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Determinants of Post-Harvest Milk Losses among Milk Producers in Tanzania

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Abstract
Despite the Tanzania's programmes that aimed at improving infrastructures for milk and milk products, milk losses continue to be substantially high. The paper evaluated the determinants of post-harvest milk losses at the milk producers in Tanzania. The study adopted the cross-sectional research design whereby data were collected from 370 household heads and 38 Farm Managers in both the dry (June to October 2021; June to September 2022) and wet (November to December 2021; January to May 2022) seasons. Generally, study findings showed that milk was mainly lost through spillage, spoilage and contamination. In addition, Generalised Linear Mixed Model results showed existence of significant associations between location (Adjusted Coefficient (AC) = -0.80; 95% Confidence Interval (CI): -1.28-0.31), cattle keeping systems (AC = -0.75; 95% CI: -1.38-0.11), market price (AC = 0.66; 95% CI: 0.23-1.10), transport means (AC = -0.69; 95% CI: -1.29—0.10) and spillage. Additionally, washing cow's udder before milking (AC = -2.10; 95% CI: -3.70-0.49), water used for washing milk utensils (AC = -1.302; 95% CI: -2.43—0.17) and storage equipment (AC = -1.26; 95% CI: -2.47—0.05) were significantly associated with spoilage. Therefore, the Tanzanian government needs to improve extension services and workable strategies to minimise milk losses.
Keywords: Households, Milk Producers, Post-harvest Milk Losses, Tanzania

1.0. Introduction
The global population is projected to increase from 7.7 billion people in 2019 to 9.7 billion people in 2050 (UN, 2019). It is further projected population increase by 91% in sub-Saharan Africa (SSA) from 1.1 billion people in 2019 to 2.1 billion in 2050 (UN, 2019). Tanzania's population in 2022 was 61.9 million people and it is projected to increase by about 144% to 151.3 million in 2050 (URT, 2022b). The projected population growth signifies the need for collaborative efforts to increase production and minimise food losses to meet the increasing demand for food, dairy products included.

Milk losses are reported to be perpetuated by various factors in different areas of the world. According to Aulakh *et al.* (2013), handling and processing, production practices, management decisions, transportation facilities, infrastructure, consumer preferences and availability of financial markets are major factors associated with milk losses. It is also argued that a typical post-harvest chain comprises of a number of stages for the movement of harvested food from the site of production to the final retail market or consumer based on organisation and technologies. In addition, Aulakh *et al.* (2013) argue that in less developed countries where the supply chain is less mechanized, larger losses are experienced during production handling, storage, processing and transportation.

Further to the above, Kowalska (2017) categorised the factors determining food losses and waste in two groups: first are the factors that occur along a food supply chain (FSC) e.g. machines (thus, investing in advanced technologies and new machinery is crucial for food losses and waste management especially in agricultural production and food processing); materials (quality of raw materials, develop thorough quality specification for acceptable materials); management (hence, need to develop and implement quality management systems); methods (proper technologies i.e. packaging technologies, processing technologies etc.); and people (knowledge, awareness and other attitudes of people engaged in a food supply chain). Second, are factors that come from the surroundings of a food supply chain e.g. political issues (policies, regulations, food and quality management standards, financial and substantive support for FSC operators 'public funds, preferential credit, professional training and education); consumer trends; consumer education; professional training; and food market development.

Furthermore, FAO (2019) identified various factors that drive food losses at supply chains i.e. on-farm level losses are caused by inadequate harvesting time, harvesting practices and handling, climate variability and product marketing. Others are inadequate storage conditions which impede products shelf life. In addition, during transportation, physical infrastructure and trade logistics play significant roles on preventing food losses. Furthermore, processing and packaging plays role in preserving foods, whereby, inadequate facilities as well as technical malfunction or human error can accelerate losses. At the retail level, food waste occurs due to limited shelf life and standard variations on demand. At consumption losses occurs due to poor purchase and meal planning, buying in excess, labelling misperception and poor storage at home (FAO, 2019).

Based on the above, Tanzania has formulated various policies, strategies and programmes aimed at contributing towards national food security through increased production, processing and by improving marketing infrastructure and marketing systems for livestock and livestock products (URT, 2006, 2010, 2011). In addition, the country insists on additional dairy investments and value addition through processing to ensure a stable market for fresh milk with the aim of reducing the losses along milk value chain (URT, 2017a). However, despite the government's initiatives, milk losses at production (household and farm levels) continue to be substantially high, approximately 6.5% (Lore *et al.*, 2005); 16% and 25% dry and rain seasons respectively (FAO, 2004 cited in ACF, 2014); 10% and 8% at the households and Farm levels respectively (Lugamara *et al.*, 2023 unpublished). Therefore, this paper evaluated the determinants of post-harvest milk losses at the milk producers (households and farms) node of Tanzania's milk value chain.

2.0. Materials and Methods

2.1. Description of Study Area

The study was conducted in three grouped livestock production systems of Tanzania namely: Central Zone (representing the agro-pastoral and semi-arid production systems); Coastal and Lake zones (representing the mixed rain-fed sub-humid and humid production systems); and the Northern and Southern Highland zones (representing a mixed rain-fed highland production systems) (Nell *et al*., 2014; URT, 2017a). In addition, about 30% and above of the households in the selected zones are engaged in livestock production (64% in the Central, 30% in Coastal and Lake; and 37% in the southern and northern highlands) (URT, 2017a).

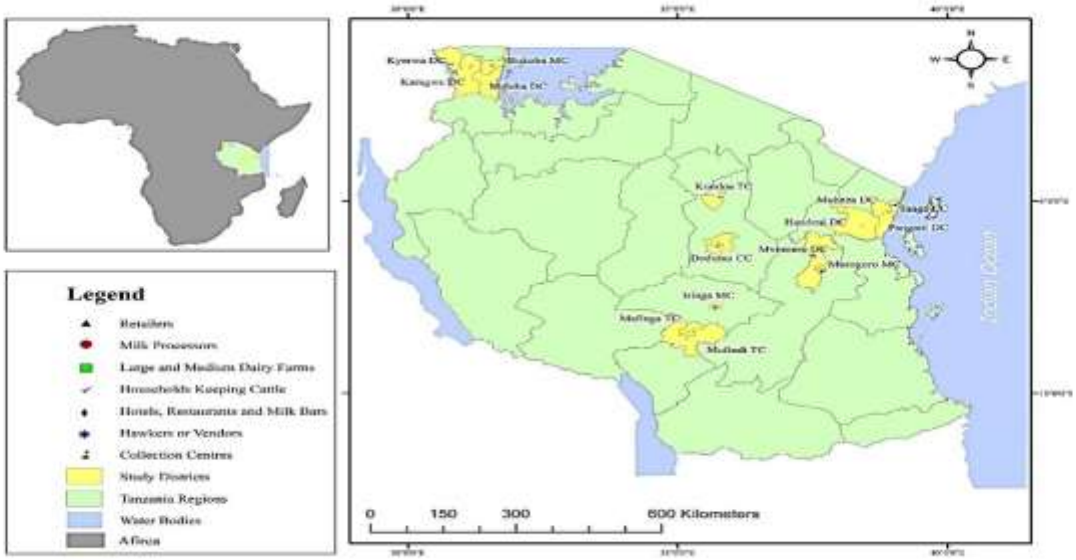

Figure 1: Map of Tanzania showing districts where the study was conducted

2.2. Research Design

A cross-sectional research design was used to collect data in both the dry (June to October 2021 in Morogoro, Dodoma and Tanga regions; June to September 2022 in Kagera and Iringa regions) and wet (November to December 2021 in Morogoro, Dodoma and Tanga regions; January to May 2022 in Morogoro, Dodoma, Tanga Iringa and Kagera regions) seasons. The research design is 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).

2.3. 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 sampled production systems. The regions were purposefully selected based on the number of household keeping cattle (NBS, 2017) and presence of cattle farms (TDB, 2019; URT, 2020). As part of sampling procedures, livestock production systems were considered as strata. Therefore, regions in each stratum were considered in the first stage, district in the second stage, wards third stage, villages fourth stage and households keeping cattle in the fifth stage. Further to the above, simple random sampling was used to select 370 household heads or their representative from households keeping cattle.

In determining the study's sample for households keeping cattle a random sample size calculation formula developed by Cochran (1977) was used as shown below:

$$n = Z^2_{\alpha/2} P\,(1 - P)/e^2 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

Where: n = sample size; $Z_{\alpha/2}$ = the probability distribution with a level of significant α = 5%, "P" = proportion of the Tanzanian households keeping livestock, (1-P) = proportion of Tanzanian households not keeping livestock and "*e*" = the level of marginal error. Then calculation of the representative sample of the household heads was estimated considering the proportion of households involved in livestock keeping in Tanzania = 35% (NBS, 2021; URT, 2017b), a 95% confidence level or ά = 0.05 and acceptable margin of error = 0.05 and non-response rate = 10%. Therefore, the required sample size was 388. n = (1.96x1.96x0.35x0.65)/0.0025/0.9 = 388.4284). But, the researcher managed to only interview 370 household heads or their representatives because, 18 respondents (3.6% non-response rate) were dropped in the process (during the second round of interview their cows were no longer producing milk - dry off season). Moreover, at least 10% of farm managers representing dairy farms obtained from TDB and MLF reports and the regions or districts list were recruited for the study.

2.4. Data Collection methods

The study's quantitative data from milk producers was collected using two sets of questionnaires (i.e., one for the household and the other for the farm). The reason for using the different questionnaires was the differences in modes of operation and the nature of data to be gathered from the particular milk producers. The questions of each questionnaire were uploaded in a computer/mobile app (KoBoKollect) for easier and efficient data collection. The collected data was on main method of operation, individuals performing operation, equipment used, quantity handled, quantity lost and root causes of loss were recorded. Other information included cattle husbandry practices (systems used to keep cattle and procedures followed before milking), and respondents' socio-demographic and economic characteristics. The data were collected during or soon after milking to have the day's milk record. In addition, respondents were asked to report their milk loses in a one-month period as milk losses do not necessarily occur daily (daily based lose). In addition, key informant interviews (KIIs) were conducted to collect qualitative data. The key informants (KIs) included Regional and District Livestock and Fisheries Officers (RLFOs, DLFOs), Tanga Dairy Cooperative Union (TDCU), TDB (Tanzania Dairy Board), Tanzania Livestock Research Institute (TALIRI), African Dairy Genetic Gains (ADGG) – Tanzania, and Dairy Nourish Africa (DNA). The discussions with KIs mainly based on the main roots of milk losses and the factors associated with milk losses.

2.5. Data Analysis

The Statistical Package for Social Sciences (SPSS) software (version 26) was used to check the accuracy of data collected where anomalies found were corrected accordingly and performing descriptive analysis. The data were then transferred to STATA software for running Generalised Linear Mixed Model (GLMM) to determine the factors associated with milk losses at each stage of the milk node. The model was seen as desirable as is good in reducing the probability of having false positives based on the fact that the drivers of 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, in order to overcome dependence problem resulting from repeated measures (data from two seasons) predictors (explanatory variables) were categorized into fixed and random variables. The random effect variables included villages for the households and farm identification number for the farms. Table 2-5 presents the Coefficients for the independent variables, the associated p-values and the 95% confidence interval (CI). Results are presented using adjusted Coefficient (Coef) and 95% CI. The differences/associations of variables were considered statistically significant if the p-value was ≤ 0.05.

3.0. Results and Discussion

3.1. Respondents Demographic and Socio-economic Characteristics

The results revealed that 83% of the households interviewed were headed by males and 17% were headed by females. This implies that a large number of households interviewed were headed by males compared to females. Also, head of the household had influences on access to and control of milk handling facilities and participation in milk operations hence leading to reducing post-harvest losses. A study by Zegeye and Teklehaymanot (2016) conducted in Ethiopia revealed that milking practices is mostly practised by men while milk handling, processing and marketing primarily practised by women. This may be due to the nature of activity involved especially hand milking which seems to be laborious in traditional cattle keeping. Other scholars (Alganesh, 2002; Tegegne *et al.*, 2013) reported women to perform many roles in milking and milk processing in some areas of Ethiopia while the role of men on milking and milk handling were not significant. Therefore, understanding household characteristics particularly the head is of important factor when looking for post-harvest milk losses. In addition, the majority (65.1%) of household heads were in the age group of 36-60. Thus, suggesting the majority of household heads were in the economic active age group (URT, 2015), hence, able to participate in milk production. Further, the majority (91.4%) of respondents had formal education (i.e. seven years of primary school education and above) suggesting the household heads are in a position to understand proper livestock husbandry practices for better milk production and handling. Moreover, about three-fifths (59.5%) of the household heads are engaged in livestock production as their main economic activity. The findings suggest that, a household's economic status has an implication on the access of milking handling facilities for milk operations (during milking, collection, storage and transport). Therefore, strategies for minimising postharvest milk losses can have a substantial effect in uplifting the economic status of the households whose livelihood depends on livestock particularly, milk production. In addition, it is reported by FAO (2019) that, households' demographic characteristics i.e., age, education and sex of the household head, and household size need to be considered when looking for post-harvest food losses as associated factors.

Table 1: Demographic and Social economic characteristics of the household head (n = 370)

Variable	Category	Frequency	%
Sex	Male	307	83
	Female	63	17
Age	25-35	28	7.6
	36-60	241	65.1
	>60	101	27.3
Education level	None	32	8.6
	Primary education	163	44.1
	Secondary	77	20.8
	Tertiary (Certificate Diploma)	62	16.8
	University	36	9.7
Marital status	Single	7	1.9
	Married	299	80.8
	Divorced	11	3
	Separated	13	3.5
	Cohabitating	1	0.3
	Widow/er	39	10.5
Main occupation	Livestock production	220	59.5
	Crop production	61	16.5
	Government employees	37	10
	Private employees	21	5.7
	Self-employees and Casual labour (on and off farm)	31	8.4

Source: Field Data 2023

3.2. Milk losses at the Producers node

The study findings (Fig. 2) show that spillage, spoilage and contamination are the main causes of milk losses at the production node. According to Fig. 2, a total of 5.9%, 1.5%, and 0.4% of the milk was lost through spillage, spoilage and contamination in dry season respectively while the same caused 10.8%, 1.4%, 0.2% milk losses in the wet season respectively. At farm level the milk losses were approximated to a total of 4.4%, 2.2%, 0.1% by spillage, spoilage and contamination in dry season and 7%, 1.9%, 0.6% by spillage, spoilage and contamination in wet season respectively (Fig. 3). The above results signify the existence of milk losses at the producers which impede the initiatives of fighting against poverty and hunger. The recorded milk losses are substantially high based on the milk consumption requirements and production costs per unit incurred. The study by Lore *et al.* (2005) conducted in Tanzania in 2003 reported 6.3% milk loss at farms (production area) due to spillage and spoilage. This implies that for many years the country (Tanzania) experiences substantial milk losses annually. Other scholars (Melesse *et al.*, 2014) reported milk losses at household level in Ethiopia to be 3.8% to 9.5% due to spoilage and spillage. Similarly, Ndungu *et al.* (2019) in Kenya and Zegeye and Teklehaymanot (2016) in Ethiopia reported milk losses at milk producers (smallholder dairy farmers) to be mainly of contamination, spoilage and spillage.

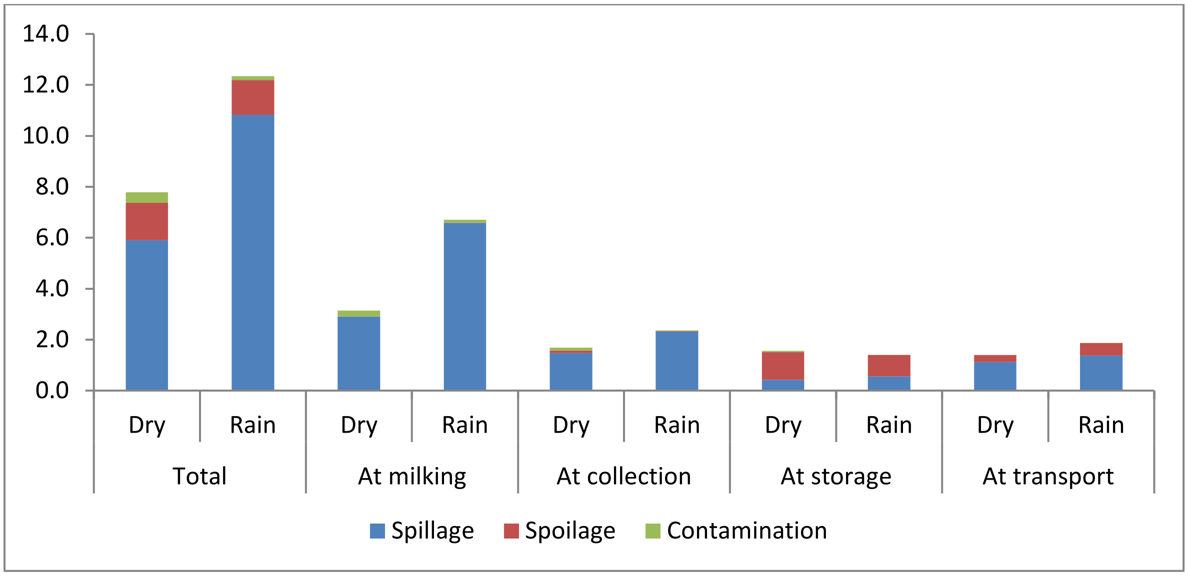

Figure 1: Percent of Milk losses by handling category at the household

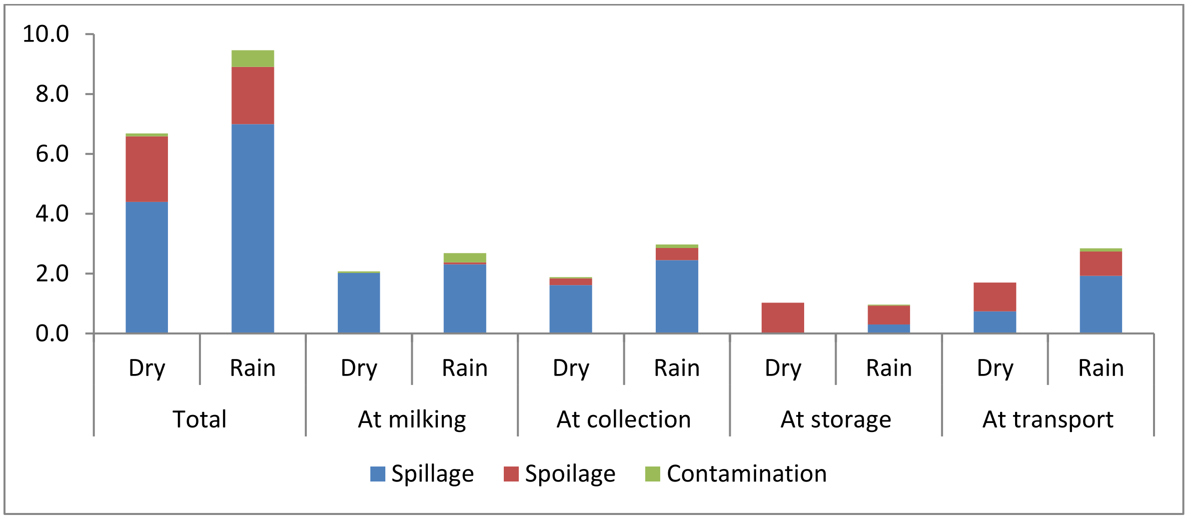

Figure 2: Percent of Milk losses by handling category at the farm

3.3. Determinants of post-harvest milk losses at the milk producers' node in Tanzania

The study assessed the determinants of post-harvest milk losses during milking, collection, storage and transport to market/sales point at the household and at the farm level. Since the outcome (dependent variable) is estimated milk losses in percentage terms and because of drivers for food losses being complex and interrelated GLMM was used to assess the determinants (Grainger *et al*., 2018). The GLMM analysis results (Table 2) surprisingly showed that being married or cohabitating was significantly associated with PHML through spillage ($p<0.01$) during milking and collection ($p<0.05$). Table 2 also shows that household size was negatively and significantly ($p<0.01$) associated with milk losses by spillage during milking, collection, and transport to market. The results is contrary to the expectation that household with many members have more demand for food and other basic needs which are the basis for more commitment to minimise milk losses and ensure milk availability for the household's consumption and income.

Results in Table 2 further showed that an increase in a household's income was negatively and significantly associated with PHML through spillage ($p<0.01$) and spoilage ($p<0.05$) at collection. The observation seems to suggest that a unit increase in household income leads to milk losses. The plausible explanation may be most of the households in the area of study do not rely much on milk production for their livelihood rather than other sources of income. In addition, the results in Table 2 showed that extensive system for keeping cattle ($p<0.05$) and lack of proper milking area/place ($p<0.05$) were significantly associated with milk spillage. The above implies that the households using extensive system of keeping cattle experienced more milk losses compared to those using semi-intensive or intensive systems of keeping cattle because of lacking proper milking and collection facilities in the extensive system of keeping cattle. The higher losses also were on the households that did not use crush (not have proper milking place) for restraining cows during milking. The above may be due to the lack of knowledge and skills on milk handling practices, though some factors like whether respondent received training on milk handling practices, methods used in milking and whether respondent heard on PHML did not fit well when undertaking likelihood ratio tests to select the most suitable models for determining losses at milking and collection stages.

In addition, Table 2 showed a significant association between washing cow's udder before milking ($p<0.05$) and milk spoilage at storage. The above imply that households that were not washing the cow's udder before milking to minimise dirty experienced significant milk losses through spoilage. Table 2 further shows that households not using lubricants on cow's teat during milking experienced significant ($p<0.05$) milk losses through spillage during milking, this normally happens due to the fact that milking without lubricating the teats, the cow get restless and may feel pain and kick the milking container. Table 2 further shows that households not washing milk utensils was significantly associated with PHML through spoilage during storage ($p<0.01$) and during transport ($p<0.05$). Generally, households use of unsafe water to clean milk utensils was significantly ($p<0.05$) associated with milk losses by spoilage during storage than the households that used borehole/tap/rain water to wash milk utensils. The observation suggests that most of livestock keepers seem to use readily available water to wash the udder without considering its quality. Spillage also observed in the households that used jug, pot, calabash to handle milk when milking cows than the households that used bucket. The results conform to Ndungu *et al.* (2019) who reported milk spillage due to cow's knocking over milking equipment such as buckets during milking. Spoilage was observed at the households that used stainless steel containers to collect milk. This may be due to the delay at the collection to take milk to the storage or to be transported to market, because at normal circumstances stainless steel containers are advisable to use for milk collection. Also spoilage was significant to the households that stored milk without cooling facilities.

Table 2 also shows that households use of towels in drying udders during milking was positively and significantly ($p<0.05$) associated with PHML. Despite the fact that it is advisable to use towels to dry the cow's teats but, for this case it seems the towel was poorly used that's why milk spoilage and contamination were observed at the households claimed to use towel for drying cow's udders. The results in Table 2 showed a negative and significant association of being located in rural areas and postharvest milk losses by spillage ($p<0.01$) and contamination ($p<0.05$) during milk collection. The observation suggests that postharvest milk losses are less likely to occur in urban households compared to rural households.

Generally, in urban areas there are high possibilities of meeting the requirements needed for milking, milk collection, storage, transports, and markets and marketing compared to rural areas. The results above conform to what has been reported by Melesse *et al.* (2014) for Ethiopia that post-harvest milk losses vary between different geographical locations particularly rural and urban areas.

Table 2 also shows that PHML significantly ($p<0.01$ at milking and $p<0.05$ at collection) differed by season whereby, PHML were higher in the wet season compared to the dry season. In addition, there were more milk losses by spillage during this period. Furthermore, PHML due to contamination was also significantly ($p<0.01$) higher during the wet season at milking and collection. The cause for the above could be the fact that during the rainy season there were many milk outlets that outflowed the market and handling facilities hence losses by spillage. During the dry season milk supply is low compared to the demand which tempted milk producers to add some foreign materials like water (adulteration) and other substances to increase the volume of milk in order to get extra revenue while by doing so it led to milk contamination. The above results conform to what reported by FAO (2004) cited in ACF (2014) and NBS (2003) cited in Kurwijila *et al.* (2012) that milk losses is high in rain season compared to dry season. Similarly, Zegeye and Teklehaymanot (2016) and Kurwijila and Boki (2003) reported milk disposal because of adulteration. In addition the result is supported by Melesse *et al.* (2014) who reported severe problem of spillage during transfer of milk from container to container and during transportation process. Similarly, Amentae *et al.* (2015) conducted a case study in Ethiopia and found that poor milk handling practices, lack of appropriate milk handling facilities and milk mismanagement is associated with milk losses.

Table 2: Generalized Linear Mixed Model results on determinants of milk losses at the households

Dependent/ Independent Variables	Milking		Collection		
	Spillage	Contamination	Spillage	Spoilage	Contamination
Geographical location, 0 Rural, 1 Urban	-	-	-2.301 (-3.433--1.168) ***	-	-0.095 (-0.179--0.012) **
Season of survey, 0 Dry season, 1 wet season	3.641 (2.575-4.706) ***	-0.122 (-0.209-0.035)***	0.694 (0.050-1.339) **	-0.051 (-0.120-0.0172)	-0.099(-0.163-0.034) ***
Sex of Household head, 0 Male, 1 Female	-	-0.084 (-0.301-0 .133)	-	0.091 (-0.120-0.0172)	-
Marital status of the Household head, 0 Otherwise, 1 Married/Cohabitating	2.755 (1.130-4.379) ***	-0.181 (-0.397-0.034) *	0.958 (0.027-1.889) **	-0.055 (-0.184-0.074)	-
Highest level of education of the Household head, 0 otherwise, 1 Secondary or above	1.678 (0.247-3.109) **	-0.111 (-0.228-0.005) *	-	-0.035 (0.104-0.033)	-
Household size, #	-0.7419 (-1.143--0.340) ***	-0.009 (-0.042-0.024)	-0.286 (-0.507--0.064) ***	-	-
Annual household income, Tzs	-2.27e-08 (-5.66e-08-1.11e-08)	-2.24e-09 (-5.02e-09-5.44e-10)	-2.48e-08 (-4.35e-08--6.11e-09) ***	-1.78e-09 (-3.43e-09--1.37e-10) **	-
System for keeping cattle, 0 Otherwise, 1 Semi/Intensive	-	0.148 (-0.032-0.328)	-	-	-
Place of milking cow, 0 Otherwise, 1 In crush	-2.098 (-3.778--0.417) **	-	-0.880 (-1.829-0.069) *	-0.078 (-0.163-0.008) *	-
Material used for drying cows teats, 0 Otherwise, 1 Towel	-	-	-	0.055 (-0.025-0.134)	-

Whether use lubricant on teats during milking, 0 No, 1 Yes	-	-0.168 (-0.314-0.023) **	-	-	
Type of Lubricant used on teats during milking, 0 Otherwise, 1 Milk salve	-	-	-	-	-0.036 (-0.116-0.044)
Whether wash milking utensils, 0 No, 1 Yes	-	-0.158 (-0.433-0.116)	-	-0.060 (-0.214-0.094)	-
Type of water used to wash milking utensils, 0 Otherwise, 1 Borehole/tape/rain	-	-	-	-0.069 (-0.151-0.014) *	-
Whether use detergent to wash milking utensils, 0 No, 1 Yes	-	0.166 (0.031-0.301) **	-	-0.052 (-0.125-0.021)	-
Method of milking, 0 hand milking, 1 Machine milking	-	-1.367 (-1.86--0.874) ***	-	-	-
Equipment used during milking, 0 Otherwise, 1 Bucket (plastic/iron)	-10.819 (-14.28--7.357) ***	-	-	-	-0.228 (-0.404--0.052) **
Equipment used for milk collection, 0 Otherwise, 1 aluminium/ stainless steel Milk can	-	-	-	0.166 (0.045-0.287) ***	-
The person performing milk collection, 0 Hired labour, 1 Family members	-		-0.600 (-1.558-0.158)	0.046 (-0.027-0.119)	
Adequacy of labour for milk operations, 0 No, 1 Yes	-	-	-	-	0.102 (-0.033-0.236)
Market availability for milk sales, 0 No, 1 Yes	-	-	1.192 (0.0193-2.365) **	-	
Membership milk association, 0 No, 1 Yes	-1.9148 (-3.967-0 .139) *	-	-1.816 (-3.028--0.605)***	-	-
Market availability, 0 Otherwise, 1 Available	-	-	-	-0.063 (-0.138-0.011) *	
Market distance, 0 long distance (>6km), 1 short distance(≤6 km)	-	-	-	-0.152 (-0.233-.071) ***	
Constant	14.45 (10.395-18.506) ***	0.517 (0.13-0.903) ***	3.461 (1.482-5.441) ***	0.572 (0.313-0.832) ***	0.312 (0.106-0.518) ***
Number of observations	740	740	653	653	740
Log likelihood	-2583.154	-724.229	-1883.225	-307.293	-464.405
Chi2	123.77	76.13	64.96	62.45	26.75
P	0.000	0.000	0.000	0.000	0.000
Random effects					
Village var(_cons)	17.519 (11.014-27.867)	0.109 (0.071-0.168)	3.944 (2.522-6.167)	0.007 (003-0.017)	0.006 (0.002-0.020)
Village var(dependent)	54.591 (48.897-60.949)	0.361 (0.324-0.402)	16.492 (14.697-18.505)	0.144 (0.129-0.161)	0.201 (0.180-0.223)
Chi2	76.02	97.46	83.32	13.31	5.15
P	0.000	0.000	0.000	0.001	0.0116

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

Results further shows that personal characteristics were associated with PHML for example, PHML were relatively higher when family members participated in transporting the milk compared to when done by hired labour: the association was statistically significant ($p<0.001$) (Table 3). The observation seems to suggest that some household members were either non-experienced or negligent in handling milk hence the losses. In addition, the results in Table 3 showed significant association between being located in rural areas ($p<0.001$), large household size ($p<0.01$), extensive system of keeping cattle ($p<0.05$), knowledge on

PHML (0.01), lack of refrigeration facilities for milk cooling ($p<0.05$), poor road to market ($p<0.05$) and milk losses by spillage during storage and transport to market. Moreover, milk spoilage during storage and transport to market at the households were significantly associated failure to wash cow's udder before milking ($p<0.05$), improper use of towel to dry cow's teats ($p<0.05$), improper cleanness of milk utensils or use of unclean water to wash milk utensils ($p<0.05$), use of storage equipment with no cooling facilities ($p<0.05$) and poor road to market ($p<0.05$). Likewise, bad use of disinfectant before and after milking ($p<0.01$) was significantly associated with milk contamination. The study results (Table 3) revealed a positive and significant association between awareness or knowledge of the household head on post-harvest milk losses and milk spillage ($p<0.01$) and spoilage ($p<0.05$) particularly when transporting milk to market. This implies that knowledge and skills are not a panacea to PHML, unless other factors like market availability, accessibility and means of transport including good roads which are passable all the time to market are taken into consideration. Except the knowledge and skills which shown a positive influence on PHML, the results in Table 3 conform to Zegeye and Teklehaymanot (2016) who reported poor milk handling practices, contamination, lack of cooling facilities, long distance to market, use of inappropriate containers, lack of market and delays of transport to have influences on milk losses. In addition, Amentae *et al.* (2015) found lack of cooling systems at the household and during transport; poor means of transportation; inappropriate milk carrying equipment and poor storage facilities to be associated with milk losses. Similarly, Lore *et al.* (2005) reported spillage and spoilage at transportation caused by the use of inappropriate containers to transport milk, poor hygiene, low level of technology application for milk preservation to be the factors influencing milk losses in Ethiopia and lack of markets and poor roads in Tanzania.

Table 3: Generalized Linear Mixed Model results on determinants of milk losses at the household

Dependent/ Independent Variables	Storage			Transport		
	Spillage	Spoilage	Contamination	Spillage	Spoilage	Contamination
Geographical location, 0 Rural, 1 Urban	-0.797 (-1.281-0.312) ***	-	-0.034 (-0.091-0.023)	- 1.773 (-3.562-0.0154) *	-0.314 (-0.773-0.145)	-
Season of survey, 0 Dry season, 1 Rain/wet season	-	-	-0.029(-0.085-0.0271)	-	0.200 (-0.116-0.517)	-
Sex of Household head, 0 Male, 1 Female	0.409 (-0.062-0.880) *	-	-	-		-
Marital status of the Household head, 0 Otherwise, 1 Married/Cohabitating	-	-	-	0.726 (-0.399-1.851)		-
Highest level of education of the Household head, 0 otherwise, 1 Secondary or above	-0.156 (-0.551-0.239)	-	-0.048 (-0.106-0.010)	-		-
Household size, #	-0.065 (-0.179-0.048)	-	-	-0.456(-0.739--0.172) ***	-0.046 (-0.152-0.060)	-
Annual household income, Tzs	-	-	-	-8.85e-09(-2.87e-08-1.10e-08)	-5.38e-09(-1.50e-08-4.22e-09)	-
System for keeping cattle, 0 Otherwise, 1 Semi/Intensive	-0.7476 (-1.384-0.112) **	-	-	-	-	-
Place of milking cow, 0 Otherwise, 1 In crush	-0.176 (-0.634-0.282)	-	-	-	-	0.005 (-0.003-0.013)
Whether wash cow udder before milking, 0 No, 1 Yes	-	-2.095 (-3.704-0.486) **	-	-	-	-
Material used for drying cows teats, 0 Otherwise, 1 Towel	-	1.023 (0.113-1.933) **	-	-	-	-

Whether use disinfectant before and after milking, 0 No, 1 Yes	-	-	-	-	-	0.077 (0.060-0.093) ***
Whether wash milking utensils, 0 No, 1 Yes	-	-3.785 (-6.014--1.556)	-	-	-0.893 (-1.771--.01489) **	-
Type of water used to wash milking utensils, 0 Otherwise, 1 Borehole/tape/rain	-	-1.302 (-2.430--0.174) **	-	-	-0.359 (-0.834-0.116)	-
Equipment used milk storage, 0 Otherwise, 1 With cooling facilities	-	-1.2628(-2.471--0.054) **	-	-	-	-
The person performing milk transport, 0 Hired labour, 1 Family members				0.864 (-0.082-1.809) *		0.012 (0.005-0.019)
Adequacy of labour for milk operations, 0 No, 1 Yes	0.400 (-0.338-1.137)	-	-	-	-	-
Market availability for milk sales, 0 No, 1 Yes	-	1.595 (0.219-2.971) **	-	-	-0.420 (-0.978-0.138)	-
Whether selling milk at home, 0 No, 1 Yes	-	-	-	-	-	-
Membership milk association, 0 No, 1 Yes	-0.159 (-0.756-0.438)	-	-	-	-	-
Whether heard on postharvest milk losses, 0 No, 1 Yes	-	-	-	2.877 (0.769-4.985) ***	0.742** (0.047-1.436)	-
Adequacy of milk storage facilities, 0 Otherwise, 1 Adequate	0.198 (-0.213-0.608)	0.457(-0.54-1.454)	0.048 (-0.009-0.105) *	-	-	-
Availability of refrigeration facilities, 0 Not available, 1 Available	-0.528 (-1.053--0.003) **	-				
Electricity for milk cooling, 0 Not Stable/Not electricity, 1 Stable		-0.836 (-1.988-0.315)				
Market availability, 0 Otherwise, 1 Available	-	-	0.030(-0.037-0.097)	-	0.338 (-0.092-0.768)	-
Market distance, 0 long distance (>6km), 1 short distance (≤6 km)	-	-0.253 (-1.141-0.635)	-0.023 (-0.081-0.035)	-	-	-0.007(-0.014--0.001) **
Milk market price, 0 Low price, 1 Good/reasonable price	0.661 (0.226-1.096) ***	0.499 (-0.554-1.551)	0.039 (-0.026-0.104)	0.771 (-0.504-2.046)	-	-
Transport means to market using road, 0 Poor road, 1 Good and passable all the time	-0.694 (-1.291--0.097) **	-2.771(-4.300--1.243) ***	-	-0.861 (-2.381-0.660)	-	-0.012(-0.022--0.001) **
Constant	2.089 (0.918-3.260) ***	10.044(6.055-14.033) ***	0.062(-0.056-0.181)	3.365 (0.762-5.968) **	1.869 (0.840-2.898) ***	0.0138(-0.001-0.029) *
Number of observations	687	740	740	592	740	592
Log likelihood	-1521.344	-2314.635	-323.766	-1755.743	-1644.844	1115.975
Chi2	57.82	63.72	15.2	29.73	28.91	130.98
P	0.000	0.000	0.034	0.000	0.000	0.000
Random effects						
Village var(_cons)	0.340 (0.224-0.712)	3.063 (1.529-6.137)	-	16.124 (10.86383-23.932)	0.229 (0.086-0.612)	0.0001 (0.0001-0.0003)
Village var(dependent)	4.620 (4.141-5.153)	28.445 (25.523-31.701)	-	16.680 (14.683-18.948)	4.809 (4.323-5.349)	0.001 (0.001-0.001)
Chi2	40.81	15.41	-	126.66	6.52	36.88
P	0.000	0.000	-	0.000	0.038	0.000

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

Further to the above Table 4 shows milk losses at the farm level. The most observed determinants were season of survey whereby rain season shown positive and significant influence on milk losses by contamination ($p<0.05$). In addition, maximum distances to market shown positive and significant influences on milk losses by contamination ($p<0.01$) (Table 5).

Table 4: Generalised Linear Mixed Model results on determinants of milk losses at the farm

Dependent/ Independent Variables	Milking			Collection
	Spillage	Spoilage	Contamination	Spoilage
V Geographical location, 0 Rural, 1 Urban	-	-	0.157 (-0.071-0.385)	-
Season of survey, 0 Dry season, 1 Rain/wet season	-	-	0.269 (0.048-0.489) **	-
Sex of the farm manager, 0 Male, 1 Female	-	-	0.292 (-0.163-0.746)	-
V Grazing System, 0 Otherwise, 1 Semi/Intensive	-0.916 (-2.211-0.378)	-0.142 (-0.285-0.0006) *	-	-
Place used to milk cow, 0 Otherwise, 1 in crush	-	-	-	-0.502 (-1.199-0.194)
Type of lubricant used, 0 Otherwise, 1 Milk salve/Norbrook	-	-	-	-0.566 (-1.278-0.147)
Water used to wash milk utensils, 0 Otherwise, 1 Borehole/tape/ rain water	-	-	-	0.446 (-.196-1.089)
Whether use detergent to wash milking utensils, 0 No, 1 Yes	-	0.17 (.009-0.331)	-	-
Whether heard on postharvest milk loss, 0 No, 1 Yes	-1.063 (-2.505-0.379)	-	-	-
Constant	3.010 (1.958-4.063) ***	0.075 (-0.034-0.183)	-0.040 (-0.223-0.143)	0.88 (0.095-1.66) **
Number of observations	76	76	76	76
Log likelihood	-184.871	-12.351	-53.607	-132.863
Chi2	4.59	6.09	9.68	8.59
P	0.101	0.048	0.022	0.035
Random effects				
Farm ID var(_cons)	-	0.003 (8.38e-08-84.853)	-	-
Farm ID var(dependent)	-	0.078 (0-0.125)	-	-
Chi2	-	0.04	-	-
P	-	0.425	-	-

Table 5: Generalised Linear Mixed Model results on determinants of milk losses at the farm

Dependent/ Independent Variables	Storage			Transport	
	Spillage	Spoilage	Contamination	Spillage	Spoilage
V Geographical location, 0 Rural, 1 Urban	-0.235 (-0.630-0.160)	-	-	-	-
Season of survey, 0 Dry season, 1 Rain/wet season	0.267 (-0.118-0.652)	-	-	1.185 (-0.408-2.775)	-
Frequency of milking per day, 0 Otherwise, 1 Twice per day (morning and evening)	-0.350 (-0.796-0.097)	-	-	-	-
Water used to wash milk utensils, 0 Otherwise, 1 Borehole/tape/ rain water	-	-	-	-	0.533 (-0.339-1.405)
Method of milking, 0 hand milking, 1 machine milking	-	1.296 (-0.387-2.979)	-	-	-
Selling milk at home/farm, 0 No, 1 Yes	-	0.915 (-0.0382-1.868) *	0.013 (-0.040-0.067)	-	-
Place for selling milk, 0 Otherwise, 1 MCC/Processors/Cooperatives	-	-	-	-	0.640 (-0.248-1.528)
Maximum distance to market, kilometres	-	-	0.002 (0.001-0.002) ***	-	-

Whether received training milk handling, 0 No, 1 Yes	-0.274 (-0.695-0.146)	-	-	-1.155 (-2.767-0.457)	-
Adequacy of milk storage facilities	-	-0.495 (-1.466-0.476)	0.014 (-0.052-0.080)	-	-
Availability refrigeration facilities, 0 Not available, 1 Available	-	-	-0.015 (-0.087-0.058)	-	-
Market distance, 0 long distance >6km, 1 Short distance ≤6km	-	-	-	-	-0.284 (-1.179-0.610)
Market Price, 0 low price, 1 Good/reasonable price	-	0.855 (-0.030-1.740) *	-	-	-
Transport to market using road, 0 Poor road, 1 Good and passable all the time	-	-	-	-	0.649 (-0.458-1.755)
Means of transport to market, 0 Otherwise, 1 By tri/motorcycle/car	-	-	-	-	0.6876 (-0.461-1.856)
Constant	0.523 (0.088-0.957) **	-0.248 (-1.306-0.81)	-0.022 (-0.068-0.023)	1.411 (-.051-2.874) *	_-0.047 (-1.349-1.256)
Number of observations	76	76	76	76	76
Log likelihood	-95.986	-148.490	69.539	-203.927	-153.94284
Chi2	10.25	10.12	70.45	4.1	9.39
P	0.037	0.039	0.000	0.129	0.1529
Random effects					
Farm ID var(_cons)	-	0.816 (0.240-2.769)		-	-
Farm ID var(dependent)	-	2.211 (1.410-3.467)		-	-
Chi2	-	2.86		-	-
P	-	0.0453		-	-

4.0. Conclusion and Recommendation

Reducing milk losses at production level is among the most impactful strategies to meet the optimal food and nutrition security of the growing population globally. The study evaluated determinants of post-harvest milk losses at the milk producers (households and farms), particularly the main forms of milk losses at the milk producers and the determinants that perpetuate milk losses in the area of study. Generally, study findings show that spillage, spoilage and contamination were the main forms of milk losses at each stage of milk handling especially during milking, collection, storage and transport to market. In addition, GLMM results showed that husbandry practices, socio-economic factors, geographical locations, season of production were positively and significantly associated with milk losses. In addition, poor milk handling facilities, storage without cooling facilities, long distance to market, poor road and market price were significantly associated with post-harvest milk losses at the households. Furthermore, poor membership to milk association and lack of education on post-harvest milk losses were significantly associated with post-harvest milk losses. Therefore, the Tanzanian government should improve extension services to impact knowledge to milk producers on milk handling practices including use of proper milk equipment during milking, collection, storage and transport, and better husbandry practices so as to minimize PHML. In addition, the government should come up with workable strategies or actions to minimise post-harvest milk losses by milk producers in order to increase their returns and save Tanzania from relying on milk imports that drain the country's foreign currency.

Limitation of the study and areas for further research

The study results are based on the respondent's self-reported postharvest milk losses occurring at each node of the value chain. Despite the limitation, the researchers carefully designed the questionnaire and the data collection exercise was carried out by well-trained enumerators. Nonetheless, further research is needed to consider a larger sample size and include other regions in Tanzania to provide a more comprehensive picture of postharvest milk losses in the country.

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