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The Relationship Between the Knowledge, Attitudes and Practices of Herders on Hygienic Milking and The Contamination Risk of Milk with Cryptosporidium Oocyst in Kaduna State, Nigeria

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SUMMARY

Dairy products are consumed by millions on daily basis worldwide and as such the potential for food-borne illness is a major concern. This study investigated the occurrence of *Cryptosporidium* oocyst in cow bulk milk and the knowledge, attitudes, and practices of herders towards hygienic milking in selected Local Government Areas (LGAs) of Kaduna State, Nigeria. A total of 120 milk samples were collected for this study. Detection of *Cryptosporidium* oocyst in milk samples was carried out by concentration technique using Magnesium Sulphate ($MgSO_4$) solution and stained with Modified Ziehl Neelsen method. Sixty (60) structured questionnaires were administered to herders in the study area to identify possible risk factors and assess their knowledge, attitudes and practices toward hygienic milking. The overall prevalence of *Cryptosporidium* oocysts in cow bulk milk was 11.7% (14/120). Questionnaires administered showed that the majority of the respondents had poor knowledge (88.3%), negative attitudes (85.0%) and adopted unsatisfactory practices (95.0%) to hygienic milking. The occurrence of *Cryptosporidium* oocysts in cow bulk milk from this study suggests that the dairy cattle in these LGAs have a high potential for transmitting *Cryptosporidium* to humans. Hence the findings of this study are of great public health significance as these group of animals sampled produce milk for consumption in both urban and rural communities. Therefore, inhabitants of these LGAs should be informed and educated on the need to improve sanitary measures while milking these animals and the need for adequate pasteurization of milk before consumption.

Key words: *Cryptosporidium* oocysts, cow bulk milk, knowledge, attitudes, and practices.

INTRODUCTION

Dairy plays a crucial role in global diets (Kamana *et al*., 2014). Milk contamination arises from inadequate handling and sub-optimal hygiene and sanitation conditions in the milking environment (Olivier *et al*., 2005). Improperly handled milk can act as a vehicle for various pathogens, including bacteria, viruses, parasitic agents, and chemical residues, leading to foodborne diseases that impact consumers' health and nutritional well-being

(Amenu *et al*., 2019). Milk, being a highly perishable product, rapidly loses its safety and quality if not managed under sanitary conditions (Kamana *et al*., 2014). The dairy sector in low-to-middle-income countries (LMICs) faces significant challenges related to poor milk quality and food safety risks, attributed to weak food safety management systems and insufficient compliance with standards (Amenu *et al*., 2019). A comprehensive approach to ensuring milk quality and safety, encompassing the entire production process from the farm to consumption ('farm to glass'), is imperative (Grace *et al*., 2007). Upholding knowledge and adherence to milk quality standards and food safety regulations are pivotal in mitigating milk-borne diseases (Dongol *et al*., 2017). Farmers tend to adopt economically viable, technically feasible, and socio-culturally acceptable milk quality and safety practices (Hermans *et al*., 2017).

Cryptosporidium parvum oocysts are commonly found on dairy farms and may be transmitted to humans through contaminated raw milk and dairy products, posing a risk for susceptible people (Fayer *et al*., 2003). *Cryptosporidium parvum* oocysts from contaminated water could be transferred via food contact surfaces into milk and dairy products such as yogurt and ice cream. Oocysts in a sanitizer deposited on the inner surface of a vat could contaminate milk products that are subsequently introduced (Marriott *et al*., 2018). Some disease-causing organisms (pathogens) can be shed through cow faeces and may contaminate the outside of the udder and teats, from the farm environment particularly the water source and utensils used for the storage of milk on the farm and during transportation (Asmahan and Warda, 2011). Consumption of unpasteurized milk is the most frequently reported cause of outbreaks of *Cryptosporidium* infection (Friedman *et al.*, 2000). Many authors showed the presence of viable oocysts in raw milk, raw meat and other raw foods (Hassan *et al.*, 2002; Smith and Nichole, 2009; Hassan *et al.*, 2018).

Limited studies have explored the knowledge, attitudes, and practices (KAPs) regarding milk quality and safety among smallholder dairy farmers, particularly in Kaduna State. Understanding the drivers of KAPs concerning milk quality is essential for improving milk quality in LMICs, especially in Africa (Dongol *et al*., 2017; Kumar *et al*., 2017). This study investigated the occurrence of *Cryptosporidium* oocysts in cow bulk milk and also evaluated the knowledge, attitudes, and practices of herders towards hygienic milking in sedentary Fulani herds in selected Local Government Areas of Kaduna State, Nigeria.

MATERIALS AND METHODS

Study Area

The study was carried out in six (6) selected Local Government Areas (LGA) of Kaduna State, Nigeria; namely, Zaria, Sabon Gari, Giwa, Igabi, Soba and Kudan.

Study Design

This was a cross-sectional study. A total 30 cattle herds, five from six different LGAs, were selected. A milk sample from the bulk milk was collected from each cattle herd during a weekly visit for four weeks, yielding a total of 120 milk samples.

Questionnaire Administration

A structured questionnaire was administered to herders (employing oral interview) within the

selected herds to assess their knowledge, attitudes and practices towards hygienic milking practices.

Ethical Clearance and Consent

An ethical clearance was obtained from the Ahmadu Bello University Committee on Animal Use and Care (ABUCAUC). Information was collected only with the farmers' consent and willingness to participate in the research.

Sample Collection

About 10 ml of milk was collected into a clean sterile sample bottle from each bulk milk. All samples were properly labeled and transported on ice packed cold boxes to the Parasitic Zoonoses Laboratory, Department of Veterinary Public Health and Preventive Medicine, Ahmadu Bello University, Zaria.

Laboratory Analysis

Microscopic analysis of milk samples

Detection of *Cryptosporidium* oocyst in milk samples was carried out by the method described by Machado *et al*. (2006). Briefly, 5ml of milk sample was placed in a 15ml centrifuge tube and 5ml of magnesium sulphate ($MgSO_4$) solution (density $1.30gml^{-1}$; $750g1^{-1}$) was added. This was stirred vigorously and centrifuged at 206 x g for 10 minutes. Three layers were formed in the tube; supernatant at the topmost layer, milk clot at the intermediate layer and sediment at the bottom of the tube. The supernatant was carefully decanted into a washing basin, while the resulting clot was transferred into a tube where it was washed with distilled water. The clot was re-suspended in 8ml of distilled water, where it was dissolved with an applicator stick and sieved. The filtrate was centrifuged at 206 x g for 10 minutes. Milk smears was made with 5µl of both the supernatant and sediment. Presence of *Cryptosporidium* oocyts was detected using the modified Ziehl-Neelsen staining technique as described by Clarke and McIntyre (2001). *Cryptosporidium* oocysts appear as pink to red, spherical to ovoid bodies against a green to purple background (WHO, 1991). Samples were considered positive if at least one morphologically distinct *Cryptosporidium* oocyst was observed.

Data Analyses

Data from the study were analysed using Statistical Package for Social Science (SPSS) version 20.0 (Standard Version SPSS Inc., Chicago, IL, USA). Chi-square or Fisher's exact test was used, as appropriate to test for association between *Cryptosporidium* oocysts in milk and the knowledge, attitudes and practices of the herders to hygienic milking/milk hygiene. P values ≤ 0.05 were considered significant. Also, for the knowledge, attitudes and practices, a marking scheme containing expected correct answers was prepared and used to mark and score the responses. For each correct and incorrect answer, one and zero points was assigned respectively. Indifferent/undecided responses were considered as wrong answers. Respondents' knowledge, attitude and practices to hygienic milking/milk hygiene were scored and graded on a 15, 12 and 15-point scale respectively. Scores were then converted to percentages. Those that scored ≥50% were considered as having "satisfactory" knowledge, attitudes and practices, while those that scored <50% were graded as having "poor" knowledge, attitudes and practices towards hygienic milking.

RESULTS

The prevalence of *Cryptosporidium* oocysts in the bulk milk samples was 11.7 % (14/120) (Table I). The demographic characteristics of respondents to this survey are presented in Table II. The overall results of the survey evaluating herders' knowledge regarding milk hygiene are presented on Table III. There was no statistically significant association between the occurrence of *Cryptosporidium* oocysts in milk and knowledge of herders that participated in the survey. Only 15% and 5% of the respondents had good attitude (Table IV) and adopted hygienic milking practices (Table V) respectively. The association between socio-demographic characteristics and the knowledge, attitudes and practices of the respondents on hygienic milking are as shown on Table VI, VII and VIII respectively.

TABLE I: Distribution of *Cryptosporidium* oocysts in bulk milk sampled from sedentary Fulani herds in selected Local Government Areas (LGAs) of Kaduna State, Nigeria.

LGA	Number of herds	Number examined	Number positive (%)	χ^2	p-value
Zaria	**5**	**20**	**2 (10.0)**	**2.588**	**0.763**
Sabon gari	**5**	**20**	**1 (5.0)**		
Giwa	**5**	**20**	**4 (20.0)**		
Igabi	**5**	**20**	**3 (15.0)**		
Soba	**5**	**20**	**2 (10.0)**		
Kudan	**5**	**20**	**2 (10.0)**		
Total	**30**	**120**	**14(11.7)**		

TABLE II: Socio-demographic characteristics of respondents in sedentary Fulani herds in the selected Local Government Areas (LGAs) of Kaduna State, Nigeria.

Characteristics	Number of respondents	Percentage (%)
Age		
11-20	8	13.3
21-30	34	56.7
31-40	16	26.7
>40	2	3.3
Gender		
Male	60	100
Female	0	0
Marital status		
Single	50	83.3
Married	8	13.3
Separated	2	3.3
Type of education		
Formal	8	13.3
Informal	52	86.7
Level of education		
Primary	8	13.3
None	52	86.7
How long rearing animals		
< 10years	40	66.7
10-20 years	18	30.0
>20 years	2	3.3

TABLE III: Relationship between the occurrence of *Cryptosporidium* oocysts in bulk milk and knowledge of the respondents on hygienic milking in sedentary Fulani herds in the selected Local Government Areas (LGAs) of Kaduna State, Nigeria

Knowledge	No. of respondents (%)	No. of milk sample	No. positive (%)	χ^2	p-value
Any knowledge of diarrhoeic illness?					
Yes	24 (40.0)	48	8 (16.7)	1.941	0.164
No	36 (60.0)	72	6 (8.3)		

Do you know that milk you consume is rich in nutrients?	60 (100)	120	14 (11.7)	-	-
Yes	0 (0.0)	0	0 (0.0)		
No					
Best form to consume milk?					
Raw	46 (76.7)	92	13 (14.1)	3.189	0.203
Parboiled	10 (16.7)	20	0 (0.0)		
Pasteurized	4 (6.7)	8	1 (12.5)		
Some diseases can be transmitted from animals to humans through milk consumption	10 (16.7)	20	1 (5.0)	1.035	0.309
Yes	50 (83.3)	100	13 (13.0)		
No					
Hands should be washed after contact with animals/their dung	18 (30.0)	36	2 (5.6)	1.864	0.172
Yes	42 (70.0)	84	12 (14.3)		
No					
Hands should be washed after defaecation					
Yes	60 (100)	120	14 (11.7)	-	-
No	0 (0.0)	0	0 (0.0)		
Milking utensils should be washed before and after milking	6 (10.0)	12	1 (8.3)	0.144	0.705
Yes	54 (90.0)	108	13 (12.0)		
No					
Unhygienic/dirty environment can contaminate milk	12 (20)	24	3 (12.5)	0.020	0.887
Yes	48 (80)	96	11 (11.5)		
No					
Zoonotic diseases/diseases transmitted from animals to humans can be prevented					
Yes	6 (10)	12	2 (16.7)	0.323	0.570
No	54 (90)	108	12 (11.1)		
Knowledge on milk parameters					
Yes	9 (15)	18	2 (11.1)	0.006	0.937
No	51 (85)	102	12 (11.8)		

Knowledge on drug withdrawal period					
Yes	0 (0.0)	0	0 (0.0)	-	-
No	60 (100)	120	14 (11.7)		
Any training needed on milk hygiene					
Yes	0 (0.0)	0	0 (0.0)	-	-
No	60 (100)	120	14 (11.7)		
Aware of tests used by milk buyers					
Yes	2 (3.3)	4	0 (0.0)	0.547	0.460
No	58 (96.7)	116	14 (12.1)		
Common condition/disease in dairy animals					
Mastitis	49 (81.7)	98	10 (10.2)	3.756	0.153
Worm infection	8 (13.3)	16	4 (25.0)		
Other diseases	3 (5.0)	6	0 (0.0)		
Knowledge of negative impact of animal diseases on milk	53 (88.3)	106	13 (12.3)	0.315	0.575
Yes	7 (11.7)	14	1 (7.1)		
No					

TABLE IV: Relationship between the occurrence of *Cryptosporidium* oocysts in bulk milk and attitudes of the respondents on hygienic milking in sedentary Fulani herds in the selected Local Government Areas (LGAs) of Kaduna State, Nigeria.

Attitudes	**No. of respondents (%)**	**No. of milk sample**	**No. positive (%)**	χ^2	**p-value**
Hands should be washed before milking	12 (20.0)	24	2 (8.3)	0.956	0.620
Agree	46 (76.7)	92	12 (13.0)		
Disagree	2 (3.3)	4	0 (0.0)		
Indifferent					
Milking utensils should be washed before milking	46 (76.7)	92	11 (12.0)	0.032	0.858
Agree	14 (23.3)	28	3 (10.7)		
Disagree					
Udder and teat should be washed before milking	56 (93.3)	112	12 (10.7)	1.479	0.224
Disagree	4 (6.7)	8	2 (25.0)		
Indifferent					

Udder should be disinfected before milking					
Disagree	38 (63.3)	76	7 (9.2)	1.213	0.271
Indifferent	22 (36.7)	44	7 (15.9)		
Fore milk should be disposed before milking					
Agree	4 (6.7)	8	2 (25.0)	1.479	0.224
Disagree	56 (93.3)	112	12 (10.7)		
Filtering of milk is a good practice					
Agree	26 (43.3)	52	4 (7.7)	1.406	0.236
Disagree	34 (56.7)	68	10 (14.7)		
Milking area should be cleaned after milking					
Agree	56 (93.3)	112	14 (12.5)	1.132	0.287
Indifferent	4 (6.7)	8	0 (0.0)		
Milking floor should be disinfected after milking	2 (3.3)	4	1 (25.0)	0.821	0.663
Agree	57 (86.7)	104	12 (11.5)		
Disagree	6 (10.0)	12	1 (8.3)		
Indifferent					
Humans can get infected by milking/handling sick animals					
Agree	8 (13.3)	16	1 (6.3)	0.526	0.468
Disagree	52 (86.7)	104	13 (12.5)		
Vet. Medical care should be sought for sick milking animals					
Agree	16 (26.7)	32	1 (3.1)	3.648	0.161
Disagree	38 (63.3)	76	12 (15.8)		
Indifferent	6 (10.0)	12	1(8.3)		
Milk from treated/sick cow should be discarded	8 (13.3)	16	3 (18.8)	0.899	0.343
Agree	52 (86.7)	104	11 (10.6)		
Disagree					
Animals should be dewormed/vaccinated routinely to improve their health					
Agree	58 (96.7)	116	14 (12.1)	0.547	0.460
Disagree	2 (3.3)	4	0 (0.0)		

TABLE V: Relationship between the occurrence of *Cryptosporidium* oocysts in bulk milk and practices of the respondents on hygienic milking in sedentary Fulani herds in the selected Local Government Areas (LGAs) of Kaduna State, Nigeria.

Practices	No. of respondents (%)	No. of milk sample	No. positive (%)	χ^2	p-value
How often do you clear the cow dung?					
Weekly	4 (6.7)	8	0 (0.0)	4.02	0.134
Monthly	14 (23.3)	28	1 (3.6)		
Seasonal	42 (70.0)	84	13 (15.5)		
How do you dispose the cow dung?					
Farm	16 (26.7)	32	1 (3.1)	3.089	0.079
Sale	44 (73.3)	88	13 (14.8)		
Frequency of milking per day					
Once	52 (86.7)	104	13 (12.5)	0.526	0.468
Twice	8 (13.3)	16	1 (6.3)		
Source of water for washing milk contact containers/utensils	2 (3.3)	4	1 (25.0)		
Borehole	4 (6.7)	8	0 (0.0)	4.636	0.200
Well	36 (60.0)	72	6 (8.3)		
River	18 (30.0)	36	7 (19.4)		
Pond					
Washing of milk contact containers/utensils					
Soap	2 (3.3)	4	1 (25.0)	4.511	0.211
Detergent	8 (13.3)	16	1 (6.3)		
Ash/mud	14 (23.3)	28	6 (21.4)		
Only water	36 (60.0)	72	6 (8.3)		
Frequency of washing containers/utensils for milking	18 (30.0)	36	3 (8.3)	0.554	0.456
Daily	42 (70.0)	84	11 (13.1)		
Weekly					
Drying of containers/utensils after washing					
Yes	6 (10.0)	12	1 (8.3)	0.144	0.705
No	54 (90.0)	108	13 (12.0)		
Always washing of udder and teat before milking	0 (0.0)	0	0 (0.0)	-	-
Yes	60 (100)	120	14 (11.7)		
No					

Always washing of hands before milking	6 (10.0)	12	4 (33.3)	6.074	0.014
Yes	54 (90.0)	108	10 (9.3)		
No					
Use of towel for teat cleaning					
Yes	0 (0.0)	0	0 (0.0)	-	-
No	60 (100)	120	14 (11.7)		
Any teat lubrication before milking?					
Yes	0 (0.0)	0	0 (0.0)	-	-
No	60 (100)	120	14 (11.7)		
Collecting vessel used					
Plastic	32 (53.3)	64	4 (6.3)	5.237	0.073
Aluminum	2 (3.3)	4	0 (0.0)		
Calabash	26 (43.3)	52	10 (19.2)		
Method of restraint of cattle during milking					
Leg restraint	58 (96.7)	116	13 (11.2)	0.714	0.398
Leg and tail restraint	2 (3.3)	4	1 (25.0)		
Method of milking					
Hand	60 (100)	120	14 (11.7)	-	-
Machine	0 (0.0)	0	0 (0.0)		
Use of calf suckling to stimulate milk release before milking					
Yes	9 (15.0)	18	1 (5.6)	0.767	0.381
No	51 (85.0)	102	13 (12.7)		
Any milk quality testing before milking					
Yes	0 (0.0)	0	0 (0.0)	-	-
No	60 (100)	120	14 (11.7)		
How collected milk is filtered					
Cloth	8 (13.3)	16	1 (6.3)	0.526	0.468
No filter	52 (86.7)	104	13 (12.5)		
Storage of milk					
Plastic	48 (80.0)	96	12 (12.5)	1.671	0.643
Aluminum	1 (1.7)	2	0 (0.0)		
Clay pots	2 (3.3)	4	1 (25.0)		
Calabash	9 (15.0)	18	1 (5.6)		

Do you discard milk from treated/sick animals?					
Yes	6 (10)	12	2 (16.7)	0.323	0.570
No	54 (90)	108	12 (11.1)		
Do you keep farm records?					
Yes	0 (0.0)	0	0 (0.0)	-	-
No	60 (100)	120	14 (11.7)		
Do you adhere to routine deworming and vaccination?	0 (0.0)	0	0 (0.0)	-	-
Yes	60 (100)	120	14 (11.7)		
No					

TABLE VI: Association between socio-demographic characteristics and knowledge of the respondents on hygienic milking

Variables		No. of respondents	Knowledge		χ^2	p-value
			Satisfactory (%)	Poor (%)		
LGA	**Zaria**	10	2 (20.0)	8 (80.0)	9.38	0.095
	Sabon gari	10	1 (10.0)	9 (90.0)		
	Giwa	10	0 (0.0)	10 (100)		
	Igabi	10	0 (0.0)	10 (100)		
	Soba	10	2 (20.0)	8 (80.0)		
	Kudan	10	2 (20.0)	8 (80.0)		
Age	**11-20**	8	1 (12.5)	7 (87.5)	7.23	0.065
	21-30	34	4 (11.8)	30 (88.2)		
	31-40	16	1 (6.3)	15 (93.8)		
	>40	2	1 (50.0)	1 (50.0)		
Gender	**Male**	60	7 (11.7)	53 (88.3)	-	-
	Female	0	0 (0.0)	0 (0.0)		
Marital status	**Single**	50	3 (6.0)	47 (94.0)	19.18	0.000
	Married	8	3 (37.5)	5 (62.5)		
	Separated	2	1 (50.0)	1 (50.0)		
Education	**Formal**	8	1 (12.5)	7 (87.5)	0.53	0.468
	Informal	52	6 (11.5)	46 (88.5)		
Rearing experience	**<10 years**	40	5 (12.5)	35 (87.5)	6.105	0.047
	10-20 years	18	1 (5.6)	17 (94.4)		
	> 20 years	2	1 (50.0)	1 (50.0)		
	Total	**60**	**7 (11.7)**	**53 (88.3)**		

TABLE VII: Association between socio-demographic characteristics and attitude of the respondents on hygienic milking

Variables		No. of respondents	Attitude		χ^2	p-value
			Satisfactory (%)	Poor (%)		
LGA	**Zaria**	10	2 (20.0)	8 (80.0)	27.45	0.000
	Sabon gari	10	0 (0.0)	10 (100)		
	Giwa	10	0 (0.0)	10 (100)		
	Igabi	10	1 (10.0)	9 (90.0)		
	Soba	10	1 (10.0)	9 (90.0)		
	Kudan	10	5 (50.0)	5 (50.0)		
Age	**11-20**	8	0 (0.0)	8 (100)	5.597	0.133
	21-30	34	7 (20.6)	27 (79.4)		
	31-40	16	1 (6.3)	15 (93.8)		
	>40	2	1 (50.0)	1 (50.0)		
Gender	**Male**	60	9 (15.0)	51 (85.0)	-	-
	Female	0	0 (0.0)	0 (0.0)		
Marital status	**Single**	50	4 (8.0)	46 (92.0)	32.86	0.000
	Married	8	5 (62.5)	3 (37.5)		
Education	**Formal**	8	1 (12.5)	7 (87.5)	0.090	0.764
	Informal	52	8 (15.4)	44 (84.6)		
Rearing experience	**<10 years**	40	6 (15.0)	34 (85.0)	0.349	0.840
	10-20 years	18	2 (11.1)	16 (88.9)		
	> 20 years	2	1 (50.0)	1 (50.0)		
	Total	**60**	**9 (15.0)**	**51 (85.0)**		

TABLE VIII: Association between socio-demographic characteristics and practices of the respondents on hygienic milking.

Variables		No. of respondents	Practices		χ^2	p-value
			Satisfactory (%)	Poor (%)		
LGA	**Zaria**	10	1 (10.0)	9 (90.0)	6.316	0.277
	Sabon gari	10	0 (0.0)	10 (100)		
	Giwa	10	0 (0.0)	10 (100)		
	Igabi	10	0 (0.0)	10 (100)		

	Soba	10	1 (10.0)	9 (90.0)		
	Kudan	10	1 (10.0)	9 (90.0)		
Age	**11-20**	8	0 (0.0)	8 (100)	2.082	0.556
	21-30	34	2 (5.9)	32 (94.1)		
	31-40	16	1 (6.3)	15 (93.8)		
	>40	2	0 (0.0)	2 (100)		
Gender	**Male**	60	3 (5.0)	57 (95.0)	-	-
	Female	0	0 (0.0)	0 (0.0)		
Marital status	**Single**	50	2 (4.0)	48 (96.0)	2.316	0.314
	Married	8	1 (12.5)	7 (87.5)		
	Separated	2	0 (0.0)	2 (100)		
Education	**Formal**	8	1 (12.5)	7 (87.5)	0.061	0.805
	Informal	52	2 (3.8)	50 (96.2)		
Rearing experience	**<10 years**	40	2 (5.0)	38 (95.0)	0.848	0.654
	10-20 years	18	1 (5.6)	17 (94.4)		
	> 20 years	2	0 (0.0)	2 (100)		
	Total	**60**	**3 (5.0)**	**57 (95.0)**		

DISCUSSION

The occurrence of *Cryptosporidium* oocysts in milk sampled from all the LGAs as revealed by this study may be attributed to factors such as poor sanitation and unhygienic management of herds in the study area, thus exposing humans to the risk of infection. However, the prevalence observed in the study is lower than that reported by Hasan *et al*. (2018) in Nineveh, Iraq, who showed that the prevalence rate of *Cryptosporidium* oocysts in ovine raw milk was 32.0% while that in caprine milk was 46.0%. Others reported that infection rates of *Cryptosporidium* in sheep and goats' milk were 35.1% and 26.4% respectively (Bakir, 2005), 32% and 46% respectively (Hassan *et al*., 2018). Variations in prevalence rates of *Cryptosporidium* spp. oocysts could be due to species of animal, type of rearing management, geographical location and season of the study. The occurrence of oocysts in milk comes from the shedding of oocysts in the faeces of these animals leading to contamination of the udder and subsequently the milk in the course of the milking process (Duffy and Moriarty 2003).

The results of this study revealed that the majority of farmers had poor knowledge of milk quality and hygiene due to their lack of interaction as a result of language bridge with buyers, e.g. cooperatives and processors, who had high milk quality demands and used milk quality tests to measure quality aspects, i.e. density and alcohol tests as reported by Ndambi *et al*. (2020). Farmers had limited knowledge of animal diseases and milk-borne zoonoses, which likely limited compliance with hygienic milk handling practices, as also noted by Lindahl *et al*. (2018). Furthermore, a large proportion of farmers also had a poor attitude towards milk quality and hygiene as well as disease prevention, which

could increase zoonoses risks. The results revealed that there was no form of training for improving farmers' knowledge and understanding regarding milk quality. Alonso *et al*. (2018) and Lindahl *et al*. (2018) have reported that training increases the adoption of hygienic milk handling practices.

The findings from this study revealed that only a small proportion of farmers demonstrated a satisfactory animal health practice that could prevent milk-borne zoonoses. Given that other research has reported endemic zoonoses in Nigeria, e.g. Q-fever and brucellosis, the findings of low adoption of animal health practices by farmers observed in this study are cause for concern (Njeru *et al*., 2016). Farmers are often reluctant to make high-risk investments due to the lack of necessary resources needed to implement such milk quality practices (Handschuch *et al*., 2013).

The detection rate of *Cryptosporidium* oocysts that were higher in herds that cleared cow dung on a seasonal basis than those who cleared on a monthly or weekly basis, could be due to exposure of the animals to a dirty and unclean environment over time. This may have a negative impact on the quality of milk and milk products produced. The proper and clean housing environment is a prerequisite for producing milk and milk products of acceptable quality (Asaminew, 2007). The practice of not discarding milk from sick cows by most of the farmers is condemnable, and may contribute to an increase in disease transmission to humans and animals within herds, as feeding of milk from sick cows to calves was observed.

Reports of mastitis in this study could be due to poor hygiene in the herd as also suggested by Shitandi *et al*. (2004). The results also revealed a compliance gap in the adoption of hygienic milking and milk handling practices which is similar to findings reported in India (Lindahl *et al*., 2018). The results revealed that the majority of the farmers contravened milk quality standards and food safety regulations by using non-food grade plastic containers for milking and storage which is similar to the findings of Muloi *et al*. (2018). The low adoption of the recommended steel and aluminium containers by farmers could be due to their high price.

Ninety five percent (95%) proportion of farmers who adopted poor hygienic practices calls for an urgent need to increase compliance with good agricultural and hygienic practices to reduce milk contamination. The results also show no knowledge of the drug withdrawal period and there exists a misconception regarding antibiotic residue risks, they assume that antibiotic residue is diluted by bulking or degraded by pasteurisation which is in agreement with the findings of Ondieki *et al*. (2017). The majority (76.7%) of the farmers stated that the best form to consume milk is the raw product which is of public health concern, as the consumption of unpasteurized milk is the most frequently reported cause of outbreaks of infection (Friedman *et al.*, 2000). Although milk boiling does not make it completely safe, there is still a risk of recontamination due to unhygienic handling (Lindahl *et al*., 2018; Muunda *et al*., 2021). Moreover, boiling and pasteurisation do not eliminate contaminants such as aflatoxins, antibiotics residues, pesticide residues and bacterial enzymes, which can lead to spoilage of the packaged milk and pose a public health risk to consumers (Ahlberg *et al*., 2016; Lindahl *et al*., 2018).

CONCLUSION

Considering the occurrence of *Cryptosporidium* oocysts in cow bulk milk, there should be increased monitoring and management practices implemented in livestock farming to reduce the contamination levels and since the knowledge, attitudes, and practices of the respondents regarding hygienic milking practices are sub-optimal, there is a need for educational interventions targeting sedentary Fulani herds in the selected Local Government Areas to improve awareness and adoption of hygienic practices to mitigate *Cryptosporidium* infection risks.

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