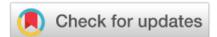


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RESEARCH ARTICLE

Farmers' Knowledge, Attitudes, Practices and Factors Contributing to Hygienic Production of Raw Milk in Malawi's Blantyre Agriculture Development Division

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Abstract

Dairy products provide nutrition to households but, could also serve as a source of many milkborne diseases when produced under poor hygiene conditions. This quantitative, crosssectional study administered 410 questionnaires, collected 90 raw milk samples and visited 90 farms to evaluate hygienic milk production practices in Malawi's Blantyre Agriculture Development Division (BLADD). Descriptive statistics were used to summarise questionnaire, farm and laboratory observations data. The majority of farmers 86% and 66.6% (n=410) had formal education and structured pre-training in hygienic milk production respectively. The overall KAP knowledge was only 54%, most smallholder dairy farmers reported positive attitudes at 88% and excellent practices at 63%. Few farmers (27.1%; n=410) had low aggregate score of knowledge, attitude and practice were six (OR=5.910, 95% CI: 1.997-17.489) times less likely to produce hygienic milk. Inadequate pre-training and a low aggregate score were identified as key factors behind the failure of smallholder farmers in Malawi's BLADD to meet Malawian and European Union (EU) standards, raising concerns about potential milkborne diseases. Out of 90 raw milk samples analysed for presence of E. coli, 11 (12%) and 50 (55.5%) raw milk samples were within acceptable limits of Malawian and European Union standards respectively. These low percentages obtained could be attributed to unsanitary animal quarters, as half of smallholder dairy farmers in Malawi's Blantyre Agriculture Development Division do not remove waste daily and some workers milk cows without supervision.

In conclusion, smallholder dairy farmers had positive attitudes and good milk hygiene practices without grounded knowledge, and it was difficult to meet legal limits of Malawi and European Union Standards for *E. coli*. Therefore, regular ongoing annual refresher farm management trainings and monitoring of hazards in raw milk production are important for safe milk.

Keywords: attitudes, complice, hygienic milk production, knowledge, Malawi and practices

Evaluation of Smallholder Dairy

1.0 Introduction

Milk is an essential component of diets worldwide, and provides vital nutrients such as proteins, vitamins and minerals. Despite being rich in nutrients, raw milk consumption poses a significant public health risk due to pathogenic microorganisms [1]. In Malawi, it is estimated that 40% of the unpasteurised milk consumed [2], while pasteurised milk is too expensive for most households [3]. Hygienic production of raw milk is therefore crucial to mitigate the inherent risks of milk.

In developed countries like the United Kingdom (UK), Germany and the United States of America (USA), smallholder dairy farmers are offered comprehensive support such as good agriculture practices (GAP) training, risk-based supervision by a coordinated food control authorities and subsidies to comply with hygiene standards [4]. This commitment ensures milk safety and animal welfare. In contrast, ensuring hygienic production of raw milk by smallholder dairy farmers in developing countries like Malawi remains a challenge due to various factors such as inadequate knowledge about hygienic practices, limited resources and the potential risks associated with contaminated milk [5-6].

Among the pathogens frequently reported to contaminate milk is *Escherichia coli* (*E. coli*) [7]. Although certain strains are commensals, pathogenic variants can cause widespread outbreaks [8]. Raw milk is often contaminated during production and serves as a vehicle for *E. coli* transmission. Luckily, effective pasteurisation reduces *E. coli* levels, enhancing milk safety [9]. In Blantyre Agriculture Development Division 40% of milk consumed is unpasteurised due to limited resources [3]. Targeted monitoring of *E. coli* levels in raw milk is therefore, imperative to align with milk safety standards set by regulatory bodies like Malawi Bureau of Standards and European Union.

Moreover, data from a few selected districts of Blantyre Agriculture Development Division highlights this risk further, with Njombwa finding 73.3% (n=15) of raw milk samples contaminated with *E. coli* at levels of 2.7-8.09 log10 CFU/ml [10]. The study provided valuable insights into *E. coli* contamination levels in raw milk [10], the sample size of fifteen samples were inadequately representing farmers in Blantyre Agriculture Development Division. Furthermore, previous studies on knowledge, attitude and practice (KAP) focused on other zoonotic diseases or animal husbandry [6], thus leaving a knowledge gap on the hygienic milk production. This study therefore, was designed to contribute in addressing the hygienic production of raw milk among small dairy farmers in Blantyre Agriculture Development Division through assessing KAP and the factors that influence adherence to *E. coli* established regulations for the Malawi Bureau of Standards and European Union.

2.0 Materials and Methods

2.1 Study design

A quantitative cross-sectional study was carried out to evaluate knowledge, attitudes, practices and factors contributing to hygienic milk production among smallholder dairy farmers in Malawi's Blantyre Agriculture Development Division.

2.2 Study duration and location

The study was conducted in the Blantyre Agriculture Development Division in Malawi from August to September 2023. A selection of four districts where smallholder dairy production is widely practiced was done [6] which are Blantyre (15.8 °S, 35.0 °E), Thyolo (16.0 °S, 35.2 °E), Chiradzulu (15.8 °S, 35.2 °E), and Mulanje (15.9 °S, 35.3 °E).

2.3 Study population

Smallholder dairy farmers (SHDFs) were the study population. The predominant dairy farming system in the Blantyre Agriculture Development Division is zero grazing, necessitated by limited land availability [5-6]. Currently, cooperatives or private companies own milk bulking groups in the BLADD [11]. Cooperative MBGs receive support from Shire Highlands Milk Producers Association (SHMPA) to conduct triennial executive elections [6]. Conversely, privately owned MBGs operate under the independent decision-making of their proprietors [10].

2.4 Sample size determination

The sample size was estimated using a single proportion estimate given the finite population, as described by Fisher [12]. Recognizing the potential participants' dropout (attrition), the study further calculated attrition rate at 10% as described by Kainga [13]. Thus, sample size was increased by adding the expected number of dropouts, resulting to new sample size of 426.

2.5 Sampling

A Multi-stage sampling technique was utilised to select participants for a survey on knowledge, attitudes and practices (KAP) in Blantyre Agriculture Development Division (BLADD). The first cluster selected four districts out of seven district in Blantyre Agriculture Development Division using simple random technique. From each district a sub-cluster of milk bulking groups was selected based on the proportion of the farmers. At this stage, the sample size for participants was proportionally calculated for representativeness across four districts based on their smallholder dairy farmers' population.

2.6 Pretesting Questionnaire

The questionnaire was developed by adopting instruments from existing studies [14-15]. The pretesting was conducted with twenty participants at Matapwata Milk Bulking Group in Thyolo. Three assistant veterinary officers (AVOs) administered the questionnaire using smartphones.

2.7 Structure of the Questionnaire

The questionnaire had 35 questions divided into three sections: socio-demographic section, knowledge, attitudes and self-reported practices. A set of five questions with three possible answers was asked to assess participants' knowledge on milk hygiene practices. Each correct answer was awarded one point, while a false or not sure answer was given a zero point. Likewise, multiple choice questions earned one point each for a correct match, while a false match was given zero points. Each participant could score between 0 and 7, with a higher score indicating a better knowledge of hygienic milk production. A Likert scale with ten questions was used to assess the attitudes of participants towards milk hygiene. A four-item Likert scale was chosen to offer participants polarity between strongly disagreeing and strongly agreeing [16]. All questions had four possible answers: strongly agree, agree, disagree and strongly disagree, which were scored at 4, 3, 2, and 1 point, respectively. Only question number 10 was scored in reverse. The calculated scores for attitudes ranged from 10 to 40. The higher the score, the more it implied a positive attitude towards hygienic milk production and vice versa. The section on self-reported practices had ten questions focusing on the role of personal hygiene, hand washing practices, and

strategies against milk-borne diseases and cross-contamination. Each question was scored with one mark for the right answer and zero for the wrong answer. The calculated total score for hygiene milk production ranged from 0 to 10.

2.8 Scoring Methods

In addition, each smallholder dairy farmer's (SHDF) score on knowledge, attitudes and practices were summed up and expressed as a percent. Then an aggregate was calculated for each smallholder dairy farmer. The aggregate score is the arithmetic average of knowledge, attitudes and self-reported practices calculated for each dairy farmer. The score of at least 75% meant that the SHDF had passed the expected threshold for hygienic milk production [15]. Furthermore, smallholder dairy farmers who scored an average of less than 75% on knowledge, attitudes and self-reported practices did not satisfy the aggregate scoring scheme.

2.9 Observing hygiene practices at smallholder dairy farms

A checklist adapted from previous studies [9],[17],was used to assess hygiene practices at ninety small scale dairy farms across the four districts. The following areas were assessed including personal hygiene, animal management environments, milk handling and transportation. Direct observation was employed to compliment self-reported practices because self-reporting under or overestimate the manner the practices is carried out [13],[17]. The limitation for direct observation required a lot more resources to execute [8]. This study therefore, sampled one third of the total KAP participants for direct observations. The scoring for this complimentary assessment was satisfactory (at least 75%) or otherwise deemed unsatisfactory.

2.10 Raw milk sampling for E. coli analysis

To compare levels of *E. coli* contamination with established Malawian and European Union standards, 25 mLs of raw milk samples were collected from smallholder dairy farmers at milk bulking groups, either before or after milk sales. The ninety bottles were labelled with unique serial number and date and time of collection to ensure proper identification and traceability using permanent marker. The bottles of raw milk samples were placed in an ice-cooled box and transported within four hours to Food Laboratory for analysis at the Malawi University of Business and Applied Sciences (MUBAS).

2.11 Sample preparation of E. coli

Samples were prepared according to the ISO 6887-1 procedure [18] and plated on Violet Red Bile Agar (VRBA) CM0107 (Oxoid, England) for *E. coli* enumeration. After incubation, positive samples were counted visually to determine *E. coli* colony forming units (CFU) per ml.

2.12 Biochemical tests for identification E. coli.

The presumptive colonies were isolated from the Violet Red Bile Agar and sub cultured on Nutrient Agar CM0003 (Oxoid, England). Colonies on nutrient agar were inoculated using a 50 microlitre sterile plastic disposable loop, and rapid biochemical confirmatory tests were performed using Bactident® Oxidase (© 2020 Merck KGaA, Darmstadt, Germany), catalase, indole, citrate utilisation, Voges-Proskauer and Methyl-red for *E. coli* identification.

2.13 Data management and statistical analysis

Data from questionnaires, checklist and laboratory results were cleaned and coded in Microsoft Excel and analysed using IBM SPSS version 26.0. Descriptive statistics characterised the outcomes including medians, frequencies and percentages. A Chi-square test was employed to assess for associated factors of hygienic milk production among smallholder dairy farmers. The analysis in binary logistic regression may have been obscured by confounding, which could have led to non-significant results even after a true association exists.

2.13 Ethical considerations

The study protocol (reference DAHLD/AHC/01/2023/4) was approved by the Animal Health Committee at the Ministry of Agriculture in Malawi. Permission was obtained from district councils and local leaders. Only participants who consented verbally were recruited into the study. Only trained research team members conducted interviews, farm observations and milk collections.

3.0 RESULTS

3.1 Socio-demographic characteristics of smallholder dairy farmers in Malawi's Blantyre Agriculture Development Division.

A total of 410 farmers participated in the KAP survey and the mean age was 41.7 (with a standard deviation of 12.2) in Table 1. Most participants were female, representing 60%. The majority of the participants (86.6%) had formal education; the highest group attended primary school (61.0%), and some attended secondary school (25.4%), while a few had no formal education (13.4%). The majority of dairy farmers (66.1%) had pre-training before starting farming. Most dairy farmers (57.1%) depend on the milk bulking group for their continuous lifetime learning.

3.2 Pre-training attendance and Knowledge, Attitudes and self-reported practices performance among dairy farmers in Blantyre Agriculture Development Division, Malawi

The results from knowledge, attitudes and practices survey conducted among smallholder dairy farmers in Blantyre Development Division are presented in Table 2. The percentage of smallholder dairy farmers who attended pre-training varied across districts, Mulanje had the highest attendance 84% (n=78), followed by Thyolo 68% (n=176), Blantyre 61% (n=31) and Chiradzulu 56% (n=125). Regarding knowledge, Mulanje smallholder farmers outperformed the other districts, with 74.4% followed by Thyolo 42.6%, whereas Chiradzulu and Blantyre had lower score 35.2% and 35.4% respectively.

Farmers' attitudes towards hygienic milk production were overwhelmingly positive in most districts. Blantyre smallholder dairy farmers exhibited the most favourable attitudes 100%, while Mulanje and Thyolo followed closely at 96.2%. Chiradzulu had lowest percentage of smallholder dairy farmers with positive attitudes at 79.2%. In terms of practices, most Mulanje smallholder dairy farmers reported correct practices, while Chiradzulu and Blantyre had similar percent of (77.6 and 77.4) respectively. The calculations of aggregate scores demonstrated that 88.5% of farmers from Mulanje has passed on aggregate scoring method.

3.3 Compliance of E. coli presence in raw milk to Malawi Bureau of Standard in Blantyre Agriculture Development Division

The evaluation of compliance of *E. coli* with Malawi Bureau of Standard within Blantyre Agriculture Development Division revealed gross rejection rate of raw milk samples. This analysis revealed that over eighty percent of raw milk samples collected from Blantyre, Chiradzulu, Mulanje and Thyolo farmers were rejected based on the Malawi Bureau of Standards as depicted in figure 1. Unfortunately, Thyolo District had highest rejection at 93% (n=29) of raw milk samples from smallholder farmers failing to meet Malawi Bureau of

Standards. In contrast, Mulanje District had the least rejection at 83% of twelve raw milk samples failing to comply with the Malawian standard.

3.4 Compliance of E. coli presence in raw milk to European Union Standards in Blantyre Agriculture Development Division.

The compliance of raw milk samples from selected four districts was assessed against European Union Standards for *E. coli* at 100 CFU/ml. Overall, more than fifty percent of raw milk samples from Blantyre, Chiradzulu and Mulanje met the European Union standard. However, from Thyolo smallholder dairy farmers, only 48% were deemed acceptable raw milk samples based on European Union Standards as shown in figure 2. Interestingly, Blantyre District had the highest compliance with 70% of the ten collected raw milk samples satisfying the EU standard. In contrast, Thyolo had the lowest proportion of satisfactory of its twenty-nine raw milk samples, trailing behind with only 48% meeting the European Union Standard.

3.5 Factors associated with the hygienic production of raw milk

The association between the hygienic productions of milk were examined through various parameters using Pearson's chi-square as detailed in Table 3 below. There was a significant association between the hygienic production of milk and pre-training and source of information. Sex of the farmer, however, did not show an association (X^2 =1.646, P value 0.266).

3.6 Predictors of the hygienic production of raw milk.

The significant predictors were dairy pre-training and aggregate score. The farmers who were not offered a structured pre-training program by Malawian government and partners' increased five times likelihood to produce unhygienic raw milk (OR=5.910, 95% CI: 1.997-17.489) compared to farmers who did not have structured pre-training (P-value =0.001). Furthermore, the farmers who failed on aggregate score were six times less likely to produce hygienic milk (OR=5.910, 95% CI: 1.997-17.489) than farmers who had passed aggregate score of at least 75% (P-value =0.001) as shown in Table 4.

4.0 DISCUSSION

The hygiene production of milk is paramount for safeguarding public health concerns from milk-borne diseases like *E. coli*. Dairy farmers play a crucial role in interrupting the transmission of these pathogens by adopting best practices informed by their knowledge and awareness of hygienic milk production. Despite farmers in Blantyre Agriculture Development Division demonstrating excellent hygienic practices, the study alarmingly revealed that over forty percent of the raw milk samples exceeded the *E. coli* threshold set by Malawi Bureau of Standards and European Union standards. Pre-training in dairy hygiene and the aggregate score significantly influenced hygienic milk production practices.

The study revealed disparities in mean hygienic milk production knowledge among smallholder dairy farmers (SHDFs) in selected Blantyre Agriculture Development Division districts, suggesting a potential challenge in ensuring consistent safe milk. Smallholder dairy farmers from Mulanje were most knowledgeable compared to those in Blantyre, Chiradzulu and Thyolo districts. This disparity aligns with findings of Berhanu [15], who found low knowledge among dairy farmers in Ethiopia. Notably, knowledge was categorised into three levels: poor (≤50%), fair (51-69.9%) and good (>70%) in study by Berhanu [15] whereas, the present study grouped knowledge into two levels: excellent (≥75%) and poor (<75%). Furthermore, the current study adopted higher scoring threshold than previous related studies because smallholder dairy farmers in Blantyre Agriculture Development Division require in-depth understanding of hygiene knowledge to change their attitude and consistently practice personal hygiene, proper milking handling and sanitation measures to prevent milk contamination at the farm level.

The present study found excellent self-reported practices among smallholder dairy farmers across four districts: Blantyre, Chiradzulu, Mulanje and Thyolo. This suggests that assistant veterinary officers' mentorship and training services provided to dairy farmers could be assisting to improve construction of animal housing, which were important in securing hygienic milk production [13]. In addition, it was also observed that some smallholder dairy farmers with improved animal housing were not consistently cleaning or removing animal

waste, which probably resulted in systemic conditions like mastitis or milk contamination. This malpractice was common in some small scale dairy farms, which had inadequate targeted supervision to support their implementation of hygienic milk production practices.

The low compliance for *E. coli* contamination threshold, as determined by Malawi Standard zero colony-forming units per millilitre which raises concerns for milk safety. In similar study, it was also reported a high prevalence of *E. coli* at 73.3% (n =15 for Blantyre) four agricultural ecological zones in Malawi [10]. This contamination poses risks of diseases, particularly children and the elderly population, who may not boil milk adequately or consume raw milk [15]. Currently, the food control authorities do not adequately conduct risk based monitoring on pathogenic microorganisms like *E. coli* for raw milk, which would derail crucial preventive efforts for immediate domestic milk safety needs.

Similarly, the compliance assessment of raw milk against European Union standards for *E. coli* across Blantyre, Chiradzulu, Mulanje and Thyolo districts revealed variations in knowledge, attitudes and practices which had implications for milk safety regulations. The higher compliance rates were observed in Blantyre, Chiradzulu and Mulanje suggesting a relatively better adherence to hygienic production of raw milk compared to Thyolo district's smallholder dairy farmers. The lower compliance rate in Thyolo district could partly be explained by role of assigning farm workers without supervision at small scale farms. This supports the study by Knight-Jones in Zambia, which also found that smallholder dairy farmers were inconsistently supervising the farmworkers [8].

In previous studies, knowledge, attitudes and practices (KAP) were assessed often separately. This approach however, fails to capture the interplay between components of KAP. A dairy farmer might score higher on knowledge alone but lack positive attitudes or practical skills to implement them effectively. This study introduced aggregate methods for addressing these limitations of existing methods. An aggregate scoring system combines knowledge, attitude and practice into a single metric, revealing hidden patterns not evident in individual scores. Participants were classified as either satisfactory (achieving at least 75%) or unsatisfactory (scoring below 75%) on each parameter. This holistic assessment is crucial for identifying farmers who are knowledgeable and apply appropriate milk hygiene practices. Consequently, any deficiencies in any of the arms of the KAPs can have a negative impact on the hygiene and safety of milk. Nevertheless, the new system has the potential to improve farmers' milk hygiene practices through targeted intervention programmes like training and infrastructure upgrading and ultimately producing safe milk.

The potential for recall bias among certain participants may have influenced the accuracy of responses of knowledge and self-reported practices, hence introducing a degree of uncertainty into the study's final results. This limitation is worthy of being reported so that results are interpreted with caution; of course, they were not gross enough to invalidate the results. Instead, the limitations could offer valuable areas for improvement in future research.

In summary, the study revealed positive attitudes and excellent practices among smallholder dairy farmers in the four districts of Blantyre, Chiradzulu, Mulanje and Thyolo. The results of *E. coli* from raw milk samples analysed however, showed a low compliance rate with Malawi and EU standards. The risk of contamination with pathogenic *E. coli* was found to be high, raising concerns given that milk is the staple diet for children in Malawi. Access to pasteurised milk is limited to households; therefore, this constitutes a major health risk, particularly diarrhoea, which can lead to dehydration and sometimes death. Interestingly, this study found that structured pre-training and aggregate scores are two factors contributing significantly to the hygiene production of milk. District veterinary officers, dairy farmers and processors in the Malawi dairy sector must invest in structured pre-training. In addition, an aggregate score scheme was another factor that could improve the hygiene of raw milk production to secure public health, nutrition and economic benefits.

Conclusion

In the study, despite inadequate knowledge, farmers had a positive attitude and excellent practice. However, they produced raw milk which had *E. coli* at higher levels than establishing limits of Malawi and European Union Standards. Unhygienic raw milk production erodes customers' confidence and is a public health risk, therefore, aggregate scores should be considered when setting threshold in KAP studies to have the best farmers who can guarantee hygienic production of raw milk.

This study provides an insight to BLADD farmer's hygienic production of raw milk knowledge, attitude, and practice. Overall, 54.1% dairy farmers in this study had poor knowledge and 67.1% composite score. Furthermore, 91.5% dairy farmers had positive attitudes and 72.9% excellent practices. Pre-training and aggregate score were identified as factors determining hygienic production of milk among farmers in BLADD.

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APPENDICES: FIGURES AND TABLES

Table 1:Socio-demographic characteristics of 410 smallholder dairy farmers within Blantyre Agriculture Development Division, Malawi.

Demographic Characteristics	Category	Frequency n=410	Proportion (%)	95%CI
District	Thyolo	176	42.9	38.1-47.9
	Chiradzulu	125	30.5	26.1-35.2
	Mulanje	78	19.0	15.3-23.2
	Blantyre	31	7.6	5.2-10.6
Sex	Female	246	60.0	55.1-64.8
	Male	164	40.0	35.2-44.9
Education	Primary	250	61.0	56.1-65.7
	Secondary	104	25.4	21.2-29.9
	Tertiary	1	0.2	0.1-1.4
	No formal	55	13.4	10.3-17.1
Pre-training	Yes	271	66.1	61.3-70.7
	No	139	33.9	29.3-38.7
Source of lifetime education	MBG	234	57.1	52.1-61.9
	None	101	24.6	20.5-29.1
	Radio	2	0.5	0.1-1.8
	Television	27	6.6	4.4-9.4
	Other	46	11.2	8.3-14.7

CI = Confidence Interval

Table 2: Smallholder dairy farmers' pre-training attendance and performance across Blantyre Agriculture Development Division.

Parameters		District					
		Blantyre	Chiradzulu	Mulanje	Thyolo		
Percentage Score		%	%	%	%		
Pre-training	Yes	61	56	84	68		
	No	39	44	16	32		
Knowledge	Passed	35.4	35.2	74.4	42.6		
	Fail	64.6	64.8	25.6	57.4		
Attitude	Positive	100	79.2	96.2	96.2		
	Negative	0	20.8	3.8	3.4		
Practice	Passed	77.4	77.6	91.0	60.8		
	Fail	22.6	22.4	9.0	39.2		
Aggregate	Passed	74.2	73.6	88.5	81.8		
	Fail	25.8	26.4	11.5	18.2		

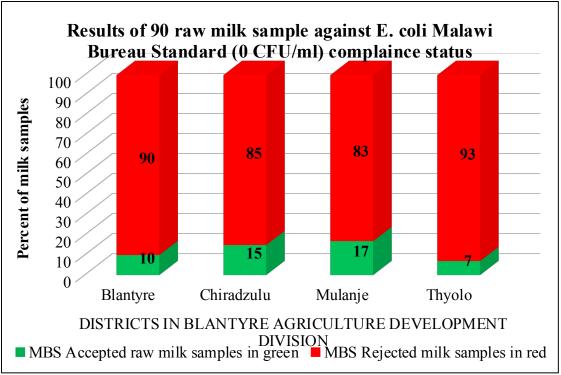


Figure 1: Results of ninety raw milk samples which complied with Malawi Bureau of Standards supplied to processors.

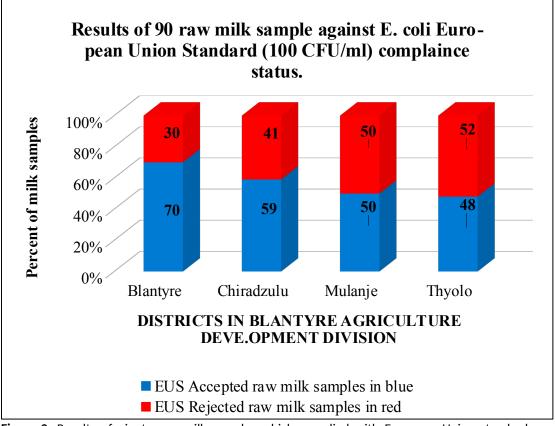


Figure 2: Results of ninety raw milk samples which complied with European Union standards supplied to processors in Malawi.

Table 3: The association of hygienic production of raw milk with various parameters.

Variable	E. coli results of dairy farmers' raw milk						
	Score	E. coli legal limits for raw milk in European Union			Р		
		Acceptable (load =<2.00log10)	Rejected (loa >2.00log10)	d	value		
Sex	Female	35	34	1.7	0.27		
	Male	14	17				
Pre training	Yes	34	22	23.6	<0.001*		
-	No	16	19				
Source of information	MBG	31	11	15.0	<0.001*		
	Radio	6	6				
	Other	7	5				
	None	6	18				
Waste management	Yes	31	12	11.6	0.001*		
·	No	17	30				
Cleans milk parlour	Yes	5	12	4.8	0.028*		
before milking	res	5	12	4.8	0.026		
	No	43	30				

^{*} Significant at P value=0.05

Table 4: Binary logistic regression of aggregate score, pre-training towards hygienic milk production of small dairy farmers in Blantyre Agriculture Development Division.

Factor	Number of participant	OR	SE	P-value	95% CI (OR)
Pre-training					
Yes	55	Ref.			
No	35	5.910	0.554	0.001	1.997-17.489
Aggregate score					
Passed	49	Ref.			
Failed	41	6.773	0.508	0.01	2.296-19.979

CI= Confidence Interval, OR= Odds ratio.