Dairy farmers' knowledge about milk-borne zoonosis in the Eastern Cape province, South Africa

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Abstract

Foodborne zoonosis is a longstanding global issue that limits and continues to threaten the food production industry and public health in several countries. The study's objective was to evaluate the dairy farmers' knowledge, attitudes, and practices about milk-borne pathogens in the Eastern Cape province, South Africa. A total of 139 dairy farmers were interviewed using a semi-structured online questionnaire. The pathogens of interest were *Brucella* spp., *Escherichia coli, Listeria monocytogenes, Salmonella* spp., *Staphylococcus aureus,* and *Cryptosporidium.* Only 20.9% of dairy farmers reported knowledge of *Brucella* spp. as a milk-borne pathogen. The most known pathogen was *E. coli* (54.7%), followed by *Listeria* spp. (41.0%), *Staphylococcus* spp. (38.8%), and *Salmonella* spp. (35.3%). In this study, knowledge of milk-borne pathogens was statistically associated ($p<0.05$) with workplace position. Only a few participants (37.2%) showed knowledge of abortion as an important clinical sign of foodborne pathogens. Also, 84.1% of dairy farmers indicated that they consume unpasteurized milk and sour milk (77%). Some respondents (18.0%) do not believe assisting a cow during calving difficulty without wearing gloves is a risk factor for zoonosis. Knowledge assessment is essential in developing countries that have experienced a foodborne outbreak, such as South Africa. There is an urgent need to educate dairy farmers about milk-borne zoonosis to minimize the threat to food security and public health.

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Informed consent: a signed informed consent was obtained from each participant before commencing with the survey.

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Introduction

The *per capita* consumption of milk and dairy products continues to rise globally, reaching an average of 116 kg in 2020 (Milk Producers Organization, 2022). The rise in *per capita* consumption is attributed to population growth, dietary preferences, and health consciousness. However, consuming milk and dairy products is a risk factor for zoonosis, as some milk-borne pathogens, such as *Brucella* spp. and *Listeria* spp., can withstand pasteurization and cold storage (Ramaswamy *et al.*, 2007). Consequently, milk and dairy products are considered vehicles and suitable environments for bacterial growth and proliferation (Jayarao *et al*., 2006; McAuley *et al.,* 2014; Abebe *et al.*, 2020). Several foodborne illness outbreaks have been reported globally (in both developed and developing countries) within the last decade (Paduro *et al.*, 2020; Boone *et al.*, 2021; El Hag *et al.*, 2021). For instance, in March 2015, over 1700 cases of listeriosis were reported from cheese and ice cream in the European region, and 2932 cases in South Africa in 2017 (Buchanan *et al.*, 2017; Ramalwa *et al.*, 2020).

Other risk factors for zoonosis include direct contact with dairy cows, contact with their feces, unhygienic milking machines and surfaces, and the entire dairy farm environment. Working on a dairy farm is a high-risk occupation. A study conducted in Eritrea (East Africa) reported a high prevalence of *Brucella* spp. in different regions (Scacchia *et al.*, 2013). Thus, dairy farmers' knowledge needs to be evaluated and equipped regularly. This is because dairy farmers regularly handle cows and milk, even though these serve as potential reservoirs of foodborne pathogens (Jaja *et al.*, 2017). Knowledge and awareness are essential tools to prevent and control the surfacing and spreading of foodborne zoonosis (Fagnani *et* *al.*, 2021). Knowledge assessment is of the essence in developing countries that have experienced a foodborne outbreak, such as South Africa. Also, South Africa has the world's second-largest dairy cow herd (average 453 cows) (Milk Producers Organization, 2022). Such intensive production would mean South African dairy farmers are at a higher risk of milk-borne zoonosis.

The Eastern Cape province is one of the top contributors (27%) to the milk industry of South Africa, alongside the Western Cape (28%) and Kwa-Zulu Natal (27.3%) (Milk Producers Organization, 2022). The only previous study in South Africa about the knowledge of foodborne zoonosis, particularly brucellosis, was conducted amongst communal farmers as a reactionary study (Cloete *et al.*, 2019). Information about the knowledge of dairy farmers regarding *Brucella* spp., *Salmonella* spp., *Listeria* spp., *Escherichia coli*, and *Cryptosporidium* in South Africa is scant. Also, South Africa, specifically the Eastern Cape, is not proactively enforcing the regulations governing milk production, sale, and consumption (Agenbag *et al.*, 2012). Therefore, researchers and tertiary institutions should ensure that the population is knowledgeable and aware of milk-borne zoonosis (Fagnani *et al.*, 2021). On that note, this study was conducted as a tool to plan, integrate, and implement some regulations that will promote good standard practices in the dairy industry. Furthermore, the study maps intervention strategies for minimizing the threat posed by milk-borne zoonosis to food security and public health.

Materials and Methods

Ethical considerations

Ethical clearance (JAJ011SDIN01) was obtained from the University of Fort Hare Research Ethics Committee before data collection. A signed informed consent was obtained from each participant before commencing with the survey.

Study area and study population

The study was conducted mainly on dairy farms located in the coastal and inland regions of the Eastern Cape province. The Eastern Cape province is the third-highest milk-producing province in South Africa, contributing 27% to the overall production (Milk Producers Organization, 2022). Moreover, the province has the highest number of cows in milk, averaging over 800 cows.

In the Eastern Cape province, there are currently 172 registered dairy farms (Milk Producers Organization, 2022). However, not all these dairy farms were traceable and contactable for the study. Also, different farms were owned by the same company or owner, and as such, access to surveying was granted to only one farm. Furthermore, access to other farms was limited by fears of the COVID-19 pandemic and foot and mouth disease outbreak. Consequently, the snowball sampling technique was adopted and used for this study. The study population comprises 139 participants from 20 commercial dairy farms in the province (5 out of 6 district municipalities). Also, a handful (4) of small-scale farmers accessed through the snowball technique were included in the study, totaling 24 dairy farms. Within the farms, participants were selected based on their availability on the farm. In this study, owners, managers, supervisors, and general workers are all regarded as dairy farmers.

Study design and data collection

A cross-sectional study design was conducted using the snowball technique. A semi-structured online questionnaire was designed using Survey Monkey software, pretested, validated, and piloted. This was done by sending it to 10 respondents located on 5 different dairy farms. The pilot study was conducted to determine the required time to complete the questionnaire and to identify and remedy any discrepancies. The questionnaire was divided into 5 sections: demography, knowledge of common foodborne pathogens such as *Staphylococcus, E. coli, and Salmonella* spp., and their milk safety practices.

Statistical analysis

The questionnaire data was analyzed using IBM SPSS version 28 (Armonk, NY, USA). Descriptive statistics analysis was performed to determine frequencies, means, and ranges. Cronbach's a based on standardized items (0.952) was generated for the reliability of the data. The statistical association between the demography of the participants and their knowledge of the foodborne pathogens was measured with a Chi-square (X^2) test with a 95% level of significance.

Results

Table 1 consists of the demography of the dairy farmers and the association between demography and their knowledge of foodborne pathogens. In this study, 139 dairy farmers were assessed for their understanding of milk-borne zoonosis. Most participants (61.9%) were males, and the remaining were females (38.1%). Compared to females, many males had an idea about milk-borne pathogens. Only 20.9% of dairy farmers reported knowledge of *Brucella* spp. as a milk-borne pathogen; most respondents were farm managers (75.0%) and owners (85.6%). The most known pathogen was *E. coli* (54.7%), followed by *Listeria* spp. (41.0%), *Staphylococcus* spp. (38.8%), and *Salmonella* spp. (35.3%). Both genders equally (54.7%) pointed out that they were more familiar with *E. coli* than any other milk-borne zoonosis. However, there was no statistical association ($p>0.05$) between gender and knowledge of foodborne pathogens except for *Cryptosporidium*.

Dairy farmers aged between 26 and 35 years accounted for the most participants (38.1%), followed by the age group 36-45 years (26.6%). In all age groups, most participants had knowledge of *E. coli*. Notably, the age group of 20-25 years was predominant (80%) in this regard. There was a significant relationship ($p<0.05$) between age and knowledge of foodborne pathogens. However, the knowledge of *Listeria* spp. was not associated ($p>0.05$) with the age of the participants.

The educational level of most participants (45.3%) was below the grade 12 level (matric), but a sizeable number of participants (36%) had reached the tertiary educational level. Most participants with tertiary education had knowledge of *E. coli* (92%), *Listeria* spp. (66%), *Salmonella* spp. (70%), and *Brucella* spp. (66%). The educational level was statistically associated with the knowledge of foodborne pathogens. Farm managers (14.4% of the study population) and owners (5%) showed more knowledge of foodborne pathogens than their counterparts (general workers and supervisors). Farm managers showed heightened knowledge of *E. coli* (90% of farm managers), *Salmonella* spp. (85%), and *Staphylococcus* (80%). There was a significant statistical association ($p<0.05$) between workplace position and knowledge of foodborne pathogens. In addition, most participants (46%) had dairy farm work experience of 5 years and above, but few of those had knowledge of foodborne zoonosis.

In Table 2, most participants (66.9%) confirmed that they have heard or know the meaning of zoonosis. Some respondents (18%) do not believe assisting a cow during calving difficulty without wearing gloves is a risk factor for zoonosis. Also, most participants (54%) did not agree that walking on pastures is a risk factor for zoonosis. Lastly, the majority of participants (63.3%) mentioned that consumption of unpasteurized milk is not a risk factor for zoonosis. Dairy farmers were further assessed for their knowledge by checking their familiarity with the common clinical signs associated with milk-borne pathogens. Table 3 shows the proportion of individuals who confirmed their knowledge of the clinical signs according to their demographic profile. Both genders predominantly indicated that diarrhea and stomach cramps are associated with milk-borne pathogens. Only a few females (28.3%) and males (43%) showed knowledge of abortion as an important clinical sign of foodborne pathogens. However, there was no significant statistical association between gender and knowledge of foodborne pathogens' clinical signs. Most dairy farmers (54%) with tertiary education levels and those aged between 20 and 25 years mentioned that periodical headaches are associated with milk-borne pathogens. The educational level had a significant association with knowledge of periodical headaches and abortion as clinical signs of milk-borne pathogens. However, there was no association

Table 1. Respondents' demographic profile and association between demography and the knowledge of milk-borne zoonosis. The table contains figures of individuals who answered YES to the question or statement.

Demography	Category	Frequency (%) n=139	Knowledge of some milk-borne pathogens						Total
			Staph.	*E. coli*	*Listeria*	*Salmonella*	*Brucella*	*Crypto.*	
All farmers		139	54 (38.8)	76 (54.7)	57 (41.0)	49 (35.3)	29 (20.9)	25 (18.0)	
Gender	Female	53 (38.1)	17 (32.1)	29 (54.7)	20 (37.7)	15 (28.3)	8 (15.1)	4 (7.5)	53 (38.1)
	Male	86 (61.9)	37 (43.0)	47 (54.7)	37 (43.0)	34 (39.5)	21 (24.4)	21 (24.4)	86 (61.9)
		p value	0.198^{NS}	0.994^{NS}	0.538^{NS}	0.178^{NS}	0.425 ^{NS}	0.012*	
Age	20-25	25 (18.0)	16 (64.0)	20 (80.0)	15 (60.0)	16 (64.0)	16 (64.0)	4 (16.0)	25 (18.0)
	26-35	53 (38.1)	19 (35.8)	28 (52.8)	22 (41.5)	19 (35.8)	18 (34.0)	10 (18.9)	53 (38.1)
	36-45	37 (26.6)	11 (29.7)	18 (48.6)	12 (32.4)	6 (16.2)	12 (32.4)	6 (16.2)	37 (26.6)
	Above 45	24 (17.3)	8 (33.3)	10 (41.7)	8 (33.3)	8 (33.3)	8 (33.3)	5 (20.8)	24 (17.3)
		p value	0.037*	0.033*	0.142	0.002*	0.043*	0.959 ^{NS}	
Educational level	No education	2 (1.4)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0)	0 (0.0)	
	Below grade 12	63 (45.3)	6 (9.5)	16 (25.4)	12 (19.0)	5 (7.9)	11 (17.5)	2 (3.2)	2 (1.4)
	Grade 12	24 (17.3)	12 (50.0)	14 (58.3)	12 (50)	9 (37.5)	10 (41.7)	5 (20.8)	63 (45.3)
	Tertiary	50 (36.0)	14 (28.0)	46 (92.0)	33 (66)	35 (70)	33 (66.0)	18 (36.0)	24 (17.3)
		p value	0.001*	0.001*	0.001*	0.001*	0.001*	0.001*	50 (36.0)
Workplace position	General worker	95 (68.3)	25 (26.3)	43 (45.3)	32 (33.7)	19 (20.0)	25 (26.3)	6 (6.3)	95 (68.3)
	Farm manager	20 (14.4)	16 (80.0)	18 (90.0)	13 (65.0)	17 (85.0)	15 (75.0)	11 (55.0)	20 (14.4)
	Supervisor	18 (12.9)	6 (33.3)	11 (61.1)	6 (33.3)	7 (38.9)	5 (27.8)	5 (27.8)	18 (12.9)
	Owner	7 (5.0)	6 (85.7)	6 (85.7)	5 (71.4)	6 (85.7)	6 (85.7)	4 (57.1)	7 (5.0)
		p value	0.009*	0.002*	0.027*	0.004*	0.001*	0.001*	
Workplace experience	Less than a year	30 (21.6)	16 (53.3)	20 (66.7)	15 (50.0)	12 (40.0)	2 (6.8)	25 (18.0)	30 (21.6)
	1-2 years	24 (17.3)	11 (45.8)	16 (66.7)	10 (41.7)	13 (54.2)	5 (20.8)	6 (25.0)	24 (17.3)
	3-4 years	21 (15.1)	5 (23.8)	13 (61.9)	10 (47.6)	6 (28.6)	2 (9.5)	7 (33.3)	21 (15.1)
	5 years and above	64 (46.0)	22 (34.4)	27 (42.2)	22 (34.4)	18 (28.1)	21 (32.8)	9 (14.1)	64 (46.0)
		p value	0.128^{NS}	0.055^{NS}	0.466^{NS}	0.177^{NS}	0.852^{NS}	0.106^{NS}	

Staph, Staphylococcus; E. coli, Escherichia coli; Crypto, Cryptosporidium; ^{NS}not significant; *significant at $p<0.05$.

Table 2. Knowledge of foodborne zoonosis (n=139). The numbers in bold are the correct answers.

Questions/statements	Category Yes (%)	No (%)	I don't know (%)
A zoonosis is an infectious disease that is transmitted from animals to humans	**93 (66.9)**	25 (18.0)	21 (15.1)
Humans can be infected with zoonosis when they drink cooked milk	30 (21.6)	**90 (64.7)**	19 (13.7)
Milk from mastitis and sick cows is good for calves	30 (21.6)	**100 (71.9)**	9 (6.5)
Milk from mastitis cows is not bad for human consumption	20 (14.4)	**110 (79.1)**	9 (6.5)
Unpasteurized milk is somewhat good and can be consumed by humans	88 (63.3)	**45 (32.4)**	6 (4.3)
Assisting cows during calving without gloves or sanitizing could lead to human infection	**108 (77.7)**	25 (18.0)	6 (4.3)
The handling of an aborted fetus without protective clothing leads to infection	**100 (71.9)**	24 (17.3)	15 (10.8)
Herding dairy cows is a risk factor for zoonosis	49 (35.3)	65 (46.8)	25 (18.0)
Entering data of infected animals into the farm computer can spread infectious disease	16 (11.5)	113 (81.3)	10 (7.2)
Walking on pastures where the animals graze is a risk factor for zoonosis	**48 (34.5)**	75 (54.0)	16 (11.5)

(p>0.05) between educational level and knowledge of other clinical signs. This lack of knowledge of clinical signs (except for diarrhea and stomachaches) was prevalent throughout the demographic profiles, *i.e.*, experience and farm hierarchy.

Half of the supervisors (50%) mentioned that abortion and coughing are associated with milk-borne pathogens. In addition, most supervisors (61.1%) associated sore throats with milk-borne pathogens. Furthermore, all the farm owners mentioned that stomachaches and diarrhea are the clinical signs of milk-borne illnesses. Regarding work experience, only 31.3% of respondents with 5 years and above of experience identified abortion as a clinical sign of foodborne zoonosis. Most participants (52.4%) with work experience between 3 and 4 years identified periodical headaches as a clinical sign of milk-borne pathogens.

Table 4 shows the common practices of the study participants. It also shows the association between demography and the common practices of dairy farmers. More women (92.5%) are responsible for milking compared to men (84%), and only 17% of women perform artificial insemination. Furthermore, 75.5% of women confirmed consumption of raw milk, compared to 89.5% of males who consume raw milk. There was a significant association (p<0.05) between gender and the type of practices performed on the farm. Most males (74.4%) mentioned that they are responsible for treating sick cows.

Exactly 94% of study participants with tertiary education mentioned that they are responsible for milking and treating (80%) dairy cows. Also, over 70% of them confirmed that they do consume unpasteurized milk. There was a significant association (p<0.05) between the educational level and artificial insemination, basic administrative work, and herd treatment. Furthermore, supervisors and farm managers mentioned that they performed all the stipulated practices, especially artificial insemination (95% of managers), including consuming unpasteurized milk (90% of managers). There was a relationship (p<0.05) between demography and common practices performed on the farm, except for milking. However, dairy farm practices were not associated with the participants' farm work experience.

Discussion

The dairy industry continues to be a male-dominated space in South Africa. The predominance of males (61.9%) in this study is similar to the 60% of males reported in a recent study in the same Eastern Cape province but in a different region (Diniso and Jaja, 2021). However, a knowledge, attitudes, and practices study on milk-borne zoonosis conducted in Ethiopia reported a low 35.7% male representation (Mandefero and Yeshibelay, 2018). On dairy farms, females are commonly entrusted with milking and calf management, which are not even half of a dairy farm's daily practices. Even on these study farms, the majority of females (92.5%) confirmed that they are mainly responsible for milking. Some dairy practices include loading and offloading feed and calves, fixing fences, manhandling dairy cows for treatment, and assisting during calving. These are hard, labor-intensive tasks that most dairy farms reserve for males, hence the low representation of females. Additionally, males' higher knowledge of foodborne pathogens can be attributed to their exposure to various tasks.

In this study, most participants were aged between 26 and 35 years, which is not significantly different from the 21-30 years

Table 3. Knowledge of foodborne pathogens' clinical signs and association between demography and the knowledge of the signs. The table contains figures of individuals who answered YES to the question or statement.

Demography	Category	The following clinical signs are associated with foodborne pathogens (yes or no)							Total
		Abortion	Coughing	Stomach	Joints pain	Headache	Sore throat	Diarrhea	
All farmers		52 (37.4)	55 (39.6)	97 (69.8)	38 (27.3)	52 (37.4)	50 (36.0)	116 (83.5)	
Gender	Female	15 (28.3)	19 (35.8)	37 (69.8)	13 (24.5)	17 (32.1)	17 (32.1)	44 (83.0)	53 (38.1)
	Male	37 (43.0)	36 (41.9)	60 (69.8)	25 (29.1)	35 (40.7)	33 (38.4)	72 (83.7)	86 (61.9)
	p value	0.163^{NS}	0.610^{NS}	0.807^{NS}	0.286^{NS}	0.416^{NS}	0.527^{NS}	0.895^{NS}	
Age	20-25	11 (44.0)	11 (44.0)	22 (88.0)	9 (36.0)	13 (52.0)	12 (48.0)	23 (92.0)	25 (18.0)
	26-35	19 (35.8)	18 (34.0)	33 (62.3)	12 (22.6)	19 (35.8)	18 (34.0)	45 (84.9)	53 (38.1)
	36-45	14 (37.8)	18 (48.6)	26 (70.3)	10 (27.0)	12 (32.4)	14 (37.8)	30 (81.1)	37 (26.6)
	Above 45	8 (33.3)	8 (33.3)	16 (66.7)	7 (29.2)	8 (33.3)	6 (25.0)	18 (75.0)	24 (17.3)
	p value	0.577^{NS}	0.012*	0.252^{NS}	0.492^{NS}	0.382^{NS}	0.449^{NS}	0.716^{NS}	
Educational level	No education	0 (0.0)	1 (50.0)	1 (50.0)	0 (0.0)	0 (0.0)	0 (0.0)	1 (50.0)	2 (1.4)
	Below grade 12	18 (28.6)	24 (38.1)	37 (58.7)	13 (20.6)	17 (27.0)	18 (28.6)	51 (81.0)	63 (45.3)
	Grade 12	9 (37.5)	8 (33.3)	18 (75.0)	8 (33.3)	8 (33.3)	12 (50.0)	22 (91.7)	24 (17.3)
	Tertiary	25 (50.0)	22 (44.0)	41 (82.0)	17 (34.0)	27 (54.0)	20 (40.0)	42 (84.0)	50 (36.0)
	p value	0.009*	0.203^{NS}	0.195^{NS}	0.228^{NS}	0.054*	0.261^{NS}	0.528^{NS}	
Workplace position	General worker	32 (33.7)	40 (42.1)	61 (64.2)	23 (24.2)	30 (31.6)	32 (33.7)	79 (83.2)	95 (68.3)
	Farm manager	10 (50.0)	6 (30.0)	13 (65.0)	7 (35.0)	9 (45.0)	5 (25.0)	14 (70.0)	20 (14.4)
	Supervisor	9 (50.0)	9 (50.0)	16 (88.9)	8 (44.4)	10 (55.6)	11 (61.1)	17 (94.4)	18 (12.9)
	Owner	1 (14.3)	1 (14.3)	7 (100.0)	1 (14.3)	4 (57.1)	3 (42.9)	7 (100.0)	7 (5.0)
	p value	0.478^{NS}	0.421^{NS}	0.862^{NS}	0.314^{NS}	0.622^{NS}	0.109^{NS}	0.428^{NS}	
Workplace experience	Less than a year	14 (46.7)	13 (43.3)	20 (66.7)	9 (30.0)	14 (46.7)	11 (36.7)	23 (76.7)	30 (21.6)
	1-2 years	12 (50.0)	9 (37.5)	17 (70.8)	7 (29.2)	11 (45.8)	10 (41.7)	21 (87.5)	24 (17.3)
	3-4 years	6 (28.6)	10 (47.6)	19 (90.5)	8 (38.1)	11 (52.4)	11 (52.4)	20 (95.2)	21 (15.1)
	5 years and above	20 (31.3)	23 (35.9)	41 (64.1)	14 (21.9)	16 (25.0)	18 (28.1)	52 (81.3)	64 (46.0)
	p value	0.244^{NS}	0.410^{NS}	0.361^{NS}	0.550^{NS}	0.067^{NS}	0.321^{NS}	0.488^{NS}	

^{NS}not significant; *significant at p<0.05.

reported in previous studies (Diniso and Jaja, 2021). This age is regarded as fit and healthy for several dairy farm activities. However, the younger group, aged between 20-25 years, displayed a significantly high level of knowledge. Their knowledge can be attributed to the inquisitive nature of this young generation and their exposure to technology they can access for information. The age group above 45 years showed minimal knowledge of food-borne zoonosis. This age group is at high risk of zoonosis; therefore, their low level of knowledge is concerning and thus warrants intervention (Fagnani *et al.*, 2021).

E. coli is one of the persistent causative agents of mastitis in dairy cows, which is the most common dairy cow disease that receives regular attention (McAuley *et al.,* 2014; Huang *et al.*, 2022). This attention includes frequent hand washing, teats, dipping, and sanitizing throughout the milking session. Also, *E. coli* species have become a huge concern for dairy farmers as they have now developed resistance against antibiotics such as carbapenem, a last-resort antibiotic (Tian *et al.*, 2020; Wang *et al.*, 2020). Therefore, the high level of knowledge of *E. coli* by most participants (54.7%) in this study can be attributed to these vigilant measures set in place by dairy farms. Furthermore, the majority of farm managers and owners have knowledge of *E. coli,* which means they are most likely to inform the workers about the risks of *E. coli* to minimize its impact. Contrarily, this high level of knowledge is questionable, considering that most participants confessed to consuming raw milk and did not regard assisting calving cows without gloves as a risk factor for zoonosis. Possibly, the farmers consume raw milk because an immediate outcome (diarrhea) can be self-limiting, which is not regarded as a fatal exercise (Fox *et al.*, 2018).

The knowledge of *Listeria* spp. among 41% of participants is of great concern. In South Africa, there were 978 listeriosis cases reported in 2017/2018, which resulted in more than 30% of fatalities (Boatemaa *et al.*, 2019). This was the deadliest listeriosis outbreak compared to other continents (Arias-Granada *et al.*, 2021). The outbreak lasted over a year and resulted in the disposal of several processed food items, such as sausage and polony. In that context, it was anticipated that *Listeria* spp. would be one of the most known foodborne pathogens by the study participants. A possible account is that listeriosis did not emanate from dairy products in South Africa. Hence, it is negligible among dairy farmers. Even so, an urgent intervention will be essential considering that the pathogen can be transmitted through consuming infected raw milk, pasture, and machinery (Van Den Brom *et al.*, 2020). Infected dairy cows can shed the pathogen into the milk, thus increasing the risk of transmission to humans; therefore, it is a public health threat. One of the lethal attributes of *Listeria* spp. is its ability to bypass pasteurization and proliferate in cold storage (below 0°C), thus increasing transmission risks (Ramaswamy *et al.*, 2007). Few dairy farmers (20.9%) knew about *Brucella* spp. in the present study. These findings are consistent with a report by Cloete *et al.* (2019), who reported poor knowledge levels regarding brucellosis

Table 4. Common practices of dairy farmers and association between practices and demographic profiles. The table contains figures of individuals who answered YES to the question or statement.

	Which of the following activities do you regularly do on the farm? (Yes Or No)								Total
	Milking	Planting	Administration	Collecting calves	A.I	Treating cows	Consume raw milk	Consume sour milk (Maas)	
Gender									
Female	49 (92.5)	14 (26.4)	14 (26.4)	24 (45.3)	9 (17.0)	28 (52.8)	40 (75.5)	36 (67.9)	53 (38.1)
Male	69 (80.2)	29 (33.7)	36 (41.9)	56 (65.1)	34 (39.5)	64 (74.4)	77 (89.5)	71 (82.6)	86 (61.9)
p value	0.051*	0.365[NS]	0.062[NS]	0.022*	0.005*	0.009*	0.027*	0.047*	139
Age									
20-25	22 (88.0)	15 (60.0)	10 (40.0)	17 (68.0)	6 (24.0)	15 (60.0)	19 (76.0)	14 (56.0)	25 (18.0)
26-35	47 (88.7)	14 (26.4)	20 (37.7)	34 (64.2)	19 (35.8)	38 (71.7)	45 (84.9)	45 (84.9)	53 (38.1)
36-45	32 (86.5)	9 (24.3)	10 (27.0)	17 (45.9)	11 (29.7)	22 (59.5)	30 (81.1)	31 (83.8)	37 (26.6)
Above 45	17 (70.8)	5 (20.8)	10 (41.7)	12 (50.0)	7 (29.2)	17 (70.8)	23 (95.8)	17 (70.8)	24 (17.3)
p value	0.208[NS]	0.006*	0.600[NS]	0.198[NS]	0.748[NS]	0.547[NS]	0.263[NS]	0.023*	
Educational level									
No education	2 (100.0)	0 (0.0)	0 (0.0)	1 (50.0)	0 (0.0)	2 (100.0)	2 (100.0)	2 (100.0)	2 (1.4)
Below grade 12	50 (79.4)	9 (14.3)	8 (12.7)	30 (47.6)	7 (11.1)	34 (54.0)	55 (87.3)	54 (85.7)	63 (45.3)
Grade 12	19 (79.2)	10 (41.7)	10 (41.7)	14 (58.3)	8 (33.3)	16 (66.7)	22 (91.7)	18 (75.0)	24 (17.3)
Tertiary	47 (94.0)	24 (48.0)	32 (64.0)	35 (70.0)	28 (56.0)	40 (80.0)	38 (76.0)	33 (66.0)	50 (36.0)
p value	0.127[NS]	0.001*	0.001*	0.123[NS]	0.001*	0.023*	0.225[NS]	0.080[NS]	
Workplace position									
General worker	78 (82.1)	17 (17.9)	15 (15.8)	50 (52.6)	11 (11.6)	55 (57.9)	80 (84.2)	79 (83.2)	95 (68.3)
Farm manager	18 (90.0)	12 (60.0)	18 (90.0)	17 (85.0)	19 (95.0)	17 (85.0)	18 (90.0)	14 (70.0)	20 (14.4)
Supervisor	16 (88.9)	10 (55.6)	11 (61.1)	12 (66.7)	11 (61.1)	16 (88.9)	14 (77.8)	11 (61.1)	18 (12.9)
Owner	7 (100.0)	4 (57.1)	7 (100.0)	3 (42.9)	4 (57.1)	6 (85.7)	6 (85.7)	4 (57.1)	7 (5.0)
p value	0.124	0.015*	0.017*	0.003*	0.001*	0.002*	0.426[NS]	0.087[NS]	
Workplace experience									
Less than a year	28 (93.3)	13 (43.3)	11 (36.7)	21 (70.0)	8 (26.7)	20 (66.7)	22 (73.3)	17 (56.7)	30 (21.6)
1-2 years	19 (79.2)	6 (25.0)	11 (45.8)	13 (54.2)	7 (29.2)	12 (50.0)	17 (70.8)	18 (75.0)	24 (17.3)
3-4 years	19 (90.5)	5 (23.8)	7 (33.3)	12 (57.1)	9 (42.9)	15 (71.4)	19 (90.5)	17 (81.0)	55 (85.9)
5 years and above	52 (81.3)	19 (29.7)	21 (32.8)	34 (53.1)	19 (29.7)	45 (70.3)	59 (92.2)	55 (85.9)	64 (46.0)
p value	0.327[NS]	0.376[NS]	0.715[NS]	0.470[NS]	0.629[NS]	0.313[NS]	0.023*	0.018*	

A.I, artificial insemination; NSnot significant; *significant at p<0.05.

among cattle farmers in the Eastern Cape province. Also, an earlier study in Ethiopia reported that approximately 2% of respondents knew *Brucella* spp. as a milk-borne zoonosis (Mandefero and Yeshibelay, 2018). However, an earlier study in Zimbabwe reported that 21.9% of farmers were aware of *Brucella* spp. (Mosalagae *et al.*, 2011). Misdiagnosis and minimal detection may be accountable for the lack of information and poor knowledge of *Brucella* spp. among livestock farmers on the African continent (Caine *et al.*, 2017). Lack of diagnosis is rife in commercial and communal farms, thus increasing the risk of infection because of the lack of vaccination against bovine *Brucella* spp. (Godfroid *et al.,* 2013; Tebug *et al*., 2014; Caine *et al.,* 2017). In South Africa, vaccination against brucellosis is not obligatory, and consuming raw milk is a common practice, thus increasing the risks of infection (Cloete *et al.*, 2019; Diniso and Jaja, 2021). Such aspects require immediate intervention and cooperation between the government and research institutions to minimize the threat posed to public health.

Salmonella spp. was one of the least known foodborne pathogens among general workers (20.0%) and experienced (above 5 years) workers (28.1%). *Salmonella* spp. is a zoonotic and reportable pathogen; as a result, there are strict control measures set by milk producers (Guiney and Fierer, 2011; Mohakud *et al.*, 2022). This may result in minimal cases of salmonellosis in dairy, hence the lack of knowledge. However, *Salmonella* spp. is normally found on dairy farms in milk filters, unpasteurized milk of dairy cows, feces, and soil (Sonnier *et al.*, 2018). As such, consuming unpasteurized milk is a major risk factor for salmonellosis (Eng *et al.*, 2015). An Ethiopian study further confirmed the prevalence of *Salmonella* spp. in milk samples (Sonnier *et al.*, 2018). Thus, the confirmation by this study's participants that they consume raw milk yet do not know of *Salmonella* spp. should be a source of worry as this practice could expose the participant to *Salmonella* food poisoning in the future.

The lack of knowledge of abortion as a clinical sign among dairy farmers in this study is concerning. Abortion is an important clinical sign of zoonosis affecting humans and animals (Tulu *et al.*, 2018). In dairy cattle, abortion can be induced by *Brucella abortus*, an etiologic agent of brucellosis. Brucellosis is transmitted to humans through the consumption and handling of contaminated, unpasteurized milk and the handling of aborted fetuses without protection (Tulu *et al.*, 2018). With that noted, dairy farmers are at high risk of succumbing to abortion, especially in a country where there is a proportion of unregulated consumption of raw milk on dairy farms (Milk Producers Organization, 2022). A possible explanation for this lack of knowledge is that dairy farms barely test for brucellosis; thus, opportunities to learn about it are scant (Tulu *et al.*, 2018; Cloete *et al.*, 2019). Furthermore, dairy farmers associate abortion with brucellosis only, whereas abortion can be caused by *Listeria* spp. (Allerberger and Wagner, 2010; Tulu *et al.*, 2018; Rossi *et al.*, 2022). Thus, the focus on *Brucella* spp. or contagious abortion only by dairy farmers may contribute to the lack of knowledge of abortion as a clinical sign.

Respondents correctly indicated that stomachaches and diarrhea were clinical signs of foodborne diseases. The knowledge of stomachaches and diarrhea can be associated with several foodborne outbreaks, signified by diarrhea, such as listeriosis and cholera (Tchatchouang *et al.*, 2020). A recent listeriosis comparative study reported that the most common signs of listeriosis were diarrhea, fever, and headaches (Tchatchouang *et al.*, 2020). Hence, the respondents could easily identify these signs. Experienced and older dairy farmers mentioned that they consumed raw milk to trigger diarrhea, thus cleaning their stomachs. The assertions indicated a high awareness of diarrhea as a clinical sign of a foodborne illness. In this study, 84.1% of dairy farmers indicated that they consume unpasteurized milk and sour (maas) milk (77%). These findings are considerably higher than the 68.1% reported in an earlier study in Zimbabwe and 66% in Pakistan (Arif *et al.*, 2017). Consumption of unpasteurized milk has been extensively reported as a major transmission route for milk-borne pathogens (Arif *et al.*, 2017; Mandefero and Yeshibelay, 2018). The consumption of raw milk can be equated with a poor or wrong attitude towards pasteurized milk informed by insufficient knowledge of milk-borne zoonosis (Mandefero and Yeshibelay, 2018). The study participants could be vulnerable to milk-borne pathogens and are at risk of illness if not adequately informed through food safety training.

Conclusions

The study's objective was to evaluate dairy farmers' knowledge about milk-borne zoonosis. The findings showed that participants had poor knowledge of milk-borne pathogens, especially *Brucella* spp., *Salmonella* spp., *Listeria* spp., and *Staphylococcus* spp. Also, most participants did not associate human and bovine abortion with any foodborne zoonosis. This is regardless of work experience or educational level. The lack of knowledge of milk-borne zoonosis and the consumption of unpasteurized milk by a large number of participants further substantiate participant misunderstandings of basic food safety concepts. This is a matter of concern considering that milk is a rich medium for bacteria proliferation, and food handlers such as study participants contribute to microbial food quality in the food value chain. Hence, their actions or inactions could result in a widespread disease outbreak among consumers. Therefore, the current study recommends food safety training and re-training for dairy farmers. The government should also provide guidelines and regulatory oversight on various food safety regulations and laws to protect public health. Other intervention strategies can include regular science engagements and farmer workshops.

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