of wastes and dead carcasses and managemental and structural biosecurity practices in surveyed farms with different species (broiler, layer, duck and mixed farms).

Biosecurity practices	Type of poultry farm				
	Broiler farm (n=46)	Layer farm (n=8)	Duck farm (n=6)	Mixed farm (n=14)	P value
Disposal of wastes and dead carcasses					
Method of disposal of farm wastes (to fish farm)	73.9 (n=34)	12.5 (n=1)	16.7 (n=1)	14.3 (n=2)	0.00001
Method of disposal of farm wastes (applied as land fertilizer)	30.4 (n=14)	12.5 (n=1)	83.3 (n=5)	14.3 (n=2)	0.0117
Method of disposal of farm wastes (to Domestic rubbish)	8.7 (n=4)	87.5 (n=7)	83.3 (n=5)	71.4 (n=10)	0.00001
Method of disposal of dead birds (throwing in canals)	30.4 (n=14)	12.5 (n=1)	16.7 (n=1)	14.3 (n=2)	0.475
Method of disposal of dead birds (burying)	17.4 (n=8)	12.5 (n=1)	16.7 (n=1)	7.1 (n=1)	0.141
Method of disposal of dead birds (fed to pet animals)	13 (n=6)	12.5 (n=1)	16.7 (n=1)	7.1 (n=1)	0.264
Method of disposal of dead birds (to Domestic rubbish)	34.7 (n=16)	87.5 (n=7)	33 (n=2)	57 (n=8)	0.005
Method of disposal of dead birds (burning)	26.1 (n=12)	12.5 (n=1)	66.7 (n=4)	28.6 (n=4)	0.051
Managemental and structural biosecurity practices					
Presence of neighboring farms within 500m	95.7(n=44)	87.5(n=7)	100(n=6)	85.7(n=12)	0.0382
Presence of trees around the farm	91.3(n=42)	12.5(n=1)	66.7(n-4)	57.1(n=8)	<0.001
Presence of pond around the farm	73.9(n=34)	50 (n=4)	33.3(n=2)	57.1(n=8)	0.0347
Presence of stray dogs and /or cats	73.9(n=34)	12.5(n=1)	16.7(n=1)	57.1(n=8)	<0.001
Presence of Rodents	43.5(n=20)	87.5(n=7)	33(n=2)	42.8(n=6)	0.115
Access of wild birds	8.7(n=4)	12.5(n=1)	16.7(n=1)	42.9(n=6)	0.004
Keeping different age group together	17.39(n=8)	87.5(n=7)	100(n=6)	57.1(n=8)	<0.001
Isolation pen for diseased chicken	78.3(n=36)	50(n=4)	66.7(n=4)	71.4(n=10)	0.402
Farm housing system (deep letter)	97.8(n=45)	87.5(n=7)	100(n=6)	85.7(n=12)	0.032
Farm housing system (cage)	2.2(n=1)	12.5(n=1)	16.7(n=1)	14.3(n=2)	0.032
Bedding material used (wood shaving)	60.9(n=28)	12.5(n=1)	16.7(n=1)	14.3(n=2)	<0.001
Bedding materials used (straw)	30.4(n=14)	50(n=4)	16.7(n=1)	42.9(n=6)	0.188
Bedding materials used (hay)	8.7(n=4)	50(n=4)	100(n=6)	28.6(n=4)	<0.001
All in All out system	65.2(n=30)	12.5(n=1)	16.7(n=1)	28.6(n=4)	<0.001

Table 4 Comparison between Commercial farm based (CFB) system and house hold based (HHB) system in relation to restricted access to the birds, cleaning and sanitation, and personal biosecurity practices

Biosecurity practices	Type of poultry farm		
	Commercial farm based (N= 42)	House hold based (N=32)	P value
Restricted access to the birds (%)			
Restriction to visitors	71.4 (n= 30)	87.5(n= 28)	0.09
Multiple Species rearing	4.8 (n= 2)	37.5(n=12)	0 .00036
Isolation and quarantine of new birds	2.4 (n= 1)	9.3(n= 3)	0.187
Presence of fence around premises	2.4 (n= 1)	3.1(n=1)	0.844
Sheds or contact with birds	19 (n= 8)	18.7(n= 6)	0.974
Utilization of borrowed equipment/sprayers	21.4 (n= 9)	3.1(n=1)	0 .0225
Cleaning and Sanitation (%)			
Cleaning and disinfection of farm equipments	95.2(n= 40)	62.5(n=20)	0.00036
Cleaning and disinfection of poultry houses	97.6(n= 41)	75(n= 24)	0.003185
Method of disinfection (spraying)	90.4(n= 38)	75(n= 24)	0.07356
Method of disinfection (Fumigation)	7.14 (n= 3)	3.1(n=1)	0.448
Personnel hygiene (%)			
Utilization of on-farm cloths and footwear	80.9(n= 34)	3.1(n=1)	0.00001
Wearing of gloves or washing hands after handling	19 (n= 8)	6.2(n=2)	0.1106
Presence of foot bath	66.7(n= 28)	6.2(n=2)	0.00001

Table 5 Comparison between Commercial farm based (CFB) system and house hold based (HHB) system in relation to disposal of wastes and dead carcasses and managemental and structural biosecurity practices

Biosecurity practices	Type of poultry farm: Commercial farm based (N= 42)	House hold based (N=32)	P value
Disposal of wastes and dead carcasses (%)			
Method of disposal of farm wastes (to fish farm)	83.3(n= 35)	3.1(n= 1)	0.00001
Method of disposal of farm wastes (applied as land fertilizer)	28.5(n=12)	12.5(n= 4)	0.0961
Method of disposal of farm wastes (to Domestic rubbish)	2.4(n=1)	84.3 (n=27)	0.00001
Method of disposal of dead birds (throwing in canals)	33.3(n=14)	6.25(n=2)	0.005
Method of disposal of dead birds (burying)	16.7(n=7)	3.1(n= 1)	0.06309
Method of disposal of dead birds (fed to pet animals)	11.9 (n= 5)	3.1(n= 1)	0.1704
Method of disposal of dead birds (to Domestic rubbish)	38(n= 16)	56.2(n= 18)	0.1205
Method of disposal of dead birds (burning)	23.8(n=10)	31.2(n=10)	0.475
Managemental and structural biosecurity practices (%)			
Presence of neighboring farms within 500m	90.4(n= 38)	96.9 (n= 31)	0.277
Presence of trees around the farm	95.2(n= 40)	43.8(n= 14)	0.00001
Presence of pond around the farm	85.7(n= 36)	37.5 (n= 12)	0.000017
Presence of stray dogs and /or cats	76.1(n= 32)	43.8(n= 14)	0.004363
Rodents	47.6(n= 20)	43.8(n= 14)	0.7407
Access of predator (wild birds)	4.8 (n=2)	25(n= 8)	0.01164
Keeping different age group together	4.8 (n=2)	75(n= 24)	0.00001
Isolation pen for diseased chicken	34(80.95%)	56.2(n= 18)	0.0212
Farm housing system (deep letter)	97.6(n= 41)	93.7(n= 31)	0.8449
Farm housing system (cage)	2.4(n= 1)	3.1(n= 1)	0.844
Bedding material used (wood shaving)	69(n= 29)	3.1(n= 1)	0.00001
Bedding materials used (straw)	28.6(n= 12)	37.5 (n= 12)	0.4163
Bedding materials used (hay)	2.4(n= 1)	53.1(n= 17)	0.00001
All in All out system	76.1(n= 32)	6.25(n= 2)	0.00001

Table 6 Prevalence of mite spp. in surveyed farms with different systems (commercial farm based and House hold based)

Parasite	Commercial based farm			House hold based			P value
Sample type	Litter/ Manure=42	Air(dust)=42	Total	Litter/ Manure=32	Air=32	Total	
	N (%)	N (%)	N (%)	N (%)	N (%)	N (%)	
Ornithonyssus bursa	14 (33.33%)	30 (71.42%)	44 (52.38)	22 (68.75)	26 (81.25)	48 (75)	0.004

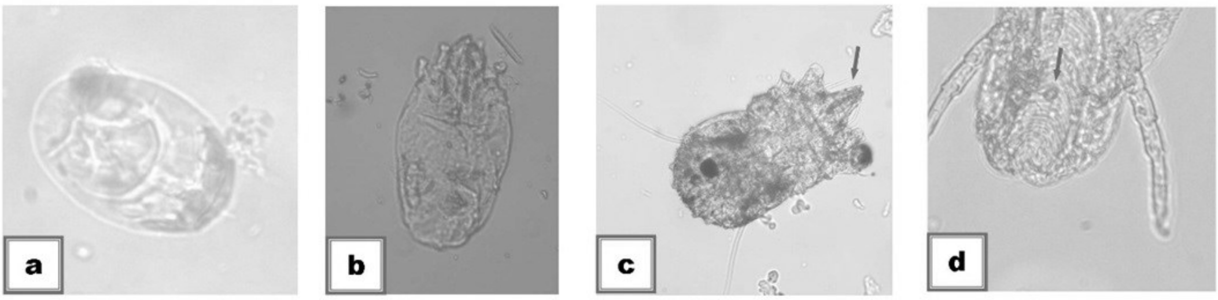

Figure 1 a) *O. bursa* eggs, b) *O. bursa* nymph stage, c) *O. bursa* adult stage showing elongated chelicerae (arrow) and d) *O. bursa* showing anus at the anterior half of anal plate (arrow)

Table 7 Prevalence of mite spp. in relation to restricted access to the bird; the application Cleaning and disinfection in surveyed poultry farms

Parasite	Restricted access to the bird		
	Restriction to visitors		
	P=58	A=16	P value
Ornithonyssus bursa	89.6 (n=52)	62.5 (n=10)	0.009
	Multiple Species rearing		
	P=10	A=64	
	100 (n=10)	81.3 (n=52)	0.49
	Isolation and quarantine of new birds		
	P=12	A=62	
	100(n=12)	80.6(n= 50)	0.35
	Presence of fence around premises		
	P=2	A=72	
	0 (n=0)	86.1(n= 62)	0.001
	Contact with birds		
	P=14	A=60	
	85.7(n=12)	83.3(n=50)	0.82
	Utilization of borrowed equipment/sprayers		
	P=10	A=64	
	60 (n=6)	87.5(n=56)	0.02
	The application Cleaning and disinfection		
	Cleaning and disinfection of farm equipment's		
	P= 60	A=14	
Ornithonyssus bursa	80(n=48)	100(n=14)	0.068
	Cleaning and disinfection of poultry houses		
	P= 66	A=8	
	81.8(n=54)	100(n=8)	0.371
	Method of disinfection (spraying)		
	P=62	A=4	
	80.6(n=5)	100(n=4)	<0.001
	Method of disinfection (Fumigation)		
	P= 4	A= 62	
	100 (n=4)	80.6(n=50)	<0.001
	Presence of foot bath		
	P=30	A=44	
	66.7(n=20)	95.4(n=42)	0.008

P: means presence of biosecurity practice in surveyed poultry farms (poultry farms that applied the mentioned biosecurity practice)
A: absence of biosecurity practice in surveyed poultry farms (poultry farms don't apply the mentioned biosecurity practice)

Table 8 Prevalence of mite spp. in relation to disposal of wastes and dead carcasses in surveyed poultry farms

Parasite	Disposal of wastes and dead carcasses		
	Method of disposal of farm wastes (to fish farm)		
	P= 36	A=38	P value
	77.8(n=28)	89.5(n=34)	0.172
	Method of disposal of farm wastes (land fertilizer)		
	P=16	A=58	
	75(n= 12)	79.3(n= 50)	0.282
	Method of disposal of farm wastes (to domestic rubbish)		
	P=28	A=46	
Ornithonyssus bursa	100(n=28)	73.9(n=34)	0.010
	Method of disposal of dead birds (Throwing in canals)		
	P=16	A=58	
	100 (n=16)	79.3(n=46)	0.047
	Method of disposal of dead birds (burying)		
	P=8	A=66	
	50(n=4)	87.9(n=58)	0.006
	Method of disposal of dead birds (fed to pet (dog)		
	P=6	A=68	
	66.7(n=4)	85.3(n= 58)	0.235
	Method of disposal of dead birds (to domestic rubbish)		
	P= 34	A=40	
	94(n= 32)	75(n=30)	0.026
	Method of disposal of dead birds (burning)		
	P= 20	A=54	
	80(n=16)	85.2(n=46)	0.590

IV- Prevalence of Ornithonyssus bursa in relation to managemental and structural biosecurity practices: Table. 9 also summarizes the effect of some structural biosecurity items and managemental factors on the prevalence of *O. bursa* in the surveyed farms. From this table, it is evident that the presence of neighboring farms (within 500 m) made farms more likely to be positive with *O. bursa*. Conversely, the presence of trees around farms was found to be associated with a reduced occurrence of mites. Keeping different age groups together was found to enhance the presence of *O. bursa.* The presence of isolation pens for diseased birds and systems for controlling rodents were shown to reduce the incidence of *O. bursa*. Cage systems of housing showed a lower prevalence of mites than deep letter systems. Using straw and hay as a bedding material was associated with a higher prevalence of *O. bursa*. than using wood shavings. Furthermore, the application of All in all-out systems of management was significantly associated with decreasing the prevalence of *O. bursa*. in the examined farms (P= 0.025). Rodents were present in 48.6% of the surveyed farms. These farms showed a higher prevalence of *O. bursa*. (88.9%) than farms with no rodents.

Table 9 Prevalence of mite spp. in relation to managemental and structural biosecurity practices in surveyed poultry farms

	Managemental and structural biosecurity practices		
Ornithonyssus bursa	Presence of neighboring farms (within 500 m)		
	P= 70	A= 4	P value
	88.6(n=62)	0 (n=0)	<0.001
	Presence of trees around the farm		
	P= 54	A= 20	
	81.5(n= 44)	90(n=18)	0.037
	Presence of grasses around the farm		
	P= 48	A= 26	
	75(n=36)	100(n=26)	0.005
	Presence of pond around the farm		
	P= 48	A= 26	
	79.2(n=38)	92.3(n=24)	0.143
	Keeping different age group together		
	P= 30	A= 44	
	100(n=30)	72.7(n=32)	0.002
	Isolation pen for diseased birds		
	P= 54	A= 20	
	77.8(n=42)	100(n=20)	0.059
	Rodent control		
	P= 34	A= 40	
	82.3(n=28)	85(n=34)	0.758
	Access of predators (wild birds)		
	P= 10	A= 64	
	80(n=8)	84.4(n=54)	0.727
	Farm housing system (deep litter)		
	P =72	A= 2	
	83.3(n=60)	100(n=2)	0.528
	Farm housing system (cage)		
	P= 2	A=72	
	0(n=0)	86(n=62)	0.005
	Bedding material used (wood shaving)		
	P= 30	A= 42	
	60(n=18)	100(n=42)	<0.001
	Bedding material used (Straw)		
	P= 24	A=48	
	100(n=24)	75(n=36)	<0.001
	Bedding material used (Hay)		
	P= 18	A= 54	
	100(n=18)	77.8(42)	<0.001
	All in all out system		
	P= 34	A= 38	
	76.5(n=26)	94.7(n=36)	0.116
	Rodents		
	P=36	A=38	
	88.9(n=32)	78.9(n=30)	0.246

P: means presence of biosecurity practice in surveyed poultry farms (poultry farms that applied the mentioned biosecurity practice).
A: absence of biosecurity practice in surveyed poultry farms (poultry farms don't apply the mentioned biosecurity practice)

Discussion

Assessment of the biosecurity practice in examined farms:

a. Farm survey: The current survey was performed mainly to increase knowledge about the importance of biosecurity practices performed on poultry farms in Kafrelshiekh Governorate as a representative of the Delta Region, Egypt.

The survey results showed that CFB type were more (56.7%) than HHB type (43.24 %) in the studied farms. Broiler farm types constituted 62.2% which is slightly less than that reported in the FAO 2017 report which stated 70%, the majority of which (86.9%) were of CFB type. In contrast the HHB type was mainly used for layer, duck and mixed farms. In CFB, 73.9% of farms used stocking density (SD) of 8-10 birds/m^2, which is the ideal (Elsaidy *et al.*, 2015), as higher SD creates stress in birds leading to a decrease in bird performance, an increase in gaseous air pollutants such as ammonia and consequently increase the liability to infection (Abouelenien *et al.,* 2016). In all surveyed layer, duck and mixed farms which were mostly HHB, SD were not adjusted, and this was attributed mostly to the ignorance of the farm owners about the exact size of the rooms or the rooftop since mostly they did not care (Geerlings *et al.*, 2007). Additionally, it was found that HHB used higher SD and this may have attributed to housing more birds in small areas inside human house and the absence of available green land for these birds (Yakout *et al.*, 2009)

b. Level of compliance with biosecurity practices in different types of poultry farms:

I- Restricted access to the birds: This means restricting access to a farm by employing fences and enclosures which create a barrier between clean areas where poultry are kept and the outside environment and it is the most important biosecurity measure for restricting sources of infection away from farms and even from the infected farm to other non-infected farm. In this study restriction to visitors, the presence of fence around the farm, separation between bird sheds and working areas, multiple species rearing, isolation and quarantine of new birds and the utilization of borrowed equipment were surveyed to understand the level of compliance in different farms.

Restriction of visitors was followed more significantly in broiler farms than in other types as most of the broiler farms are CFB, this result is in line with that reported by Hamilton *et al*., (2012) and Negro-colduch *et al*., (2013). In house hold farms visitors are sometimes allowed to enter which increases the risk of disease transmission. Additionally, multiple species rearing was significantly more in HHB (37.5%) than CFB (4.76%) farms. Keeping multiple species was, unfortunately, not deliberate in the surveyed HHB farms. As there was no separate pen for each spp. and all kinds were reared in the same pen with the same person this result was near to that obtained by Egyptian Demographic and Health Survey EDHS (El Zanaty 2008; Windsor 2017). Borrowed equipment was considered the main vehicle for transmission of infection from farm to farm. The use of borrowed equipment was higher in CFB than HHB, as usually this equipment is of high price and on the farms were huge numbers of birds in the CFB rather than HHB which had no need for this equipment (Haftom *et al*., 2015). Introduction of new birds was considered as the most common source of infection to the farm. This can occur within flocks or from flock to flock by the introduction of new birds bought at a market or received as a gift (Permin and Detmer, 2007). So isolation and quarantining of new birds is a very important practice. In the current study 18.9% of farms only applied this practice, with significant differences between farms.

II- Cleaning and Sanitation: Effective cleaning and disinfection is an essential component of good hygiene and thus one of the key biosecurity measures for disease control (Wanaratana *et al*., 2010; Negro-colduch *et.al.,* 2013). It includes cleaning and disinfection of movable parts (equipment) and fixed parts (farm buildings).

Of the surveyed farms 81% applied cleaning and disinfection to farm equipment (drinkers, feeders and material leaving markets going back to the farm) with the highest practice in broiler farms and lowest among layer farm; same result as obtained by Scott *et al.,* (2018). This item was more highly applied in CFB than HHB with significant differences between them; this was explained in discussion with HHB owners by their only cleaning equipment with water.

Cleaning and disinfection of farm buildings was compliant in 85% of surveyed farms, broiler farms were the highest type (97.8%). Disinfection is a very important practice to cut the cycle of infection (Steenwinkel *et al*., 2011; Negro-colduch *et al*., 2013). In CFB system usually the building material (floor and wall) allowed for washing with water under pressure and the spraying of disinfectant. In contrast to HHB which were constructed in old houses with earthen floors or old tile and brick walls which are difficult to wash or disinfect, so only physical cleaning is applied and only lime is added to the floor. Spraying was the most used method for disinfection compared to other methods. As fumigation needs special precautions and professional workers, spraying is easier. On the other hand, spraying is harder to apply in the old buildings of HHB farms.

III- Personal Hygiene: Utilization of farm clothes and foot wear was the practice that was more used among poultry farms than other kinds and also in CFB farms rather than house hold farms. This result was much lower than that stated by Negro-colduch *et al*., (2013) who stated that 97% of all kinds of farms use special footwear and clothes. Most farm workers or owners neglected hand-washing, even after handling dead carcasses. Hand washing/wearing of gloves was applied only in less than 8% of the surveyed farms. This result was not in line with Scot *et al*., (2018) who observed hand washing facilities in more than 88% of all farm types but they could not survey hand washing practice. Foot bath presence in front of farms and in front of each bird pen is an essential biosecurity parameter. In the current study the percentage of farms that constructed footbaths was much lower (66% of CFB used foot baths compared to only 6% of HHB farms with statistically significant difference) than those recorded by Scott *et al*., (2018) and Haftom *et al*., (2015) who recorded 93% and 80 % for both kinds respectively.

IV- Disposal of waste and dead carcasses: Hygienic disposal of waste and carcasses is a key factor in the prevention and control of infectious and even contagious diseases (Steenwinkel *et al*., 2011). In the surveyed farms it was found that poultry litter and /or manure was disposed of in fish farms or domestic rubbish or thrown into canals located near the farm. Waste from CFB was mostly disposed to fish farms, while HHB farms mainly disposed with rubbish. This result was near to that obtained by Negro-colduch *et al.*, (2013) who stated that there is a difference between HHB and CFB farms in waste disposal methods. Generally the using of litter on fish farms or throwing it into rubbish or canals without any type of treatment is considered a very hazardous practice for environmental, animal, fish and human health because it helps in the spreading of infection.

The disposal of dead birds to domestic rubbish was the most applied practice in all kinds of surveyed farms. This result was in line with Haftom *et al.*, (2015) who stated that 56% of farms used this method for the disposal of dead birds and this was considered very dangerous to the environment, neighbors and caused the spreading of infection. This result was attributed to the fact that farm owners or workers had no idea about the benefit of hygienic disposal of dead birds by either burning or burying. Additionally, they had no space for these practices (Negro-colduch *et al.*, 2013).

V- Managemental and structural biosecurity items: Most of the surveyed farms have neighboring farms within 0.5km which is a much shorter distance than that obtained by Scot et al., 2018 who reported 0.8 to 1.5km and in contrast to the result reported by Ajewole and Akinwumi (2014) who found that the average distance between poultry farms is about 5.68 to 8km. Additionally, it was stated that the distance between farms, and physical barriers such as fences, showers, foot baths all of which limit the spread of disease agents was shorter. As the distance increased the chance of infection transmission decreased (Vaillancourt 2001). The presence of trees and grasses acts as a barrier around the farm and lessens the dust and wind. In contrast, trees also act as places for wild birds. The presence of ponds or canals near farms was reported mostly in broiler farms (73.9%) and encouraged the throwing of dead birds and waste into canals contributing to the risk of pathogen transmission (Barnes 2009; Scot *et al.*, 2018).

Stray dogs and cats were recorded in 73.9% of broiler farms and in 76% of CBF. This result was near to that obtained by Scot *et al.*, (2018). Due to the absence of fences, stray dogs and cats can access the farms and play a serious role in the transmission of infection between farms through the scavenging of dead carcasses that have been thrown in canals or the trash.

Wild birds were more reported in HHB (42.9%) than in CFB but Scot et al., (2018) reported a higher percentage than the current results. This could be explained by HHB farm birds either being housed on roof tops or in the front of houses in the field during the day so they are in contact directly with wild birds. Potential pathways of infection transmission include the contact of free range chickens with waterfowl on the range or the consumption of contaminated drinking water from canals. In contrast CFB farms birds are mostly housed indoors with nets on windows decreasing the contact with wild birds. Additionally, the presence of canals and trees attracts wild birds, particularly waterfowl and sparrows on farms; their presence is a potential biosecurity risk due to the likely introduction of pathogens to chickens on the farm.

Keeping different age groups together occurred mostly on duck farms (100%) followed by layer farms (87.5%). Scott *et al.*, (2018) got lower percentage on layer farms (78%) which practiced in layers to ensure the continuity of egg production. It was found that mixed age resulted in difficulties in application of terminal sanitation which helped in circulating infection (East, 2007). Negro-colduch *et al.*, (2013) recorded that a lower percentage of HHB farms (13.9%) than the current (75%) kept different age groups, as usually farms on rooftops contain different ages and species. Through questionnaire, rodents were recorded more on layer farms (87.5%), than on in CFB farms(47.6%). Rodents being able to access feed storage and water is considered very dangerous in infection transmission (Steenwinkel *et al.*, 2011). The presence of isolation pens for diseased birds was observed mostly on CFB farms (81%) and this was attributed to the space availability and presence of veterinary services on CFB farms. The most used housing system in the surveyed farms was the deep litter system (97 % in CFB and 94% in HHB) and the most used bedding material was wood shavings (Teixeira *et al.*, 2015). An all in all out system was applied in 76% of CFB. It was considered a very important practice to control infection and allow for terminal sanitation between batches (Steenwinkel *et al.*, 2011).

Correlation between biosecurity measures and prevalence of Ornithonyssus bursa: The current study showed that the percentage of infection reached 83.8% in surveyed farms and the only reported mite species was *O. bursa.* On the other hand, Rahbari et al., (2009) declared that *Dermanyssus gallinae* was the most prevalent blood feeder mite in breeder and caged layer flocks, while *O. bursa* was reported as a first record, which was found only in a breeder flock (8.3%) in Iran. This difference in results could be attributed to the weather conditions (high humidity percentage) during the survey period.

The present survey declared that the dust samples showed the highest prevalence (71.42 and 81.28%) in both types of surveyed farms, as compared to the litter samples (33.3% and 68.7%), with marked statistical significance (P<0.05). This result can be attributed to cracks and hidden parts in the farm wall escaping cleaning, as well as usually rough wall material that can hide mites. Besides, most of farms were visited during marketing weight prompting dust burden mite.

Poultry mites (*O. bursa*) are the most popular species for attacking people especially those who are mainly resident near poultry farms and who manipulate infested birds (Silva et al., 2018; Bassini-Silva, et al., 2019). This mite can cause lesions with intense pruritus and even kill the host (Coimbra et al., 2012). In this study the authors focus on poultry mites present in the surveyed farms and the effect of biosecurity measures compliance on their prevalence.

Of the surveyed biosecurity items, it was found that housing of multiple species and mixed age group leads to an increase in the prevalence of mites. This can be attributed to direct contact between wild birds and the source of infection in free range birds in fields and roof tops (HHB). So farms with fences and those applying entrance control have less incidence of *O. bursa* than those that do not.

Absence of cleaning and disinfection of farm buildings and farm equipment, absence of foot baths and absence of spraying as a method of disinfection were linked to a higher prospect of *O. bursa* Physical cleaning includes the removal of dust and litter followed by wet cleaning, leading to a decrease in the amount of dust and consequently decreases *O. bursa* incidence (Salaün et al., 2010).

There was a positive correlation between rodents and the prevalence of *O. bursa*, as farms with rodents showed (88.9%) *O. bursa* prevalence compared with those without rodents; the same result was obtained with Okiki and Olgbemide (2014).

Throwing of litter and dead birds into domestic rubbish was significantly associated with a higher prevalence of *O. bursa* (P=0.01) than other methods of waste disposal. As these practices are considered very hazardous and cause re-entrance of the dust carrying mites into the farm either through the air (dust infection) or via wild birds, rodents and even cats and dogs which act as vehicles or carriers (Tomberlin et al., 2007).

The presence of neighboring farms within 0.5 km showed a higher prevalence of *O. bursa*. as dust carrying mites transmitted easily from farm to farm within this short distance unlike with the presence of trees and grasses around the farm which was found to reduce the occurrence of mites as they act as a filters of the air from dust.

The presence of isolation pens for diseased birds and the using of rodenticide were shown to reduce the prevalence of *O. bursa.* Concerning systems of housing it was found that cage systems showed a lower prevalence than deep letter systems. As bedding material increases with bird movement amount of dust provides a fertile area for mites (Okiki and Olagbemide, 2014).

The use of straw and hay as a bedding material was associated with a higher prevalence of *O. bursa*. than the use of wood shavings. This result can be explained by straw and hay being associated with a higher dust content than wood shavings (Soo-Youg et al., 2008; Okiki and Olgbemide, 2014).

Farms which applied all in all-out systems of management had a significantly lower percentage of *O. bursa.* This could have resulted from the application of terminal cleaning and disinfection which allow for the removal of dust, chicken debris and litter which are considered the main breeding sites for different species of mites. (Rahbari et al., 2009).

In conclusion, the results showed that CFB farms have a higher level of biosecurity than HHB farms, and the only biosecurity program clearly known to most farm owners and workers is cleaning and disinfection. *Ornithonyssus bursa* was the only mite species isolated from all surveyed farms with a higher prevalence in HHB farms (75%). Additionally, there is a positive correlation between the noncompliance with biosecurity practices and the prevalence of *O. bursa.*

Declaration of Competing Interest: The authors declare no conflict of interest.

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