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Assessment of biosecurity status in dairy cow farms

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Abstract

Background: Biosecurity plays an irreplaceable role in preventing diseases, increasing productivity of dairy herd and welfare on the farm, prevention of drug resistance and public health safety. Assessment of biosecurity measures were carried out both by observations and questionnaires from December 2019 to April 2020 in dairy cows' farms. In addition to assessment of biosecurity, the present study also intended to identify factor associated to biosecurity and its specific component implementation.

Results: Out of 125 biosecurity practices considered to evaluate the overall biosecurity status of dairy farms, the scores ranged from 34 to 75. The overall percentage of the biosecurity score varied from 27.2 to 60%. Out of 20 dairy farms included in the present study, nine farms gained a percentage score of greater than or equal to 50% (ranging from 50.4 to 60%), thus their biosecurity status was evaluated as "**Good**". The remaining 11 farms attained a percentage score lower than 50% (varying from 27.2 to 46.4%) and therefore graded as "**Poor**". In this study biosecurity categorized in to four components: traffic control (21.5 ± 4.3), isolation (14.45 ± 2.2), sanitation (16.65 ± 6.83) and health management (3.25 ± 1.07) with their respective mean ± standard deviation of each component. Out of four biosecurity components: isolation and traffic control were implemented better, but sanitation and animal health management were poorly implemented. Fisher's exact test analysis of the obtained results showed that among all factors assumed to affect biosecurity adoption, however only a significant association ($P < 0.05$) between biosecurity status and location of farms was appreciated.

Conclusions: In conclusion, the overall adoption of biosecurity measures in the dairy farms was evaluated to be poor. Thus, raising awareness of herd owners, facilitating dairy husbandry training by the concerned body, pushing herd owners to develop a biosecurity plan and practicing it. And, especially improvement of sanitation and animal health management systems should be prioritized by policy makers or the concerned organizations.

Keywords: Biosecurity, Dairy farm, Preventive medicine, Sanitation, Isolation, Traffic control

Background

Ethiopia is endowed with the largest livestock population in Africa (CSA 2013; Belay 2020) and the sector contributes 17% to the gross domestic product (GDP), 36% to the agricultural GDP (Metaferia et al. 2011; Belay 2020), and provides a livelihood for 65% of the population. The cattle population of Ethiopia is estimated at 57.83 million head, of which 55.48% are females, and 98.66% are of traditional Zebu breed (CSA 2016; Belay 2020). In addition, Ethiopia has a large dairy herd (around 14 million) and high diversity of agro-ecologies, many of which are favorable for dairying (Ndambi et al. 2017). Dairy cattle production is the main component of livestock farming in Ethiopia and there are four major dairy production systems, namely specialized commercial dairy

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production systems, pastoral and agro-pastoral production, rural smallholder (mixed crop-livestock) production and urban and peri-urban smallholder dairy production (Afras 2019).

Ethiopia is expected to double the number of middle class consumers by the year 2030, due to the growth in the middle class population and increased urbanization, which lead to an increased purchasing power and hence higher demand for livestock products including milk (Ndambi et al. 2017). However, the productivity of the dairy industry is constrained by diseases (Ahmed 2018), specially, in urban areas; shortage of land, shortage of feed and/or high feed prices, and manure related waste management, water scarcity, shortage of labour and animal disease prevalence were the common constraints to dairy production (Ndambi et al. 2017).

Diseases have many negative impacts on production and productivity of dairy cattle, imposing significant economic losses resulting from mortality, morbidity, loss of weight, poor growth rate, and poor fertility (Belay 2020). Weak enforcement of hygiene and safety regulations adulterated, and poor-quality milk can be found in the markets (Ndambi et al. 2017). Biosecurity, defined as a set of management practices or measures to prevent introduction and spread of pathogens within and between farms (Gunn et al. 2008; Fasina et al. 2012), has been reported to be the cheapest way to control diseases in flocks or herds (Kouam and Moussala 2018). It is important in avoiding not only catastrophic or foreign animal diseases, but also in reducing the risks of endemic diseases, like; digital dermatitis, paratuberculosis (Johnes' disease), contagious mastitis and enzootic bovine leukosis (Bickett-Weddle and Ramirez 2005; Stankovic and Zlatanovi 2016).

Biosecurity in this context is the management systems implemented to reduce the risk of introducing infectious disease to a herd and prevention of diseases spread within the herd (Caldow 2004), preventing economic losses and protection of public health. Information about the biosecurity level on the farms is important for contingency planning for emerging diseases, when combating endemic diseases in a country, or to see if and where the biosecurity needs to be improved (Sahlström et al. 2014). The observation of a gap between biosecurity recommendations and on-farm practices have been documented (Moore et al. 2008). On-farm biosecurity measures are implemented differently depending on the farm (Sahlström et al. 2014). Research suggests that uptake of biosecurity measures on dairy farms is low with certain practices being rarely carried out (Sayer et al. 2013).

Research in the UK and Ireland suggests low uptake of biosecurity practices, even though dairy farmers consider biosecurity as important (Brennan and Christley 2013). Other studies also examined the implementation of biosecurity on a variety of farming enterprises, the majority highlighted that awareness of biosecurity may exist but its implementation at farm level is often poor (Mee et al. 2012). Thus, inadequate attention to the implementation of biosecurity in such circumstances could have a significant negative impact on animal health which causes economic loss (van Schaik et al. 1998), poor animals and risk to public health. Thus, it is crucial for dairy farmers to understand the importance of disease prevention through implementation of on-farm biosecurity.

There are few published reports on the assessment of dairy biosecurity measures in livestock production in Ethiopia. However, to mention some of them, biosecurity assessment was undertaken in central cattle feedlot in Ethiopia (Alemayehu and Leta 2014) and in small scale commercial poultry farms Birhanu et al. (2015) in and around Mekelle and by Melkamu et al. (2016) in and around Debre Markos. These studies reported a poor implementation of biosecurity measures by the farmers, along with the different constraints and challenges expressed by the farmers such as cost, usefulness, importance, workload and lack of clarity and knowledge. To date, there is no information on basic biosecurity measures that are undertaken to maintain the health of cattle in commercial dairy farms established in and around Harar and Dire Dawa cities (Fig. 1). Thus, the present study aims to facilitate the adoption, and awareness of the key areas of Biosecurity that need improvement.

Therefore, the objectives of this study are;

- To assess the biosecurity status of commercial dairy farms located in and around Dire Dawa and Harar cities.
- To identify factors associated with generally assessed biosecurity status.
- To appreciate specific (individual) biosecurity status.

Methods

Study area

This study was carried out in medium to small scale dairy cow's farm found in and around Dire Dawa and Harar cities (Fig. 1). Dire Dawa city is located at about 515 km to the east of Addis Ababa. The area is found between 9° 27′ and 9° 49′ N latitude and 41° 38′ and 42° 19′ E longitude. The total area of the administration is 128,802 ha. Dire Dawa is situated at an altitude of 1276 m above sea level. The mean annual rainfall of the area varies from 550 mm in the lowland northern part to 850 mm in the southern mountains with average 640 mm. The monthly mean minimum and maximum temperature ranges from 14.5 to 34.6 °C respectively (CSA 2012). Harar, a walled city in

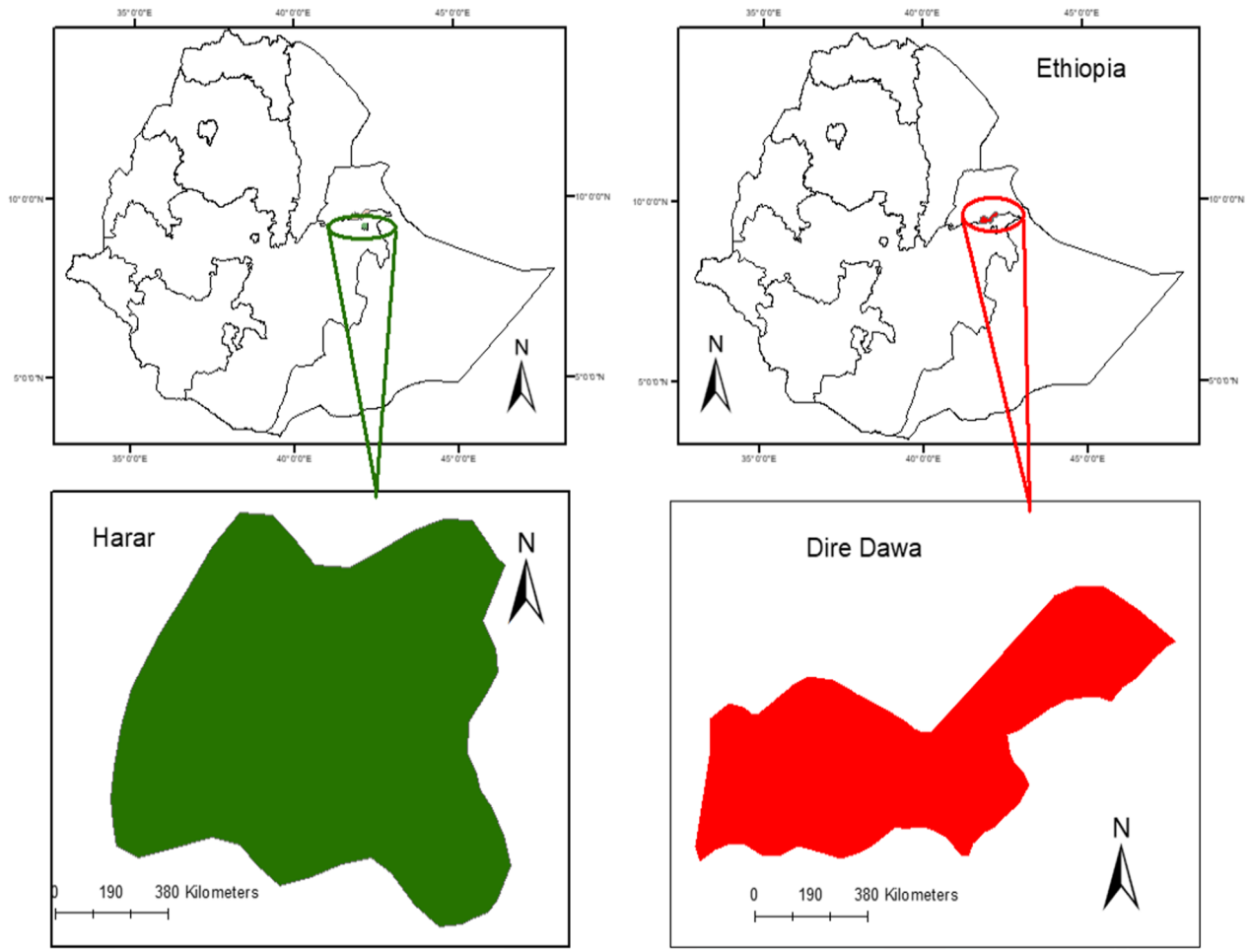

Fig. 1 Map of study area depicting Harar region and Dire Dawa city council

eastern Ethiopia, is a regional city for the Harari region and a zonal capital for the East Hararghe zone of Oromia region. The city has an estimated population of 232,000 for the year 2015 (Mengistu et al. 2016). It is located at about 525 km from Addis Ababa situated at an elevation of 1885 m.a.s.l. These two cities are places where privately owned commercial dairy farms were located and the major milk consumption centers in eastern Ethiopia. In addition to these modern dairy farms, the wider surrounding rural districts are other sources for milk and milk products supply (CSA 2013; Mengistu et al. 2016).

Target and study population

For this study, the target population are all commercial dairy farms established in and around Harar and Dire Dawa cites (Fig. 1). Farms having more than ten cattle were taken as the study population. Generally, there are 32 medium to large scale producing dairy farms within the study areas, which are acquired from offices of livestock and fisheries development offices and from other concerned offices. Of 32 herd owners contacted, 6 of them had already closed their dairy business and the remaining 6 dairy owners refused to participate. Therefore, 81.25% agreed to participate in this study. Therefore, 20 dairy herd owners/managers were interviewed, both by observations using a checklist and semi-structured questionnaire.

Study design and study methodology

The study was a cross-sectional survey carried out from December 2019 to April 2020, which involved collection of information from all dairy farms established in and around Dire Dawa and Harar cities (Fig. 1), containing more than ten cattle (medium to large scale population) as categorization by (Megersa et al. 2011). Therefore, it did not require sampling. At first, all dairy farms were identified using the official registry of dairy farms obtained from the respective Agricultural offices

and located with the help of local veterinary health officials until all farms were included. Then, farm owners requested to participate in the study and the required information was gathered after obtaining their verbal consent. The number of those dairy owners who refused to participate was also documented.

Data collection

A questionnaire-based survey was undertaken to evaluate the status of the different components of biosecurity measures practiced. Information about biosecurity was obtained through on -farm observations using a structured-questionnaire by checklists and interviews made with owners and workers. The questionnaire contained 125 questions, mainly closed and semi-closed (Additional file 2). It was divided into four sections. The first question set consisted of demography characteristics of farm owners (sex, age, marital status, occupation, level of education, experience (years), previous training on dairy farm management, being member of a dairy farm cooperative and knowledge of biosecurity among others). The second part was related to awareness on disease control and biosecurity such as owners' understanding of cattle diseases, awareness on biosecurity, source of biosecurity information, and importance of biosecurity and presence of biosecurity plan. The third section was farm characteristics such as farm location, year of establishment, farm size (m^2), presence of buildings in the farm, presence of cattle barn(s), number of cattle (herd size) and breed of cattle. The last section was on components of biosecurity measures such as isolation, traffic control, sanitation as defined by (FAO 2010; Kouam et al. 2018) and Nitovski et al. (2013) and animal health management (Nitovski et al. 2013) which was developed to collect data on biosecurity practices. To ensure validity and reduce bias, interviews and farm observation were carried out by one person.

Biosecurity scoring system and biosecurity status

The Biosecurity measures were divided into four sections, each section corresponding to a biosecurity component (isolation, traffic control, and sanitation and animal health management). Biosecurity was quantified using a scoring system based on the assumption that all the potential biosecurity measures to have an equal weight and scoring each measure as either 1 or 0 as in Kouam et al. (2018). The biosecurity measure was coded as 1 if this measure is present or 0 if the measure is absent. The answers to all 125 dichotomous questions or findings of observations were converted into a score of 0 and 1. The maximum score for a given farm was 125 points (40 for isolation, 27 for traffic control, 46 for sanitation and 12 for animal health management) equaling the total biosecurity measures under investigation. A total of 125 marks were allocated to the biosecurity indicators in the questionnaire and checklist. The cattle farms were categorized based on biosecurity status as per the methodology described by (Wijesinghe et al. 2017) with slight modification. The total score earned by each farm was changed to percentage and if it is above or equal to 50% a farm was said to have as "Good biosecurity" and below 50% as "Poor biosecurity".

Data analysis

The data collected were stored in Microsoft Excel Spreadsheet and analyzed using StataCorp statistical software version 15. Data were analyzed, using descriptive statistics to calculate frequencies and percentages. The association of respondents' demographic as well as farm characteristics with biosecurity compliance was evaluated using Fisher's exact test statistics and a statistically significant association was said to exist when $P < 0.05$.

Results

Farm characteristics

From all dairy farms located in and around Harar and Dire Dawa cities, majority of dairy farms were established above the years 2016 whereas some of them were established from 2007 to 2016. Again, all farms, established on areas lower than 5001 m^2 in size. Some cattle farms (7 that are 35%) were established on areas of less than 1000 m^2 while the other 12 (60%) had sizes between 2001 and 5000 m^2. All farms had buildings in the farm, however, 5 (25%) described that there were no cattle barns. Majority (65%) of dairy farms comprised less than 100 dairy cows and 65% of cattle were Holstein Friesians breed (Table 1). The range, mean, median of dairy cows in the overall study is 16–150, 79.4 and 88.5 respectively.

Herd owners awareness on disease control and biosecurity

From 20 dairy herd owners interviewed, 80% disclosed that they had knowledge of cattle disease whereas 20% disclosed that they had not. With regard to disease control, all of the respondents replied that prevention of diseases was the cheapest method and 85% of them said prevention was less time consuming (Table 2).

Demographic characteristics of dairy Herd Owners

From these 20 interviewed participants, 14 (70%) were male, 12 (60%) older than 45 years, 17 (85%) married, and 15 (75%) had higher education status. Occupationally, 15% were civil servants, 30% were traders and 55% had occupations other than the two (artesian). Majority (60%) of the herd owners had experience of one to ten years while 40% of them had more than ten years of experience in dairy farming. 85% of the owners were not

Table 1 Characteristics of dairy farms established in and around Harar and Dire Dawa cities

Characteristics	Categories	Number	Percentage (%)
Farm location	Harar	10	50
	Dire Dawa	10	50
Year of establishment (Ethiopian Calendar)	2007–2016	6	30
	> 2016	14	70
Farm size (m^2)	< 2000	8	40
	≥ 2000	12	60
Presence of buildings in the farm	Yes	20	100
	No	0	0
Presence of cattle barn(s)	Yes	15	75
	No	5	25
Number of cattle (herd size)	< 100	13	65
	100–150	7	35
Breed of cattle	Holstein Friesian	13	65
	Cross breed	7	35

Table 2 The percentage of cattle owners aware of cattle disease control and biosecurity

Awareness	Category	Number	Percentage (%)
Owners understanding of cattle diseases	Yes	16	80
	No	4	20
The cheapest method	Treatment	0	0
	Prevention	20	100
Less time consuming	Treatment	3	15
	Prevention	17	85
Information on biosecurity	Yes	7	35
	No	13	65
Source of biosecurity information	Veterinary	3	15
	Internet	2	10
	Professional	2	10
	Not aware	13	65
Importance of biosecurity	Very important	9	45
	Important	4	20
	I don't know	7	35
Presence of biosecurity plan	Yes	1	5
	No	19	95

trained on farm management, only 5% were members of dairy cooperatives and 35% claimed to be aware of biosecurity (Table 3).

Component specific biosecurity status

Tables 4, 5, 6, 7 and 8 presents, assessment results of various components of biosecurity. A total of 32 biosecurity practices were included to assess traffic control biosecurity status (Table 4). The biosecurity score ranged from 10 to 18 out of 32 and the percentage varied from 32.5 to 57.5%. Mostly applied traffic biosecurity components (100%), were;—no vehicles frequently move off property, go to property, sale yard, abattoir or show and then return, no equipment used for different purposes, no sharing of equipment and machinery with other farms, no more than one main entry point to the farm, locating animal loading areas away from the rest of the stock, not grazing resting pastures recently spread with waste, when loading animals the lorry or truck didn't enter the stables. From traffic control biosecurity, 'Nine (45%) farms attained a good biosecurity score whereas 11 (55%) were poor' (Table 8).

Table 3 The demographic characteristics dairy farm owners

Demographic characteristics	Category	Number	Percentage (%)
Gender	Male	14	70
	Female	6	30
Age (years)	31–45	8	40
	>45	12	60
Marital status	Married	17	85
	Not married	3	15
Level of education	Secondary education	5	25
	Higher education	15	75
Occupation	Civil servant	3	15
	Trader	6	30
	Others	11	55
Experience (years)	1–10	12	60
	More than 10	8	40
Previous training on dairy farm management	Yes	3	15
	No	17	85
Member of a dairy farm cooperative(s)	Yes	1	5
	No	19	95
Awareness on biosecurity	Yes	7	35
	No	13	65

Regarding the isolation, 27 biosecurity practices were used to evaluate biosecurity level. As presented in Table 5, the biosecurity score and percentage of isolation varied from 11 to 24 and 40.7–88.84%, respectively. Majority of dairy farms (17) gained a "Good" and the remaining three are "Poor" status. Frequently applied isolation biosecurity measures such, as no pasture area, fence off dead-animal pits and garbage tips, fencing off stock access to water courses, maintain no contact of preweaned calves with older cattle, maintain no contact of dry cow with lactating cows, no mixing of different species, separate calves and young stock from older animals.

Concerning sanitation practices, 46 biosecurity practices were chosen and evaluated (Table 6). Regarding sanitation biosecurity practices, its score and percentage extended from 3 to 25, and 6.5–54.3%. The sanitation level was "Good" for five farms and "Poor" for 15 farms.

From biosecurity practices were considered for the evaluation of animal health management. The biosecurity score ranged from 1 to 5 and the percentage ranged from 8.3 to 41.7%. The adoption level was assessed as "Poor" for all dairy farms included in the study (Table 7).

Overall, 125 biosecurity practices were considered to evaluate the general biosecurity status. The percentage of the biosecurity score varied from 27.2 to 60%. Nine farms gained a percentage of score greater than or equal to 50% (ranging from 50.4 to 60%), thus their biosecurity compliance was evaluated as "Good". The remaining 11 farms attained a percentage score lower than 50% (varying from 27.2 to 46.4%) and therefore graded as "Poor" (Table 9).

Factors associated with overall biosecurity measures

Several demographics as well as farm characteristics were assessed for their association with the overall biosecurity level using Fisher's exact test. Among those characteristics, only location of the farm (Fisher's exact value = 9.90; $P < 0.005$) was significantly associated with the overall level of biosecurity measure (Table 10). From ten dairy farms located in Harar city, only one (10%) was evaluated to have "Good" biosecurity level. On the other hand, from ten study dairy cow farms in Dire Dawa city, eight (80%) were assessed to have "Good" biosecurity.

Discussion

In the present study, a relatively small sample size was used. One of the important reasons is that checklists were completed by the researchers on each farm based on observations, instead of sending a questionnaire to the farms. Again, the believe that more reliable data concerning biosecurity could be obtained by conducting farm visits, which requires more time and resources compared to sending the questionnaires by mail. Moreover, it is not always easy to obtain producers' permission to visit their farms. Although, this study provides important information on the demographic characteristics of dairy herd owners, farm characteristics, and awareness

Table 4 Percentage of biosecurity practices of the traffic control component

Biosecurity practices	Yes (%)	No (%)
Farm located > 500 m from the main road	1 (5)	19 (95)
Farm sited > 500 m from the nearby dairy farm	5 (25)	15 (75)
Farm established > 500 m from the nearby animal farms other than dairy such as beef feedlot, poultry etc	5 (25)	15 (75)
Farm situated > 500 m from abattoir(s)	12 (60)	8 (40)
Farm located > 500 m from residential area	2 (10)	18 (90)
Not infested with wild animals	10 (50)	10 (50)
Presence of parking lot	9 (45)	11(55)
No driveway	3 (15)	17(85)
No additions to the herd	8 (40)	12(60)
Source animals directly from the herd of origin	10 (50)	10(50)
Transfer information including animal health records for all new animals	0 (0)	20(100)
Outgoing animals moved off the farm with information on animals health status	0 (0)	20(100)
Keeping records of livestock (cattle) movements	0 (0)	20(100)
Have and follow a movement plan (e.g. work with animals from youngest to oldest, healthy to sick	11 (55)	9 (45)
Closing gates and seeing visitors by appointment	9 (45)	11 (55)
No Exchange of production material (drinkers, feeders, buckets, and tools) between farm	19 (95)	1 (5)
No vehicles frequently move off property, go to property, sale yard, abattoir or show and then return	20(100)	0 (0)
No equipment used for different purposes	20(100)	0 (0)
Not allowing frequent visits to the farm	9 (45)	11 (55)
No sharing of equipment and machinery with other farms	20(100)	0 (0)
Notify non-professional visitors, professional visitors and drivers of permitted areas of access to them and transport vehicles prior entry	7 (35)	13 (65)
No more than one main entry point to the farm	19 (95)	1 (5)
Presence of entry restriction sign post	1 (5)	19 (95)
Use own vehicle to transport visitors	0 (0)	20(100)
Record presence to the routine veterinary visit	0 (0)	20(100)
Locating animal loading areas away from the rest of the stock	20(100)	0 (0)
Maintaining and monitoring health records for individual animals	0 (0)	20(100)
Management of sick animals after healthy ones	17 (85)	3 (15)
Not grazing resting pastures recently spread with waste	20(100)	0 (0)
Use own vehicle for animal movements	0 (0)	20(100)
Work from young to old animal	19 (95)	1 (5)
Separation of material for young and old animals	19 (95)	1 (5)
When loading animals, the lorry or truck **didn't** enter the stables	20(100)	0 (0)
Nonprofessional visitors are not allowed to enter into farm	8 (40)	12 (60)
Availability of visitors logbook	0 (0)	20(100)
Visitors **do not** have direct access to the stables or barns	10 (50)	10 (50)
Absence of freely moving cats and/or dogs on the farm	9 (45)	11 (55)
Presence of permanent rodent control	15 (75)	5 (25)
Presence of own feed and milk collection trucks	6 (30)	14 (70)
Total score of the traffic control biosecurity practices	40	
Minimum–maximum biosecurity score of dairy farms	13–23	
Mean ± standard deviation biosecurity score of dairy farms	18.2 ± 3.25	

on dairy farms disease control, implementation of biosecurity measures from medium-scale to large-scale dairy farms were found poor thus larger and more comprehensive studies are needed for Ethiopia dairy farm regarding its biosecurity measure. In this study, biosecurity categorized in to four components: traffic control, isolation, sanitation and health management. Out of four biosecurity components: isolation and traffic control were implemented better, but sanitation and animal health management were poorly implemented.

Table 5 Percentage of isolation biosecurity practices component

Biosecurity practice	Yes (%)	No (%)
Presence of calf pen/hutch	10 (50)	10 (50)
Presence of separate milking house	13 (65)	7 (35)
Presence isolation room for sick cattle	11 (55)	9 (45)
Presence of feed storage sheds	15 (75)	5 (25)
No pasture area	18 (90)	2 (10)
Presence of maternity pen	2 (10)	18 (90)
Purchase replacement animals from herd with known health status	12 (60)	8 (40)
Know the animal health practices of all suppliers	4 (20)	16 (80)
Keep clinically sick animals separately until they are completely cured	12 (60)	8 (40)
Quarantine incoming cattle for a period	8 (40)	12 (60)
Minimizing contact with neighbors' animals	12 (60)	8 (40)
Fence off dead-animal pits and garbage tips	19 (95)	1 (5)
Fencing off stock access to watercourses	19 (95)	1 (5)
Maintain no contact of pre-weaned calves with older cattle	18 (90)	2 (10)
Maintain no contact of dry cow with lactating cows	18 (90)	2 (10)
No mixing of different species	19 (95)	1 (5)
Prevent animals from having fence line contact with livestock from farms	11 (55)	9 (45)
Keep buildings and facilities well maintained and in good repair	13 (65)	7 (35)
Separate calves and young stock from older animals	19 (95)	1 (5)
Isolate animals with abortion	13 (65)	7 (35)
Calving takes place in a separated calving box or maternity pen	2 (10)	18 (90)
Use isolation room to house sick animals	11 (55)	9 (45)
Presence of cadaver storage facility present	13 (65)	7 (35)
Cadaver storage facility inaccessible for vermin	14 (70)	6 (30)
Absence of other farm animals in the farm	13 (65)	7 (35)
Absence of pasture contact with others cattle	17 (85)	3 (15)
Presence of adequately maintained boundary fence around the farm	17 (85)	3 (15)
Total score of the isolation biosecurity practices	27	
Minimum–maximum biosecurity score of dairy farms	11–24	
Mean ± standard deviation biosecurity score of dairy farms	18.05 ± 5.92	

Herd owners awareness on disease control and biosecurity

In the present study, only 15% of the participants disclosed veterinarians as their sources of information on biosecurity in contrast to Gunn et al. (2008) and Derks et al. (2012) that reported veterinarians have been identified as one of the most important, reliable and credible sources of information for farmers on biosecurity.

Demographic characteristics of the farm

Among 20 dairy cattle farmers in Harar and Dire Dawa, the majority believed that biosecurity (prevention) was more cost-effective (cheapest method) (100%, n = 20) and more time-efficient (Less time consuming) (85%, n = 17) than treating individuals disease on-farm, which are the same or even more implemented as reported by Collineau and Stärk (2019). Some farmers (45%, n = 9) also believed that benefits (verily important) could be attained by implementing even a small number (45% or medium) of biosecurity measures (Brennan and Christley 2013; Collineau and Stärk 2019).

This study revealed, the majority are not aware of biosecurity which is in contrast to (Mee et al. 2012) that the majority aware of biosecurity and again, among 35% of herd owners informed about biosecurity measures, 15% got biosecurity information from veterinarians, (10%) from internet and (10%) were professional. Thus in this study, only 15% participants got information channels about biosecurity from veterinarian in contrast reported by (Brennan and Christley 2013; Collineau and Stärk 2019) that information channels regarding biosecurity measures were obtained primarily from private veterinarians 93%, and unlike the present studies(10%), research papers/professional press share as 77% as channel of information to biosecurity (Brennan and Christley 2013; Collineau and Stärk 2019). In this study, the majority highlighted that awareness of biosecurity does not

Table 6 Percentage practices of sanitation biosecurity component

Biosecurity component	Yes (%)	No (%)
Location on elevated ground	13 (65)	7 (35)
No evidence of flooding during the wet season	12 (60)	8 (40)
Year round supply of fresh water	11 (55)	9 (45)
Enforce cleaning of vehicles entering the farm	9 (45)	11 (55)
Cleaning of on-farm animal health equipment after each use	7 (35)	13 (65)
Asking visitors to wash their hands before and after contact with your livestock?	1 (5)	19 (95)
Presence of protective clothing for visitors	0 (0)	20 (100)
Encourage 'come clean, go clean' practices for visitors	0 (0)	20 (100)
Ensuring visitors cleaning and disinfection after visits	0 (0)	20 (100)
If lent, clean down equipment and vehicles before use on farm	1 (5)	19 (95)
Provide clean down equipment or facilities for visitors to clean boots and equipments	1 (5)	19 (95)
Clean vehicles and equipment prior to moving from one farm to the other	0 (0)	20 (100)
Provision of protective clothing for visitors	0 (0)	20 (100)
Disposal of contaminated and pest damaged stock feed	12 (60)	8 (40)
Routinely clean and/or disinfect housing after removing manure	13 (65)	7 (35)
Cow stalls are clean	13 (65)	7 (35)
Good hygiene of cow from dirt	11 (55)	9 (45)
Presence of control programs for feral-animal, wildlife and weed	15 (75)	5 (25)
Inspect for feeding and drinking equipments for cleanliness	17 (85)	3 (15)
Prevention of stored stock feed contamination by livestock, vermin, wildlife, feral and domestic animals and other feed types	14 (70)	6 (30)
Regular pest control	16 (80)	4 (20)
Testing water for quality	2 (10)	18 (90)
Visual Inspection of stock feed for contaminants and pest damage etc	17 (85)	3 (15)
Have written instructions for cleaning and disinfecting different types of equipment	0 (0)	20 (100)
Have written sanitation, disinfection procedures and schedules for all animal holding areas/facilities	0 (0)	20 (100)
Have appropriate and effective cleaning and disinfection materials	4 (20)	16 (80)
Disinfect livestock related equipment between uses	6 (30)	14 (70)
Practice sanitation to minimize contamination of livestock waters by manure and urine	17 (85)	3 (15)
Specific cleaning and sanitizing protocols for higher-risk practices(e.g. AI or treatment of sick animals)	2 (10)	18 (90)
Have walls, ceilings and facility parts that are easy to clean and disinfect	11 (55)	9 (45)
Remove and renew bedding on a Regular schedule	6 (30)	14 (70)
Presence of dead-stock disposal protocol	10 (50)	10 (50)
Ensures dead stock is removed from animal housing quickly so that no livestock have contact with the carcass	14 (70)	6 (30)
Dispose of dead stock by burying, composting or pickup by a dead-stock disposal service	17 (85)	3 (15)
Use equipment for a single purpose only	17 (85)	3 (15)
Clean and disinfect cattle barn after abortion	12 (60)	8 (40)
Clean calving box or maternity pen after each calving	9 (45)	11 (55)
Cleaning and disinfecting hands between age groups handling	7 (35)	13 (65)
Cadaver storage facility frequently cleaned and disinfected	15 (75)	5 (25)
Nonprofessional visitors use farm-specific footwear	0 (0)	20 (100)
Nonprofessional visitors use farm-specific clothing	0 (0)	20 (100)
Check for visitors use of a disinfection footbath	0 (0)	20 (100)
Professional visitors wear or dressed in herd-specific protective clothing	1 (5)	19 (95)
Presence of disinfection footbaths at the gate	0 (0)	20 (100)
Presence of car wash dip at the gate	0 (0)	20 (100)
Presence of disinfectant foot baths between premises	0 (0)	20 (100)
Total score of the isolation biosecurity practices	46	
Minimum–maximum biosecurity score of dairy farms	3–25	
Mean ± standard deviation biosecurity score of farms	16.65 ± 6.83	

Table 7 Percentage practices of the animal health management biosecurity components

Biosecurity practice	Yes (%)	No (%)
Vaccination of cattle before being introduced into the herd	7 (35)	13 (65)
Testing animals moving onto the farm	0 (0)	20 (100)
Presence of accurate disease record	0 (0)	20 (100)
Offering newborn calves more than 2–4 L of colostrums within 2–12 h of birth	14 (70)	6 (30)
Recording of the number of animals that died or destroyed	0 (0)	20 (100)
Documenting of relevant disease management strategies	0 (0)	20 (100)
Routine diagnostic testing farm stock	0 (0)	20 (100)
Following veterinarian-reviewed infectious disease and parasite control program	18(90)	2 (10)
Routine inspection of farm stock	10(50)	10 (50)
Routine vaccination of cattle	16(80)	4 (20)
Recording the number of animals with disease	0 (0)	20 (100)
Test all purchased animals	0 (0)	20 (100)
Total score of the isolation biosecurity practices	12	
Minimum–maximum biosecurity score of dairy farms	1–5	
Mean ± standard deviation biosecurity score of farms	3.25 ± 1.07	

Table 8 Component specific biosecurity score, percentage and level implemented by dairy farms

Farm ID	Traffic control			Isolation			Sanitation			Animal health management		
	BS	%	BL	BS	%	BL	BS	%	BL	BS	%	BL
01	13	32.5	Poor	13	48.1	Poor	17	37.0	Poor	4	33.3	Poor
02	15	37.5	Poor	18	66.6	Good	16	34.8	Poor	3	25.0	Poor
03	17	42.5	Poor	17	62.9	Good	16	34.8	Poor	4	33.3	Poor
04	15	37.5	Poor	14	51.8	Good	3	6.5	Poor	2	16.7	Poor
05	14	35	Poor	12	44.4	Poor	9	19.6	Poor	2	16.7	Poor
06	16	40	Poor	11	40.7	Poor	7	15.2	Poor	2	16.7	Poor
07	20	50	Good	19	70.3	Good	21	45.7	Poor	3	25.0	Poor
08	23	57.5	Good	22	81.4	Good	23	50.0	Good	4	33.3	Poor
09	21	52.5	Good	18	66.6	Good	24	52.2	Good	5	41.7	Poor
10	20	50	Good	18	66.6	Good	21	45.7	Poor	4	33.3	Poor
11	22	55	Good	21	77.7	Good	22	47.8	Poor	4	33.3	Poor
12	19	47.5	Poor	20	74.1	Good	10	21.7	Poor	4	33.3	Poor
13	19	47.5	Poor	17	62.9	Good	14	30.4	Poor	3	25.0	Poor
14	16	40	Poor	24	88.8	Good	23	50.0	Good	3	25.0	Poor
15	21	52.5	Good	24	88.8	Good	25	54.3	Good	5	41.7	Poor
16	18	45	Poor	16	59.2	Good	6	13	Poor	1	8.3	Poor
17	19	47.5	Poor	16	59.2	Good	13	28.3	Poor	3	25.0	Poor
18	18	45	Poor	18	66.6	Good	25	54.3	Good	2	16.7	Poor
19	18	45	Good	20	74.1	Good	16	34.8	Poor	4	33.3	Poor
20	20	50	Good	19	70.3	Good	22	47.8	Poor	3	25.0	Poor

BS: Biosecurity score; BL: Biosecurity level

exist as well as its implementation at farm level was also poor which are the same reported by (Mee et al. 2012).

Among highly implemented biosecurity practices in the present study (> 90%) are:-no vehicles frequently move off property, go to property, sale yard, abattoir or show and then return, no equipment used for different purposes and no sharing of equipment and machinery with other farms which is different with Brennan et al. (2008) that reported almost half of the farmers shared equipment with other farms. In the present study, having

Table 9 Summary of general biosecurity score, percentage and Implementation status of dairy herd owners in and around Harar and Dire Dawa cities

ID.No	Biosecurity score ($n=125$)	Percentage of score	Biosecurity compliance
01	47	37.6	Poor
02	52	41.6	Poor
03	54	43.2	Poor
04	34	27.2	Poor
05	37	29.6	Poor
06	36	28.8	Poor
07	63	50.4	Good
08	72	57.6	Good
09	72	57.6	Good
10	63	50.4	Good
11	69	55.2	Good
12	52	41.6	Poor
13	53	42.4	Poor
14	66	52.8	Good
15	75	60.0	Good
16	41	32.8	Poor
17	51	40.8	Poor
18	63	50.4	Good
19	58	46.4	Poor
20	64	51.2	Good

an implementation of insect or rodent control plan was 15 (75%) which was more implemented than (Can and Altuğ 2014), that reported (46%) and (Renault et al. 2017), that reported around 65% of insect or rodent control plan. Among participant of the present study dairy herd owners, 9 (45%) closing gates and seeing visitors by appointment, which implemented less than (Damiaans et al. 2019), that reported (65%) access to the stables was controlled by a closing gate and a requirement for visitors to announce themselves before entering.

Component specific biosecurity status

Traffic control biosecurity was found the second mostly implemented by status as there were 11-participant "poor" status and 9 participants received "good" status. All the participants (100%) do not share equipment and machinery with other farms and do not allow vehicles to frequently move off property, go to property, sale yard, abattoir or show and then return, implemented more as (Renault et al. 2017). The average traffic control biosecurity score (measures to prevent pathogens from entering a herd was 14.45 (range, 10–18) (Table 8), which is in contrast to (Laanen et al. 2013), that reports average 65 (range, 45–89).

From isolation biosecurity components, 11 (55%) implemented isolation of sick animals in contrast to Damiaans et al. (2019) that reported none of the farmers isolates sick animals. Thus, according to the present study, only 45% of farmers would have a chance of direct and indirect contact to the herd unlike 100% by Damiaans et al. (2019). Practices of purchasing of replacement animals from a herd with known health status was 60% in this study but the studies reported by Damiaans et al. (2019) was implementing only 20% of purchasing of replacement animals from a herd with known health status. In the present study, 40% of herd owners quarantined or tested new animal additions to their farm in contrast to USDA that reported only 20% of herd owner implement quarantine or test of new animal addition. In the present study average internal biosecurity score/isolation (measures to reduce the within-herd spread of pathogens) was 21.5 (range, 13–28) which is different from (Laanen et al. 2013) that reported an average 52 (range, 18–87). Of producers of dairy farming, 12 (60%) introduced new animals directly into the herd without prior isolation which was approximately the same reported by Noremark et al. (2010). In these studies, dairy farmers do not have a written plan for implementation of biosecurity measures which was the same reported by Milanovic (2019). Isolation component of biosecurity was recorded of all biosecurity for its better implementation as there were only three farms found with "Poor" status and the other 17 participants were "Good" by status. From ten dairy farms located in Harar city, only one (10%) was evaluated to have "Good" biosecurity. On the other hand, from ten study dairy farms of Dire Dawa town, eight (80%) were evaluated to have "Good" biosecurity.

In the present study, none of the producers provided protective clothing for visitors, which was less than (Can and Altuğ 2014) that reported, 32% and 40% by Noremark et al. (2010). Among professional visitors, who wear or dress in herd-specific protective clothing was only 5%, which was the same reported by Damiaans et al. (2019). Regarding sanitation, only 5 of them got "good" and 15 of them got "poor" status. Thus, sanitation was the second least implemented biosecurity component. Vaccination of cattle before being introduced into the herd performed by 7 (35%) farms and 13 (65%) are not and again most farmers implement routine vaccination of cattle 16 (80%) which was contrary to veal farms (Damiaans et al. 2019) that reported below this value. The health management was the least implemented of all biosecurity components due to all farms being found "Poor "by status. In this study there was nothing found regarding the impacts of education in implementation of biosecurity. However, other studies reported the important role of education in ensuring biosecurity practices (Moore et al. 2008; Wolff

Table 10 Assessment of association between respondent's socio-demographic and farm characteristics with general biosecurity status

Variables	Categories	Number	Biosecurity compliance		Fisher's exact value	*p*-value
			Good (%)	Poor (%)		
Gender	Male	14	6 (42.9)	8 (57.1)	0.09	1.000
	Female	6	3 (50.0)	3 (50.0)		
Age (years)	31–45	8	2 (25.0)	6 (75.0)	2.15	0.197
	>45	12	7 (58.3)	5 (41.7)		
Marital status	Married	17	9 (52.9)	8 (47.1)	2.89	0.218
	Not married	3	0 (0.0)	3 (100.0)		
Level of education	Secondary	5	3 (60.0)	2 (40.0)	0.61	0.617
	Higher education	15	6 (40.0)	9 (60.0)		
Occupation	Civil servant	3	1 (33.3)	2 (66.7)	0.90	0.835
	Trader	6	2 (33.3)	4 (66.7)		
	Others	11	6 (54.5)	5 (45.5)		
Experience (years)	1–10	12	5 (41.7)	7 (58.3)	0.13	0.714
	More than 10	8	4 (50.0)	4 (50.0)		
Previous training on dairy farm management	No	17	8 (47.1)	9 (52.9)	0.19	0.660
	Yes	3	1 (33.3)	2 (66.7)		
Member of a dairy farm cooperative(s)	No	19	9 (47.4)	10 (52.6)	0.86	0.353
	Yes	1	0 (0.0)	1 (100.0)		
Knowledge of biosecurity	No	13	5 (38.5)	8 (61.5)	0.64	0.423
	Yes	7	4 (57.1)	3 (42.9)		
Farm location	Harar	10	1 (10.0)	9 (90.0)	9.90	0.005*
	Dire-Dawa	10	8 (80.0)	2 (20.0)		
Year of establishment	2007–2016	6	3 (50.0)	3 (50.0)	0.09	0.769
	>2016	14	6 (42.9)	8 (57.1)		
Farm size (m^2)	<2000	8	3 (37.5)	5 (62.5)	0.30	0.582
	≥2000	12	6 (50.0)	6 (50.0)		
Number of animals (herd size)	<100	13	4 (30.8)	9 (69.2)	3.04	0.081
	100–150	7	5 (71.4)	2 (28.6)		
Breed of cattle	Holstein Frisian	13	7 (53.9)	6 (46.1)	1.17	0.279

et al. 2017; Robertson 2019). Despite low uptake of biosecurity practices, in this study dairy farmers consider biosecurity as important, which was also reported by Brennan and Christley (2013).

Factors associated with overall biosecurity measures

Education improves the ability of searching and processing information leading to a tendency of adopting improved dairy technologies (Mengistu et al. 2016) and affecting the implementation of innovation (Kouam et al. 2018). In this line, a lot has to be done to motivate herd owners to improve the educational status to enable them to make an informed farm decision (Mengistu et al. 2016). In the present studies, 75% of dairy owners have a higher education completed which was more practical than 26.67% of (Lestari et al. 2019) and that of (Mengistu et al. 2016), that reported 28% of the producers were educated. However, in this study education and herd size was not found to affect the level of biosecurity adoption unlike (Lestari et al. 2019), who claimed education and herd sizes affect biosecurity adoption. Again, in other studies, herd size is often correlated with the biosecurity score (Can and Altuğ 2014; Laanen et al. 2013). Reference Musaba (2010), stated that adoption of biosecurity measures was impacted by training, but in this study, biosecurity was not impacted by training.

The significant association of location with biosecurity of studies areas, significantly associated with the level of biosecurity measure, could be due to culture, climate and variation in the training and technical support between regions, which are the same to Sayers et al. (2013).

Conclusions

Although the present study, provides important information on the socio-demographic characteristics of farm owners, farm characteristics, awareness on disease control and biosecurity aspects in dairy farms, only location of studies areas was found to have significant association with general biosecurity status or level. Again, there are a component of biosecurity, that used to evaluate general biosecurity status which are isolation, traffic control, sanitation and animal health management with respective implementation status. This study showed, majority of biosecurity indicators were not being implemented except isolation components. No training has been provided to the farmers by the concerned government's body, no cooperation found on dairy farming by dairy farmers. Thus, more studies that are comprehensive would be needed for the future, especially; those of concerned government bodies should be included for investigation of the reason for poor biosecurity status. Most of animal health management and sanitation biosecurity, are poorly implemented.

Thus, based on the above conclusion the following recommendations are forwarded.

- Thus, raising awareness of dairy farm owners on the importance of biosecurity on their farms and its significance in disease prevention and economic productivity.
- Frequent delivery of capacity building training to dairy farmers to develop their own biosecurity plan and policy driven advocacy for the proper implementation of the biosecurity measures implementation at farmers and country level.
- Specially, isolation and animal health management biosecurity component practiced in dairy cow farms should be improved and followed by concerned regulatory body.
- An update training programs should be arranged regarding biosecurity to change the attitudes and perception of producers concerning biosecurity practices.
- In order to encourage producers to increase biosecurity implementation, regulations regarding financial support and penalties could be quite useful both at the regional and national levels.

Abbreviations

BRM: Biosecurity risk management; BP: Biosecurity practices; CFIA: Canadian food inspection agency; CSA: Central statistical agency; DVM: Doctor of veterinary medicine; FAD: Foreign animal diseases; FAO: Food and Agriculture Organization; OIE: Office of Interracial des Epizooties (World Organization for Animal Health).

Supplementary Information

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Additional file 1. Questionnaire and Checklists for Boisecurity.

Additional file 2. spreadsheet for coded biosecurity reference data.

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References

Afras AA (2019) Review on breeding objectives and practices of dairy cattle production in Ethiopia. J Cell Anim Biol 13(1):1–7

Ahmed AF (2018) Assessment of major constraints of dairy cattle and its associated risk factors in Mekelle city Ethiopia. Glob Vet 20(5):225–238

Belay D (2020) Survey of management practices and major diseases of dairy cattle in smallholdings in selected towns of Jimma zone, south-western Ethiopia. Anim Prod Sci 60:1838–1849
Birhanu H, Tehetena A, Yohannes H, Away T (2015) Assessment of bio-security conditions in the small scale poultry production system in and around Mekelle, Ethiopia. Eur J Biol Sci 7(3):99–102
Brennan ML, Christley RM (2013) Cattle producers' perceptions of biosecurity. BMC Vet Res 9:71. https://doi.org/10.1186/1746-6148-9-71
Brennan ML, Kemp R, Christley RM (2008) Direct and indirect contacts between cattle farms in north-west England. Prevent Veter Med 84:242–260
Caldow G (2004) Biosecurity, does it have a place in the management of beef herds in the United Kingdom? Cattle Practice 12:149–153
Can MF, Altuğ N (2014) Socio-economic Implications of biosecurity practices in small-scale dairy farms. Vet Q 34(2):67–73. https://doi.org/10.1080/01652176.2014.951130
Damiaans B, Renault V, Sarrazin S, Catharina A, Pardon B, Ribbens S et al (2019) Biosecurity practices in Belgian veal calf farming: level of implementation, attitudes, strengths, weaknesses and constraints. Prevent Vet Med 172:104768. https://doi.org/10.1016/j.prevetmed.2019.104768
Derks M, van de Ven LMA, van Werven T, Kremer WDJ, Hogeveen H (2012) The perception of veterinary herd health management by Dutch dairy farmers and its current status in The Netherlands: a survey. Prev Vet Med 104:207–215
Fasina FO, Lazarus DD, Spencer BT, Makinde AA, Bastos ADS (2012) Cost implications of African SwineFever in small- holder farrow-to-finish units: economic benefits of disease prevention through biosecurity. TransboundEmerg Dis 59:244–255
Gunn GJ, Heffernan C, Hall M, McLeod A, Hovi M (2008) Measuring and comparing constraints to improved biosecurity amongst GB farmers, veterinarians and the auxiliary industries. Prev Vet Med 84(3–4):310–323
Kouam MK, Moussala JO (2018) Assessment of factors influencing the implementation of biosecurity measures on pig farms in the western highlands of Cameroon (Central Africa). Vet Med Int. https://doi.org/10.1155/2018/9173646
Kouam MK, Jacouba M, Nsangou IN, Teguia A (2018) Assessment of biosecurity level in small-scale broiler farms in the Western highlands of Cameroon (Central Africa). Trop Anim Health Prod. https://doi.org/10.1007/s11250-018-1591-x
Laanen M, Persoons D, Ribbens S, de Jong E, Callens B, Strubbe M, Maes D, Dewulf J (2013) Relationship between biosecurity and production/antimicrobial treatment characteristics in pig herds. Vet J 198:508–512
Mee JF, Geraghty T, O'Neill R, More SJ (2012) Bioexclusion of diseases from dairy and beef farms: risks of introducing infectious agents and risk reduction. Vet J 194:143–150
Megersa M, Feyisa A, Wondimu A, Jibat T (2011) Herd composition and characteristics of dairy production in Bishoftu Town, Ethiopia. J Agric Ext Rural Dev 3(6):113–7
Melkamu BY, Berhan TM, Ashenafi MW (2016) Disease management and biosecurity measures of small-scale commercial poultry farms in and around DebreMarkos, Amhara Region, Ethiopia. J Vet Med Anim Health 8(10):136–144
Mengistu K, Mohammed A, Eyassu S, Tarekegn G, Estifanos H, Yonas H (2016) The dairy value chain and factors affecting choice of milk channels in Harar and Dire Dawa Areas, Eastern Ethiopia. Rev Agric Appl Econ 19:10–18. https://doi.org/10.15414/raae/2016.19.02.10-18
Metaferia F, Cherenet T, Gelan A, Abnet F, Tesfay A, Ali JA, Gulilat W (2011) A review to improve estimation of livestock contribution to the national GDP. Ministry of Finance and Economic Development and Ministry of Agriculture, Addis Ababa
Moore DA, Merryman ML, Hartman ML, Klingborg DJ (2008) Comparison of published recommendations regarding biosecurity practices for various production animal species and classes. J Am Vet Med Assoc 233(2):249–256
Musaba EC (2010) Analysis of factors influencing adoption of cattle management technologies by communal farmers in Northern Namibia. Livest Res Rural Dev 22(6):104
Nitovski A, Milenković M, Grčak D, Radović B, Stoja J, Milanovic V, Vukasinovic S (2013) Biosecurity assessment measures on a cow farms. Res People Actual Tasks Multidiscip Sci 1:2013
Noremark M, Frossling J, Lewerin S (2010) Application of routines that contribute to on-farm biosecurity as reported by Swedish livestock farmers. Transbound Emerg Dis 57:225–236
Robertson ID (2019) Disease control, prevention and on-farm biosecurity: the role of veterinary epidemiology. Engineering 6:20–25. https://doi.org/10.1016/j.eng.2019.10.004
Sahlström L, Virtanen T, Kyyrö J, Lyytikäinen T (2014) Biosecurity on Finnish cattle, pig and sheep farms - results from a questionnaire. Prev Vet Med 117:59–67
Sayers RG, Sayers GP, Mee JF, Good M, Bermingham ML, Grant J et al (2013) Implementing biosecurity measures on dairy farms in Ireland. Vet J 197(2):259–67. https://doi.org/10.1016/j.tvjl.2012.11.017
Stankovic B, Zlatanovi Z (2016) Sustainability and efficiency of dairy farms biosecurity plans biosecurity planning-initial assumptions. AGR 16:437–453. https://doi.org/10.7251/AGREN1504437S
van Schaik G, Dijkhuizen AA, Benedictus G, Barkema HW, Koole JL (1998) Exploratory study on the economic value of a closed farming system on Dutch dairy farms. Vet Rec 142(10):240–242
Wijesinghe WMJB, De Silva PGJC, Gunaratne SP (2017) Evaluation of biosecurity in commercial broiler farms in Sri Lanka. Int J Sci Res Publ 7(4):114–119
Wolff C, Boqvist S, Ståhl K, Masembe C, Sternberg-Lewerin S (2017) Biosecurity aspects of cattle production in Western Uganda, and associations with sero prevalence of brucellosis, salmonellosis and bovine viral diarrhoea. BMC Vet Res 13(1):382–389
Alemayehu G, Leta S (2014) Biosecurity practices in central Ethiopian cattle feedlots: its implication for live cattle export. https://doi.org/10.5897/IJLP2014.0221. Accessed 7 March 2020
Bickett-Weddle DA, Ramirez A (2005) Dairy biological risk management. Veterinary Diagnostic and Production Animal Medicine Publications. https://lib.dr.iastate.edu/vdpam_pubs/9
CSA (2012) Central Statistics Authority (CSA). Agricultural sample survey 2008–2009. In: Report on livestock and livestock characteristics vol. II. Statistical Bulletin No. 446. Addis Ababa, Ethiopia
CSA (2013) Agricultural sample survey 2012/13. In: Report on livestock and livestock characteristics. Private Peasant Holdings. Statistical Bulletin 570. (Central Statistical Agency, Federal Democratic Republic of Ethiopia: Addis Ababa, Ethiopia)
CSA (2016) Livestock and Livestock characteristics, agricultural sample survey. Federal Democratic 611 Republic of Ethiopia. Livestock and Livestock characteristics (Private Peasant Holdings). Stat Bull 2(612):9–13. (Central Statistical Agency, Federal Democratic Republic of Ethiopia: Addis Ababa, Ethiopia)
Collineau L, Stärk KDC (2019) How to motivate farmers to implement biosecurity measures. In: Biosecurity in animal production and veterinary medicine, vol. 4
FAO (2010) Good practices for biosecurity in the pig sector—issues and options in developing and transition countries. In: FAO Animal production and health paper No. 169. FAO, Rome
Lestari VS, Sirajuddin SN, Saleh IM, Prahesti KI (2019) Some factors influencing the level of biosecurity adoption in beef cattle farms. Faculty of Animal Husbandry, Hasanuddin University Jl. Perintis Kemerdekaan Km. 10 Makassar 90245, South Sulawesi, Indonesia. https://doi.org/10.4108/eai.18-7-2019.2290400
Milanovic V (2019) Proceedings of the fourth international conference publisher Bulgarian National Multidisciplinary Scientific Network of the professional society for research work. June 2013
Ndambi A, van der Lee J, Endalamaw T, Yigrem S, Tefera T, Andeweg K (2017) Four important facts on opportunities in the Ethiopian dairy sector. In: Practice brief dairy BISS project. Wageningen Livestock Research, Wageningen University and Research, Wageningen
Renault V, Damiaans B, Sarrazin S, Humblet M, Dewulf J, Saegerman C (2017) Biosecurity practices in cattle farming: level of implementation, constraints and weaknesses. In: ECVPH Scientific Meeting

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