Factors Associated with Post-harvest Milk Losses at Collection Centres and among Vendors in Tanzania

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Abstract

Tanzania has engaged in various interventions to improve the countries food and nutritional security among which is the creation of a good environment for increased milk production, collection, storage, marketing and consumption. However, milk losses continue to occur along the country's milk value chain (4.4% and 7.0% at the collection centres and the milk vendors respectively). The study on which the paper is based assessed factors associated with post-harvest milk losses among milk collectors and vendors in Tanzania. A cross-sectional research design was adopted whereby 35 individuals who were in-charge of milk collection centres (MCCs) and 52 milk vendors were selected for the study covering the period June 2021 to September 2022. Generally, the results show that milk was mostly lost through spoilage (2.7% & 3.5%), spillage (1.9% & 3.3%) and contamination (0.1% & 0.2%) at the MCCs and vendors respectively. In addition, Generalised Linear Mixed Model results show that characteristics of the milk transporter (Adjusted Coefficient (AC) = -3.519; 95% Confidence Interval (CI): -5.752--1.286), market stability (AC = -9.525; CI: -18.092--0.958), season (AC = -0.19; 95% CI: -0.37--0.010) and awareness/knowledge on post-harvest milk losses (AC = -0.274; 95% CI: -0.490--0.058) were negatively and significantly associated with post-harvest milk losses. Therefore, respondents' characteristics, market stability, season, milk handling facilities and awareness/knowledge of post-harvest milk loss were the main drivers of post-harvest milk losses (PHMLs). Therefore, there is a need for the livestock extension officers in Tanzania to create awareness but, also train milk collectors on how to reduce PHMLs. In addition, there is a need for collective investment in milk infrastructures and other logistics if milk losses by the above-mentioned are to be reduced. Lastly, the Government needs to create a conducive environment that enhances the availability of quality and affordable milk handling equipment to allow the storage and transportation of milk that minimizes its losses.

Keywords: Milk Collectors, Milk Vendors, Post-harvest Milk Losses, Tanzania

Introduction

Globally, there are great concerns of feeding the growing population which is projected to increase from 7.7 billion people in 2019 to 9.7 billion people in 2050 (UN, 2019). In Tanzania, the population is projected to increase from 61.9 million people in 2022 to 151.3 million in 2050 (URT, 2022b). The projected population growth requires various initiatives to expand production, but also sustainable mechanisms to preserve what has been produced. For example, on increasing livestock production and productivity, Tanzania has reported an increase of its livestock population base from 25.8 million cattle in 2015 to 36.6 million cattle in 2022 with milk production increasing from 2.1 to 3.6 billion litres in the same period (URT, 2015; 2023). The above increase is a result of improvements in Tanzania's livestock production environment such as improvement in health services, livestock feed and water resources, improved animal breeding as well as enhanced extension services (URT, 2021; 2022a; 2023).

In addition, based on Tanzania's Livestock Master Plan (TLMP) the government has been trying to transform the dairy sector through value addition and marketing (URT, 2017).

The TLMP promotes formation, formalization and strengthening primary dairy societies and cooperatives in milk potential areas through awareness creation, training, and provision of equipment (URT, 2017). Furthermore, TLMP enhanced the establishment of milk collection centres which are equipped with necessary cooling facilities in order to improve collection, storage and marketing of milk and milk products. However, despite the above-mentioned, milk losses among milk collectors (milk collection centres "MCCs" and the vendors) are high. According to FAO (2004) cited in ACF (2014) total milk losses account to 16% and 25% in the dry and rain seasons respectively in all nodes of the milk value chain. In addition, Lore *et al.* (2005) reported 0.44% milk losses due to spoilage at the collection centres. Similarly, a total loss of about 4.7% and 7% were recorded at the MCCs and vendors respectively (these results are part of the current study). Therefore, this paper assesses the factors associated with post-harvest milk losses among milk collectors (MCCs and vendors) node of Tanzania's milk value chain.

The study is in line with the United Nations Sustainable Development Goal (SDG) 12.3, the African Union's Malabo Declaration Number III 3 (b), Agricultural Sector Development Programme Two (ASDP II) paragraph 220 and Tanzania's National Livestock Research Agenda (NLRA) 2020-2025 (AU, 2014; UN, 2015; URT, 2019, 2016) that aims to halve/reduce food losses along the food chains (livestock and livestock products included). The findings from the study could be of great use to policy makers, academia, research institutions and other stakeholders interested in reducing post-harvest milk losses. Moreover, the study could provide basic useful information as an entry point for Tanzania's Ministry of Livestock and Fisheries to develop a "National Livestock Products Post-Harvest Management Strategy" and "Country Program on Livestock Products Post-Harvest Losses (LPHL) Reduction". The paper generally answers two research questions i.e., what are the main/roots causes of milk losses? And what perpetuates milk losses in Tanzania?

Methodology

Description of Study Area

The study was conducted in three grouped livestock production systems of Tanzania namely the agro-pastoral and semi-arid production systems (represented by Dodoma Region); the mixed rain-fed sub-humid and humid production systems (represented by Morogoro and Kagera regions); and a mixed rain-fed highland production systems (represented by Iringa and Tanga regions) (Nell *et al.,* 2014; URT, 2017).

Research Design

A cross-sectional research design was used to collect data from the above-mentioned regions in the three livestock production systems described in section 2.1. The data was collected in both the dry (June to October 2021; June to September 2022) and wet/rain (November to December 2021; January to May 2022) seasons. The research design was preferred because it allows determination of relationships between variables and can be done in a relatively short period of time while covering a large sample (Creswell, 2009; Gray, 2014; Kothari & Garg, 2014). In addition, it allows data collected to be used in determining association between variables (Matthews and Ross, 2010).

Sampling procedure and sample size

The study used a multistage sampling technique whereby livestock production systems covered are as explained in sub-section 2.1 above. In addition, five regions of Iringa, Morogoro, Kagera, Dodoma and Tanga were purposively selected from the above mentioned production systems. The regions and two districts per region (rural and urban districts) were purposefully selected based on the presence of milk collection centres (MCCs) and/or milk vendors. In cases where the selected districts had few or no MCCs or vendors, the nearby districts were sampled for example in Kagera Region the target were Bukoba Municipality and Kyerwa District but Karagwe and Muleba districts were also included; Iringa Region the target were Iringa Municipality and Mufindi District but Mafinga Town Council was also added; and in Tanga Region the target were Tanga City Council and Muheza District but Pangani District was also added. The other regions the target were maintained for example Dodoma City Council and Kondoa District in Dodoma Region; Morogoro Municipality and Mvomero District in Morogoro Region. As part of sampling procedures, livestock production systems were considered as strata. Therefore, regions, districts and wards were considered in the first, second and third stages respectively. Further to the above, simple random sampling was used to select at least 10% of MCC in-charges and milk vendors obtained from TDB, MLF and the regions or districts reports or records.

Data Collection methods

Two sets of questionnaires were used to collect quantitative data from milk collectors (i.e., one for the MCCs and the other for vendors). Different questionnaires were used based on the nature of data to be gathered from the particular milk collectors and the differences in modes of operation. The questions of each questionnaire were uploaded in a KoBoKollect tool (data collection mobile App) for easier and efficient data collection. Data based on individuals performing milk handling, equipment used, quantity handled, quantity lost, root causes of loss and respondents' socio-demographic and economic characteristics were recorded. The data were captured soon after milk collection and respondents were asked to report their milk loses in a month due to the fact that milk losses do not have to occur on a daily basis. In addition, key informant interviews (KIIs) were conducted with informants from Tanzania Dairy Board (TDB), Tanzania Livestock Research Institute (TALIRI), Regional and District Livestock and Fisheries Officers (RLFOs, DLFOs), Tanga Dairy Cooperative Union (TDCU), African Dairy Genetic Gains (ADGG) – Tanzania, and Dairy Nourish Africa (DNA). The in-depth interviews with KIs concentrated on the main forms of PHMLs and its associated factors.

Data Analysis

The collected data was checked for accuracy where anomalies found were corrected accordingly. For example, some of the milk vendors were interviewed only once (in one season), during the second round/season they did not qualify as they had exited the milk vending business therefore, their information had to be omitted from the analysis. Thereafter, descriptive statistics were determined using Statistical Package for Social Sciences (SPSS) software (version 26). The data were then transferred to STATA software for running the Generalised Linear Mixed Models (GLMMs) to determine the factors associated with milk losses at each stage of the milk collection node. The GLMM model was seen as desirable as it is good in reducing the probability of having false positives based on the fact that the drivers for food losses are complex and interrelated (Grainger *et al.,* 2018). In addition, the likelihood ratio tests were undertaken to select the most suitable models. Furthermore, data were categorized into fixed and random variables in order to overcome dependence problem resulting from seasons of data collection. The random effect variables included districts where MCCs and vendors were located.

Further to the above, the dependent variable used in the GLMM was the proportion (percent) of milk lost from the total milk collected/handled at the particular milk supply chain node. The definition and measurements of the independent variables used in the GLMMs are shown in Table 1 with their expected sign predicting their influences on PHML. Table 2 and 3 presents the adjusted Coefficients for the independent variables, 95% confidence interval (CI) and the associated p-values. The differences/associations of variables were considered statistically significant if the p-value was ≤ 0.05. In addition, the quantity of milk handled and lost at the MCCs and by vendors are well described in another paper which is part of the study. Generally, at the MCCs a total of 664 910 and 1 078 910 litres of milk were handled/collected in both the dry and wet seasons respectively while a total of 11 317 and 24 913 litres of milk were lost in the same seasons. At the vendors node total amount of milk handled was 73 935 and 94 730 litres while milk lost was 3 045 and 4 330 litres in both the dry and wet seasons respectively.

Table 1: Definition and measurement of the independent variables used in the GLMMs

Variable description	Measurement	Expected sign
Season of survey, 0 Dry season, 1 Rain/wet season	Dummy	-
Sex of the respondent, 0 Male, 1 Female	Dummy	±
Age of the respondent (years)	Continuous	±
Highest level of education of the respondent, 0 otherwise, 1 secondary or above	Dummy	-
Years in business	Continuous	-
Whether they get milk from farmers/ farms, 0 No, 1 Yes	Dummy	±
Whether they get milk from group collection points	Dummy	-
Cost of buying milk	Continuous	±
Price of selling milk	Continuous	±
Equipment used for milk collection, 0 Otherwise, 1 Aluminum milk can	Dummy	-
The person involved in milk collection, 0 Otherwise, 1 hired labour	Dummy	±
Equipment used for milk storage, 1 With cooling facilities, 0 Otherwise	Dummy	-
Equipment used for milk transport, 0 Otherwise, 1 Motorized	Dummy	-
The person involved in milk transport, 0 Otherwise, 1 hired labour	Dummy	±
Adequate labour available for milk operations, 0 No, 1 Yes	Dummy	-
Market availability for milk sales, 0 No, 1 Yes	Dummy	-
Maximum distance to market – km	Continuous	-
Whether respondent received training on milk handling, 0 No, 1 Yes	Dummy	-
Membership to a milk association, 0 No, 1 Yes	Dummy	-
Whether respondent has heard of post-harvest milk losses, 0 No, 1 Yes	Dummy	-
Adequacy of storage facilities, 0 Not adequate, 1 Adequate	Dummy	-
Availability of refrigeration facilities, 0 Not available, 1 Adequate	Dummy	-
Electricity for milk cooling, 0 Not stable, 1 Stable	Dummy	-
Market stability, 0 Lack of stable market, 1 Available and stable	Dummy	-
Distance to market, 0 Otherwise, 1 Short distance (<=10km)	Dummy	-
Market Price, 0L price, 1 Good/reasonable price	Dummy	-
Transport to market using Road, 0 Poor road, 1 Good and passable all the time	Dummy	-
Transportation means to market, 0 Otherwise, 1 Car	Dummy	-

Results and discussion

Milk losses at the collection node

The study findings (Fig. 1) show that spillage, spoilage and contamination are the main causes of milk losses at the milk collection node. The results (Fig. 1) show that 1.5%, 0.9% and 0.2% of the collected milk was lost through spillage, spoilage and contamination in the dry season respectively and 2.2%, 4.5% and 0.04% in the wet season respectively at the MCCs. The above results suggest that initiatives for fighting poverty and hunger could be hampered by the reported milk losses at the collection points. Except for contamination which contributed to higher milk losses in the dry season, milk losses were mostly recorded in the wet season. One of the reasons for higher milk losses through contamination during the dry season could be the low milk supply coupled with higher demand which tempts some milk suppliers to add foreign materials such as water to the milk to increase volume in pursuit of profit maximization, while doing so contaminate the milk (adulteration). The study's findings conform to Lore *et al.* (2005) who reported substantial milk losses at the MCCs approximated to be 0.44% in Tanzania, 2.8% in Kenya and 2% in Uganda due to milk spoilage during handling. Similarly, the results conform to Amentae *et al.* (2015) who reported milk losses at the MCCs in Ethiopia to be 5.46%. In addition, Thiam (2018) reported milk losses at the cooperatives/MCCs in Mali to be 3.58%.

At the vendors the milk losses were approximated to be 3.3%, 2.5% and 0.01% by spillage, spoilage and contamination in the dry season and 3.2%, 4.4% and 0.4% by the same in wet season respectively (Fig. 2). Generally, at the vendor's node milk was highly lost during the wet season except for spillage which showed a slight difference in dry season. The reason for higher milk losses in dry season by spillage may be because of using poor equipments during milk transport to market or lack of adequate knowledge on milk handling. Although, the mentioned reasons may also cause milk losses even in the wet season. The above conform to Lore *et al.* (2005) who reported high milk losses by spillage during the dry season as quoted below:

"During transportation of milk by vendors to collection centres, spillage is the most significant type of loss. Vendors transport milk by bicycle over an average distance of 12 kilometres" (Lore *et al.,* 2005).

The above results also conform to Kurwijila & Boki (2003) who witnessed a Health Officer supervising a milk vendor dispose of the contaminated (adulterated) milk in Mwanza Region. Similarly, Abunna et al. (2019) reported poor cleanness (dirty) of milk vendors and their surroundings to be an indicator of the milk supplied by them to be spoiled or contaminated.

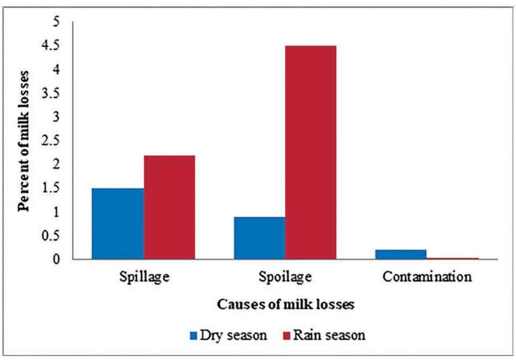

Figure 1: Main cause of milk losses at the MCCs (n=35)

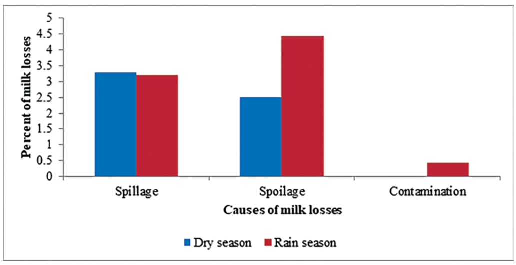

Figure 2: Main cause of milk losses at the milk vendors (n=52)

Factors associated with post-harvest milk losses at the milk collectors' node in Tanzania

The study assessed the factors affecting post-harvest milk losses during collection, storage and transport to market/sales point at the MCCs and the vendors. The results in Table 2 show that age of the MCC in-charge (Coef = 0.102; 95% CI: 0.008-0.196), equipment used for milk transport (Coef = 2.515; 95% CI: 0.697-4.333), the person who performs milk transport (AC = -3.519; 95% CI: -5.752 - -1.286), market price (Coef = 2.535; 95% CI: 0.31-4.76) were

Table 2: Generalized Linear Mixed Model results on the factors associated with milk losses at the MCCs

Factors	Spillage	Spoilage	Contamination
	Coef (CI) p-value	**Coef (CI) p-value**	**Coef (CI) p-value**
Season of survey, 0 Dry season, 1 Rain/wet season		2.929(-0.878-6.736)	-0.19(-0.37--0.010)**
Sex of the MCC in-charge, 0 Male, 1 Female			0.116(-0.166-0.398
Age of the MCC in-charge	0.102(0.008-0.196)**		
Whether get milk from farmers/ farms, 0 No, 1 Yes	-1.670(-4.277-0.937)		
Cost of buying milk	-0.003(-0.006-0.0001)*	-0.008(-0.016-0.0001)*	
Equipment used for milk transport, 0 otherwise, 1 Motorised	2.515(0.697-4.333)***	4.877(-0.180-9.935)*	
The person who performs milk transport, 0 Otherwise, 1 hired labour	-3.519(-5.752--1.286)***	1.871(-3.419-7.16)	
Adequate of labour for milk operations, 0 No, 1 Yes	-2.324(-6.092-1.444)	-14.644(-25.185--4.105)***	
Market availability for milk sales, 0 No, 1 Yes		6.410(-2.056-14.877)	
Membership milk association, 0 No, 1 Yes	-1.683(-3.95-0.583)	-3.137(-7.487-1.213)	
Heard on post-harvest milk loss, 0 No, 1 Yes			-0.274(-0.490--0.058)**
Adequacy of storage facilities, 0 Not adequate, 1 adequate		-0.204(-5.683-5.274)	
Market stability, 0 lack of stable market, 1 available and stable		-9.525(-18.092--0.958)**	-0.286(-0.612-0.04)*
Distance to market, 0 Otherwise, 1 short distance (<=10km)		-3.952(-8.339-0.436)*	
Market Price, 0 low price, 1 good/reasonable price	2.535(0.31-4.76)**		-0.183(-0.399-0.032)*
Transport to market using Road, 0 poor road, 1 good and passable all the time		8.952(3.968-13.937)***	
Constant	4.79(-1.627-11.207)	15.772(3.049-28.496)**	0.64(0.294-0.985)***
Number of observations	70	70	70

significantly associated with milk spillage. The above suggests that milk losses at the MCC node decreased with an increase the person's age. Generally, this could be attributed to the fact that older individuals have adequate experience on milk handling and are more careful than their younger counterparts. In addition, milk losses were observed to be more when milk handling practices were carried out by other members of the MCCs compared to when milk handling practices were carried out by hired labour. This may be because some of the members of the MCCs are not competent enough to carry out milk operations properly or no sanctions are imposed on them compared to hired persons who may lose their jobs if losses mount to unbearable levels.

Further to the above, adequacy of labour for milk operations (Coef = -14.644; 95% CI: -25.185 - -4.105), market stability (Coef = -9.525; CI-18.092 - -0.958), transport to market using road (Coef = 8.952; 95% CI: 3.968-13.937) were significantly associated with milk spoilage. Although, availability of electricity and its stability as a variable did not fit in the GLMM during modelling, but the same was claimed to have an adverse impact in some of the MCCs. For example, on 25th March, 2022 the researcher witnessed a thousand litres of milk spoiled due to inadequate electricity supply at Asari farm collection point in Mufindi district, Iringa region (Appendix I). The above observation conforms to what has been reported by Lore *et al.* (2005) that electricity failure was the main cause of milk spoilage at the MCCs. The results in Table 2 also conform to those of Amentae *et al.* (2015) who reported poor milk handling practices at collection points; lack of appropriate facility; lack of cooling systems at collection points and during transport; poor means of transportation; inappropriate milk carrying equipment; poor storage facilities to perpetuate milk losses. Similarly, Thiam (2018) reported poor infrastructure and lack of market to be the drivers of milk losses at the cooperatives of which MCCs are included. Moreover, the study results (Table 2) show that season (Coef = -0.19; 95% CI: -0.37 - -0.010) and awareness/knowledge on post-harvest milk loss (Coef = -0.274; 95% CI: -0.490 - -0.058)

Table 2: Generalized Linear Mixed Model results on the factors associated with milk losses at the MCCs

Factors	Spillage	Spoilage	Contamination
	Coef (CI) p-value	Coef (CI) p-value	Coef (CI) p-value
Log likelihood	-187.464	-243.939	-31.829
Chi^2	45.51	62.05	17.64
P	0.000	0.000	0.003
Random effects			
District var(-cons)	-	-	0.006(0.000-0.597)
District var(dependent)	-	-	0.140(0.098-0.201)
Chi^2	-	-	0.24
P	-	-	0.3131

NB: Number outside the bracket refers to adjusted coefficient while the number in bracket indicates 95% confidence interval. ***, **, * are significance levels at 1%, 5%, and 10%, respectively

Source: Field data 2023

Table 3: Generalised Linear Mixed Model results on the factors associated with milk losses at the vendors

Factors	Spillage	Spoilage
	Coef (CI) p-value	**Coef (CI) p-value**
Season of survey, 0 Dry season, 1 Rain/wet season		1.898 (-0.678-4.474)
Years in business		0.165 (-0.174-0.504)
Whether get milk from group collection points, 0 No, 1 Yes	-2.778 (-7.332-1.776)	-2.571 (-6.843-1.702)
Equipment used for milk collection, 0 Bucket/plastic can, 1 Aluminium/stainless steel milk can	-2.139 (-5.746-1.467)	
Adequate of labour milk for operations, 0 No, 1 Yes		-2.245 (-6.337-1.847)
Respondent received training on milk handling, 0 No, 1 Yes	4.301 (-2.354-10.955)	5.050 (0.988-9.111)**
Adequacy of storage facilities, 0 Not adequate, 1 adequate		1.871 (-1.177-4.919)
Availability of refrigeration facilities, 0 not available, 1 adequate		0.315 (-2.848-3.478)
Market Price, 0 low price, 1 good/reasonable price		0.672 (-2.186-3.530)
Transport to market using Road, 0 poor road, 1 good and passable all the time		-1.138 (-5.355-3.079)
Constant	3.155 (0.577-5.733)**	3.694 (-4.176-11.564)
Number of observations	104	104
Log likelihood	-344.195	-345.246
Chi²	5.69	24.62
P	0.128	0.003
Random effects		
District var(-cons)	6.639	-
District var(dependent)	40.148	-
Chi²	1.72	-
P	0.095	-

*NB: Number outside the bracket refers to adjusted coefficient while the number in bracket indicates 95% confidence interval. ***, **, * are significance levels at 1%, 5%, and 10%, respectively*
***Source:** Field data 2023*

were significantly ($p \leq 0.05$) associated with milk contamination at the MCCs.

Study findings in Table 3 show that with an exception of training on milk handling which was positively and significantly ($p \leq 0.05$) associated with milk spoilage (Coef = 5.05; 95% CI: 0.99-9.11) the other factors in the model were not significantly associated with milk losses or did not fit in the GLMMs at the milk vendors. But, in reality most of the vendors complained of the lack of storage facilities, unstable electricity supply and high costs associated with advisable milk packaging materials, as a result most of them continued using empty water bottles as their cheap packaging materials (Appendix II). The above results conform to Lore *et al.* (2005)

who reported poor handling and the use of inappropriate milk containers to be associated with milk losses at the vendors.

Conclusion and Recommendations

Generally, based on the study findings it is concluded that spillage, spoilage and contamination were the main forms of milk losses at collection, storage and transport to market. It is also concluded that less milk loss was reported with an increase in age of those transporting milk. It is further concluded that adequacy of labour for milk operations, market stability, season of production and awareness/ knowledge of post-harvest milk loss were negatively and significantly associated with post-harvest milk losses. Lastly, age of the MCC in-charge, equipment used for milk transport, market price, transport to market using road were positively and significant associated with milk losses. Therefore, the Tanzanian government through use of livestock extension officers needs to create awareness but, also train milk collectors on how to minimize milk loses at their node. In addition, there is need for coordinated and collective investments in milk infrastructures and other logistics required in handling milk at collection centres and if milk loses by the above-mentioned is to be reduced. Lastly, the Government needs to create a conducive environment that enhances the availability of cheaper quality and affordable milk handling equipment to allow storage and transportation of milk that minimizes postharvest losses.

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Appendices

Appendix I: Spoiled milk due to inadequate electric supply at Asari Farm collection point in Mufindi DC, Iringa Region on 25th March, 2022

Appendix II: Packaging materials mostly used by milk vendors