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The Extent of Milk Losses in Rain and Dry Seasons along the Milk Supply Chain in Tanzania

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Abstract
The study determined the extent of cattle milk losses at the various nodes of the milk supply chain in Tanzania in two seasons and between regions. A cross-sectional research design was used to collect data in both the dry and wet seasons (June 2021 to September 2022) from milk producers, milk collectors, milk processors, retailers and hotels/restaurants/milk bars. Paired sample t-test results show statistically significant differences in milk losses between dry (7.8%) and wet (12.3%) seasons, p=0.000 at the households; dry (3.5%) and wet (1.6%) seasons, p=0.006 for mtindi/sour milk at the hotels/restaurants; dry (0.5%; 0.4%) and wet (0.02%; 0.05%) for fresh milk (UHT) and yoghurt respectively, $p<0.05$ at the retailers; as well as Wilcoxon signed-rank test show significant differences in milk losses between dry (3%) and wet (6.8%) seasons, p=0.014 at the processors. In addition, a one-way ANOVA shows a statistically significant variations of milk losses across the studied regions (p=0.000) of fresh milk at the households; p=0.018, p=0.005; p=0.000 for fresh milk, mtindi and yoghurt respectively at the retailers. Therefore, awareness creation of the milk supply chain actors is needed on the magnitude of the losses and the likely costs. Enforcement of laws and policies will be helpful to minimise post-harvest milk losses.

Keywords: Milk losses, post-harvest, milk supply chain, wet and dry seasons, Tanzania

1.0 Introduction
Post-harvest food loss emerged a global concern that calls for various initiatives to minimise food losses and ensure food availability to feed the projected global population increase (estimated to reach 9.7 billion people by 2050 from 7.7 billion people in 2019) (UN, 2019). It is also forecasted that, the growing human population will lead to the increase in demand for agricultural products by 35-50% between the year 2012 and 2050 (FAO, 2019). Globally, about 702 and 828 million people are hungry (FAO *et al.*, 2022). In addition, about 2 308.5 million people globally reported to be moderately or severely food insecure, of which 794.7 million people are from Africa particularly East Africa (306.0 million people) (FAO *et al.*, 2022).

Further to the above, about 13.8% of the food produced for human consumption globally is lost from the post-harvest stage before it reaches the retailers (FAO, 2019). Approximately, one-eighth (12%) proportionate of the global food lost is for meat and other animal products milk included (FAO, 2019).

Possibly the food losses contribute in part to global hunger reported in the first paragraph. In Sub Saharan Africa (SSA) milk losses and waste per year is estimated to be 17% during post-harvest handling and 25% during storage (FAO, 2011). In Tanzania, post-harvest milk losses are experienced in the small-scale informal dairy sector whereby, post-harvest milk losses at the farm level per year was quantified at 46.4 million litres (6.5%) (Lore *et al*., 2005). Similarly, post-harvest losses in Tanzania estimated to about 59.5 million litres of milk annually with over 16% and 25% of total dairy production being lost during the dry and wet seasons respectively. Therefore, the need for increasing production, storage, distribution, post-harvest food loss (PHFL) reduction strategies occurs.

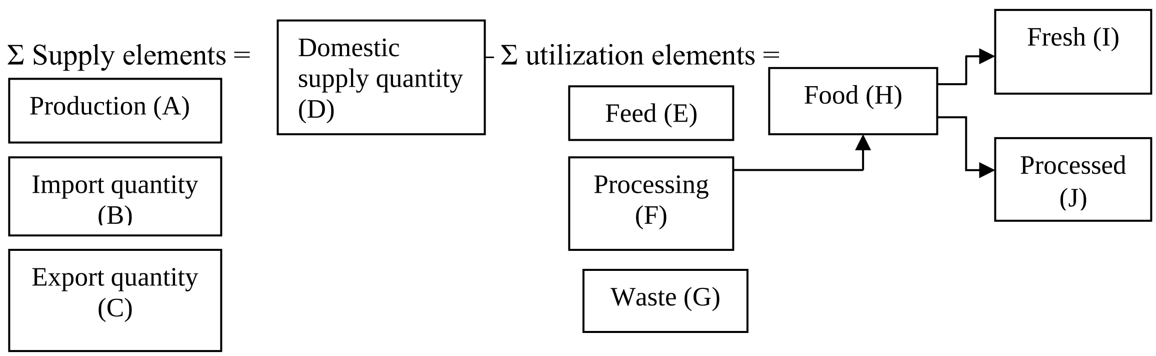
It is evidenced in literature that reducing PHFLs as well as proper handling of what has been produced boosts food availability for local/domestic consumption (Nanda *et al*., 2012; Aulakh *et al*., 2013). Similarly, FAO (2019) justified three gains of reducing food losses such as increased productivity and economic growth, improvement on food security and nutrition, and reduced environmental impacts by lowering pressure on land and water resources (reduced waste disposal and additional production as a substitutes of loss). FAO (2018) referred post-harvest losses as all quantity losses (food and non-food) along the food supply chain for all utilizations (food, feed, seed, other) up to but excluding the retail to consumption level. In addition, in this study milk is referred as the products obtained from the cattle particularly normal cows.

In Tanzania various initiatives have been in place to increase milk production, milk processing for value addition, improving milk shelf life, milk losses reduction (URT, 2017a, 2011, 2010, 2006) and increasing per capita milk consumption (URT, 2022a). Despite the Tanzanian government's efforts milk production slightly increased, approximately from 1.3 billion litres in 2005/06 (TDB, 2021) to 3.97 billion litres in 2023/24 (URT, 2024). In addition, the rate of milk consumption nationally is 67.5 litres per person per year (URT, 2024) which is far below the global recommended average of 200 litres of milk per person per year (FAO, 2011 cited in URT 2018). Furthermore, Tanzania still uses a lot of money to import milk. For example, in 2019/20, Tanzania imported 11.7 million litres of milk (Liquid Milk Equivalent - LME) with value of 6.7 million USD (URT, 2020), in 2021/22 the importation was about 5.2 million litres of milk (LME) from various countries with the total value of 4.8 million USD (URT, 2022b), and in 2023/24 the importation reached 11.7 million litres of milk (LME) with value of 9.0 million USD (URT, 2024). The above may be because of keeping cattle with low genetic potential which cannot produce more milk, poor enforcement of policies, and/or un-prevented milk losses leading to milk supply deficit. Therefore, there need for the current study to determine the extent of Tanzania's post-harvest milk losses at various milk supply chain actors in both dry and wet/rain seasons and among regions occurred. Generally, the study was guided by two hypotheses i.e. H_01 "there is no significant difference in milk losses between the dry and wet/rain seasons", H_02 "there is no significant difference in post-harvest milk losses between the studied regions".

The study aligns to Tanzania's policies and strategies that aim at increasing agricultural productivity and well-being of the farmers/producers. For example, the country's Agricultural Sector Development Programme Two (ASDP II) paragraph 220 among other things aims to reduce post-harvest losses by promoting and disseminating technologies that promote better handling and improved storage and preservation of food and food products including milk (URT, 2016). In addition, Tanzania's National Livestock Research Agenda (NLRA) 2020-2025 generally aims at increasing communities' socio-economic benefits in relation to livestock, livestock products and by products. Furthermore, thematic area 4.1.5 aims at reducing post-harvest losses through increased products' shelf life, quality and biosafety (URT, 2019).The study is also in line with the United Nations Sustainable Development Goal (SDG) 12.3 which aims to halve per capita global food waste at the retail and consumer levels and reduce food losses along the production and supply chains by the year 2030 (UN, 2015). Similarly, the African Union's Malabo Declaration Number III 3 (b) aims to halve crops, livestock and fisheries post-harvest losses by the year 2025 (AU, 2014). 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".

1.1 Model for Mass Flow of Milk Supply Chain

The study was guided by the "Mass Flow of Milk Supply Model" developed by FAO (2011) which shows that, food losses take place at every stage on the food supply chain especially at the farm production, postharvest handling and storage, processing and packaging, distribution and amount taken for consumption. The 'Mass flow milk supply model' (Figure 1) considers: Σ Supply elements (production, importation and exportation) = Domestic supply quantity – Σ utilization elements (feeding to calves, processing and waste) = Food (consumed as fresh or processed). The model regards animal feeds (milk used to feed calves) as food loss. However, according to literature (FAO, 2019, 2018) food used as animal feed should not be regarded as loss due to the fact that in the long run animals return to the food system. Therefore, milk loss in this study was calculated in each step of the food supply chain by considering proportional (in percent) of milk lost particularly at: Milking (households and Farms); at collection (milk collection centres - MCCs and hawkers/vendors); at Processing (processors); and at retailers and hotels/ restaurants/milk bars).



A+B-C=D-(E+F+G) = H = I + J

Figure 1: Mass flow model of milk supply chain

Source: Adapted from FAO (2011)

1.2 Conceptual Framework for the Study

The study's conceptual framework (Figure 2) shows the summarised four stages of the food supply chain. The stages include production, collection, processing, and sales. Though, losses occur at each stage, they are of different forms and magnitude. The stages were modified from the work of Aulakh *et al.* (2013), and the losses from the mentioned stages were accounted at milking, collection, storage and transport key areas because each one was reported and recorded differently. Finally, the quantity handled versus quantity lost was reported in terms of litres or promotional loss (percent).

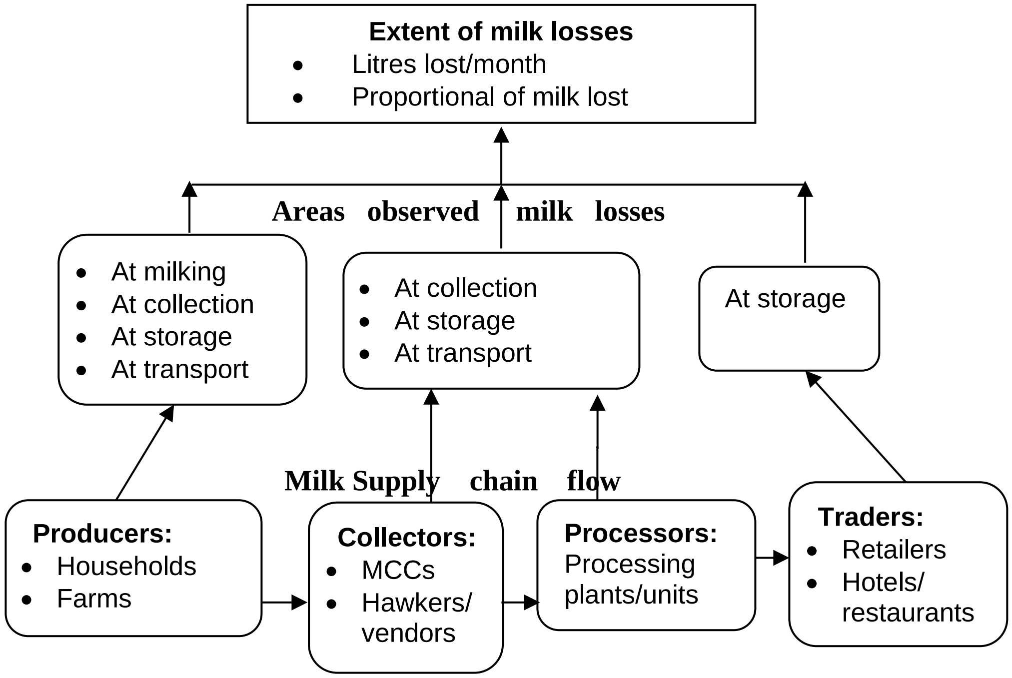


Figure 2: The conceptual framework for estimating post-harvest milk losses
Source: Modified from the work of Aulakh *et al.* (2013)

2.0 Methodology

2.1 Description of the Study Area

The study was conducted in five regions of Tanzania i.e., Dodoma representing the agro-pastoral and semi-arid production systems; Morogoro and Kagera representing the mixed rain-fed sub-humid and humid production systems; and Tanga and Iringa representing the mixed rain-fed highland production systems (Nell *et al*., 2014; URT, 2017b). In addition, about a third or above of the households in the selected regions are engaged in livestock production (64% in Dodoma, 37% in Tanga and Iringa and 30% in Morogoro and Kagera) (URT, 2017b). Further, the above regions were purposively selected based on the number of household keeping cattle (NBS, 2017); presence of cattle farms, milk collection centres (MCCs) and milk processing plants (TDB, 2021; URT, 2021) whereby regions that exceled in at least two or more of the criterion was sampled.

2.2 Research Design

A cross-sectional research design was used to collect data in both the dry and wet seasons (June 2021 to September 2022). 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). The study population involved milk producers (households and farms keeping cattle), milk collectors (collection centres and hawkers/vendors), milk processors, retailers and hotels/restaurants/ milk bars in the study areas.

2.3 Sampling Procedure and Sample Size

The study used a multistage sampling technique to select the above-mentioned regions were considered as strata, therefore, the regions (stratum), districts, wards, villages and households keeping cattle were taken as the first, second, third, fourth and fifth sampling stages respectively. Further to the above, simple random sampling was used to select the respondents (household head or their representatives from households keeping cattle).

The sample size was determined using Cochran (1977) formula. It is estimated that 7.8 million Tanzanian households (65.3%) were involved in agricultural activities of which, 65% were involved in crop farming, 33% were involved in both crops and livestock keeping and 2% were involved in livestock keeping only (NBS, 2021). Similarly, Tanzania Livestock Sector Analysis 2016/17 – 2031/32 shows that, out of 4.6 million households owning livestock, about 35% households keep cattle (URT, 2017b). Therefore, using Equation 1, given by Cochran (1977), the study's sample was 388 respondents (household heads or their representatives) as shown below:

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

Where: n = sample size; Zα/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%, 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 interview 370 household heads or their representatives because, 18 respondents (3.6% non-response rate) missed the criteria to be interviewed in the second round/season, therefore were dropped in the process. In addition, 10% of MCCs, dairy farms, milk processors, hawkers/vendors, retailers, and hotels/restaurants/milk bars obtained from TDB and MLF reports and the regions or districts list were purposefully recruited for the study.

2.4 Data Collection

Quantitative data for the post-harvest milk losses and average milk production/handling were collected using seven different questionnaires: the Households keeping cattle Questionnaire, the Large and Medium dairy farms Questionnaire, the Hawkers/Vendors Questionnaire, the Milk Collection Centres Questionnaire, Milk Processors Questionnaire, the Retailers Questionnaire and the Hotels/ Restaurants/Milk Bars Questionnaire. The reason for using different questionnaires was the differences in model of operation and the nature of data to be gathered at the particular milk supply chain actors. Then, the questions of each questionnaire were uploaded in a computer/mobile app (KoBoKollect) for easier and efficiency data collection. A total of 370 household heads or their representatives, 38 livestock farms managers, 35 in-charge of MCCs, 52 hawkers/vendors, 23 managers or in-charge of the processing units/plants, 51 retailers and 62 supervisors of hotels/ restaurants/milk bars interviewed.

In addition, key informant interviews (KIIs) were conducted to collect qualitative data. KIs included 5 Regional and 10 District Livestock and Fisheries Officers (RLFOs, DLFOs), Dairy Production Officer from TDB, Tanzania Livestock Research Institute (TALIRI), Dairy Nourish Africa's (DNA) Project Coordinator, Country representative of African Dairy Genetic Gains (ADGG) – Tanzania, and Tanga Dairy Cooperative Union (TDCU) Secretary. The discussions with KIs mainly based on the identifying the location of milk supply chain actors, scale of milk production, losses and the causes, markets and marketing situation and strategies to be undertaken to reduce milk losses in their areas.

2.5 Data Analysis

The Statistical Package for Social Sciences (SPSS) software (version 26) was used to check the data collected for accuracy where anomalies found were corrected accordingly. Data was analysed by running the paired sample t-test several times to measure proportion of mean difference of milk lost between the dry and rain/wet seasons in all the supply chain actors nodes except for the processors where the Wilcoxon signed-rank test (non-parametric) was run because the sample size was small (less than 30 respondents), therefore not meeting the criteria of being normally distributed for parametric tests. In addition, one-way analysis of variance (ANOVA) was used to test the variation of milk losses across the five regions in all the milk supply chain actors nodes except for the processors where Kruskal-Wallis test was used because the sample size was small (less than 30) therefore non-parametric test was opted. The differences between variables were considered statistically significant if the p-value was ≤ 0.05. Qualitative data collected from the KIs was analysed using content analysis.

3.0 Results and Discussions

3.1 Respondents Demographic and Socio-Economic Characteristics

The results in Table 1 show that over four-fifths (83%) of the households were headed by males while 17% were headed by females. The average household size in the area of study was 4.1, slightly below to what recorded during the 2022 Population and Housing Census for the United Republic of Tanzania which was 4.3 (URT, 2022c). Household size is an important indicator of the households economic status and individual wellbeing (URT, 2022b), which may also have implications on post-harvest milk losses at the household level. Also, sex of respondents (household heads) had implication 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 & Teklehaymanot (2016) revealed that, milking practices is mostly practised by men while milk handling, processing and marketing primarily practised by women (wives). Therefore, understanding household characteristics particularly households head's sex is an important factor when looking for post-harvest milk losses. In addition, the majority (65.1%) of household heads were in age group of 36-60. Thus, suggesting the majority of the heads were in the economic active age group (URT, 2015) hence, able to participate in milk production, also age determines the competence and efficiency of milk handling operations, hence reduce or accelerate post-harvest losses (FAO, 2019). Table 1 further shows the majority (91.4%) of household heads 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 Thus, suggesting the economic status of the household has an implication on the access of milking handling facilities for milk operations (during milking, collection, storage and transport). Therefore, strategies for minimising post-harvest 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, demographic characteristics of a household such as 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 Socio-economic characteristics of the household head (n = 370)

Variable	Category	Total n(%)	Dodoma, n(%)	Iringa, n (%)	Kagera, n (%)	Morogoro , n (%)	Tanga, n (%)
Sex	Male	307(83)	61(82.4)	60(81.1)	64(86.5)	64(86.5)	58(78.4)
	Female	63(17)	13(17.6)	14(18.8)	10(13.5)	10(13.5)	16(21.6)
Age	25-35	28(7.6)	9(12.2)	2(2.7)	0(0)	7(9.5)	10(13.5)
	36-60	241(65.1)	39(52.7)	48(64.9)	51(68.9)	44(59.5)	59(79.7)
	>60	101(27.3)	26(35.1)	24(32.4)	23(31.1)	23(31.1)	5(6.8)
Education level	None	32(8.6)	12(16.2)	4(5.4)	2(2.7)	13(17.6)	1(1.4)
	Primary education	163(44.1)	38(51.4)	48(64.9)	41(55.4)	23(31.1)	13(17.6)
	Secondary	77(20.8)	12(16.2)	10(13.5)	10(13.5)	20(27)	25(33.8)
	Tertiary (Certificate Diploma)	62(16.8)	7(9.5)	3(4.1)	15(20.3)	8(10.8)	29(39.2)
	University	36(9.7)	5(6.8)	9(12.2)	6(8.1)	10(13.5)	6(8.1)
Marital status	Single	7(1.9)	5(6.8)	0(0)	0(0)	2(2.7)	0(0)
	Married	299(80.8)	59(79.7)	63(85.1)	65(87.8)	65(87.8)	47(63.5)
	Divorced	11(3)	0(0)	0(0)	1(1.4)	0(0)	10(13.5)
	Separated	13(3.5)	3(4.1)	2(2.7)	1(1.4)	0(0)	0(0)
	Cohabitating	1(0.3)	0(0)	1(0.4)	0(0)	0(0)	0(0)
	Widow/er	39(10.5)	7(9.50	8(10.8)	7(9.5)	7(9.5)	10(13.5)
Main occupation	Livestock production	220(59.5)	53(71.6)	48(64.9)	50(67.6)	46(62.2)	23(31.1)
	Crop production	61(16.5)	14(18.9)	18(24.3)	14(18.9)	15(20.3)	0(0)

Government employees	37(10)	4(5.4)	1(1.4)	5(6.8)	4(5.4)	23(31.1)
Private employees	21(5.7)	1(1.4)	1(1.4)	0(0)	6(8.1)	13(17.6)
Self-employees & Casual labour (on and off farm)	31(8.4)	2(2.7)	6(8.2)	5(6.8)	3(4.1)	15(20.3)

NB: Figures outside the bracket are frequency and in brackets are percent

Age: Median 52; Mean 53; Standard Deviation 11.92

Household size: Median 4; Mean 4.1; Standard Deviation 1.81

3.2 Extent of milk losses at the various nodes of the milk supply chain

The study findings (Table 2) show that, total fresh milk handled in supply chains (households, farms, MCCs, hawkers/vendors and processors) was high during the rainy season compared the dry season. High milk production during wet season is due to the availability of quality feed resources and adequate water supply while in dry season feeds especially pastures are of a poor quality and water is scarce making watering of cattle a challenge. In addition, the total milk losses by volume were also high in the rainy season compared to the dry season. The reported reasons by farmers were high milk supply during the rain/wet season to outflow the normal market available and the possibility of the whole milk produced to reach the processors is limited. In addition, handling and storage facilities are inadequate as well as difficulties some farmers face on transporting their milk from remote areas to the market during rainy season. The results suggest post-harvest milk losses vary by season and therefore, more needs to be done during the rainy season when there is a high production of milk compared to the dry season. The above results conform to what has been reported by Zegeye & Teklehaymanot (2016) that, shortage of animal feed resources (particularly in the dry season) cause low milk production. According to NBS (2003) as cited by Kurwijila *et al.* (2012) milk production during the dry season can be as low as 56% of that of the rainy/wet season due to variations in availability of feed/pastures. In addition, the results conform to Häsler *et al.* (2019) who revealed the existence of high milk outlets during rainy season and gradual decrease during the dry season. The result is supported by views of the KI who said:-

> *"Milk losses are more during the rainy season because milk production is high in the whole region to the extent of overflowing the market. During the dry season it is difficult to feel the situation but, during the rainy season livestock keepers especially in remote areas particularly where MCCs is hardly available face challenges of marketing their milk hence, milk losses" (RLFO Morogoro. 18/06/2021).*

Table 2: Amount of fresh milk handled and lost (litres) per supply chain per month

Category	Households, n=370		Farms, n=38		MCCs, n=35		Vendors/ hawkers, n=52		Processors, n=23	
	Litres handled	Litres lost	Litres handled	Litres lost	Litres handled	Litres lost	Litres handled	Litres lost	Litres handled	Litres lost
Dry season	159,450	6,814	156,544	5,481	664,910	11,317	73,935	3,045	470,433	28,987
Rain season	238,212	16,683	210,938	10,651	1,078,910	24,913	94,730	4,330	652,941	86,242
At milking - Dry season	159,450	2,752	156,544	2,263	NA	NA	NA	NA	NA	NA
At milking - Rain season	238,212	8,174	210,938	2,934	NA	NA	NA	NA	NA	NA
At collection - Dry season	109,807	1,210	153,092	1,527	664,910	6,497	73,935	810	470,433	17,326
At collection - Rain season	232,524	2,835	172,792	3,505	1,078,910	13,956	94,730	1,553	652,941	22,448
At storage - Dry season	34,183.25	1,925	36,840	510	525,709	2,222	24,749	1,026	446,649	7,194
At storage - Rain season	76,403	2,979	48,002	1,614	863,359	8,486	18,221	1,137	617,589	11,469

At transport - Dry season	89,829	927	109,304	1,181	531,041	2,598	46,358	1,209	429,424	4,467
At transport - Rain season	213,367	2,695	122,928	2,598	902,478	2,471	33,259	1,640	59,9617	52,325

Source: Field data (2023)

Further to the above, the study results (Table 3) shows that, total fresh milk, *mtindi* (locally fermented/sour milk) and yoghurt lost in two supply chains (retailers and hotels/restaurants/milk bars) varies between rain and dry seasons.

Table 3: Amount of fresh milk and other milk products handled and lost (litres) per supply chain per month

Category	Hotel/restaurants (n=62)		Retails (n=51)	
	Litres handled	**Litres lost**	**Litres handled**	**Litres lost**
Fresh milk - Dry season	20 715	1 050	73 012.4	178.4
Fresh milk - Rain season	39 165	1 502.3	95 324	222
Mtindi - Dry season	7 920	765	40 075	151.6
Mtindi - Rain season	8 430	375	60 979	188.5
Yoghurt - Dry season	1 950	390	7 492	15
Yoghurt - Rain season	3 750	525	7 772	36.4

3.3 Determination of extent of milk losses in the dry and wet seasons using paired sample t-test

On determination of the extent of post-harvest milk losses, a paired sample t-test was run to measure the proportional of mean difference of milk losses. The results in Table 4 show a significant ($p \leq 0.01$) difference of fresh milk losses at the household level between the dry season (7.8%) and rainy season (12.3%) particularly, at milking the loss is 3.2% and 6.8% during the dry rainy seasons respectively; and at the transport to market level the loss is 1.6% and 2.5% in the dry and rainy seasons respectively and this was statistically significant at $p \leq 0.05$ level. In addition, the results in Table 4 show a significant ($p \leq 0.01$) difference of milk product losses (mtindi) at the Hotels/restaurants/milk bars at the rate of 3.5% and 1.6% during the dry season and rainy season respectively. Furthermore, the study shows a significant ($p \leq 0.05$) difference of milk product losses at the retailers level whereby the rate of fresh milk (Ultra-Heat Treatment - UHT) losses were higher during the dry season compared to the rainy season ($p \leq 0.05$), for yoghurt the rate of losses were higher in the rainy season and low in the dry season however, the difference was not statistically significant between the seasons. The results in Table 4 suggest that, households, hotels/restaurants/ milk bars and retailers' milk supply chain experiences significant difference on milk losses between seasons (dry and wet/rain). However, for farms, MCCs and milk vendors/hawkers there were no significant difference of losses between the seasons. The above results conform to what was reported by Lore *et al.* (2005) that, milk losses are substantially high at the small-scale production (household) level. Similarly, a study by FAO (2004) as cited in ACF (2014) reported that, out of 59.5 million litres of milk lost per year in Tanzania, above 16% is during the dry season while 25% is during the rain/wet season. In addition, the study results conform to Amentae *et al.* (2015) who reported to have milk losses at the farmers, cooperatives (MCCs), retailers and processors. The result is supported by views of one KI who said: -

> *"Milk losses severally occur in wet season because milk supply is high, automatically the price goes down to the extent of discouraging some of milk supply chain actors which makes some of the actors to be reluctant to sell their products at low price hence, milk spoilage or forced consumption, others feed to animals or offered to neighbours for free. Though, this goes hand by hand with lack of knowledge and skills of some actors on milk handling, markets and marketing" (DLFO Mufindi DC - Iringa.* 25/03/2022).

Table 4: Paired Samples t-test results of post-harvest milk losses per supply chain

Actors	Groups compared	n	Mean milk losses (%)	t-value	df	Sig. (2-tailed)
Household	Dry season	370	7.788	-6.235	369	**0.000*** **
	Rain season	370	12.331			
	At milking - Dry season	370	3.151	-9.214	369	**0.000*** **
	At milking - Rain season	370	6.776			
	At collection - Dry season	285	3.324	-0.369	284	0.713
	At collection - Rain season	285	3.551			
	At storage - Dry season	169	7.460	1.645	168	0.102
	At storage - Rain season	169	5.143			
	At transport - Dry season	273	1.567	-2.18	272	**0.03** **
	At transport - Rain season	273	2.530			
Farms	Dry season	38	6.680	-1.766	37	**0.086* **
	Rain season	38	9.462			
	At milking - Dry season	38	2.070	-0.9	37	0.378
	At milking - Rain season	38	2.689			
	At collection - Dry season	38	1.881	-1.486	37	0.146
	At collection - Rain season	38	2.968			
	At storage - Dry season	38	1.030	0.171	37	0.865
	At storage - Rain season	38	0.960			
	At transport - Dry season	38	1.700	-1.133	37	0.265
	At transport - Rain season	38	2.845			
MCC	Dry season	35	2.627	-1.581	34	0.123
	Rain season	35	6.757			
	At collection - Dry season	35	1.640	-1.336	34	0.191
	At collection - Rain season	35	3.936			
	At storage - Dry season	35	0.511	-1.229	34	0.227
	At storage - Rain season	35	2.201			
	At transport - Dry season	35	0.477	-0.438	34	0.664
	At transport - Rain season	35	0.620			
vendors/hawkers	Dry season	52	5.785	-1.077	51	0.286
	Rain season	52	8.079			
	At collection - Dry season	52	1.986	-0.522	51	0.604
	At collection - Rain season	52	2.403			
	At storage - Dry season	52	1.748	-0.652	51	0.517
	At storage - Rain season	52	2.285			
	At transport - Dry season	52	2.050	-1.251	51	0.217
	At transport - Rain season	52	3.391			
Hotels/restaurants/milk bars	Dry season - fresh milk	62	4.448	0.164	61	0.871
	Rain season - fresh milk	62	4.279			
	Dry season – mtindi	62	3.466	2.865	61	**0.006*** **
	Rain season – mtindi	62	1.592			
	Dry season – yoghurt	62	0.599	0.534	61	0.595
	Rain season – yoghurt	62	0.419			
Retailers	Dry season - fresh milk (UHT)	51	0.463	2.48	50	**0.017** **
	Rain season - fresh milk (UHT)	51	0.434			
	Dry season – mtindi	51	0.556	-1.91	50	**0.062* **
	Rain season – mtindi	51	0.605			
	Dry season – yoghurt	51	0.021	-2.052	50	**0.045** **
	Rain season – yoghurt	51	0.049			

*****, **, * are significance levels at 1%, 5%, and 10% respectively**

Further to the above, a study by Melesse *et al.* (2014) in Ethiopia found that, milk price is high during the high demand (in dry season when milk production is low) and price is low during the rain season when milk production is high, therefore post-harvest losses is prominent and forced milk consumption is obvious when production is high and price is low because milk actors fails to market all their produce. Based on the study results, the first hypothesis which stated that "there is no significant difference of milk losses between the dry and rain seasons" is rejected.

Furthermore, Wilcoxon signed-rank test was run to measure the extent of milk losses at the Processors. The results in Table 5 show a significant difference in milk losses at the processors between the dry and rainy seasons. The extent of milk losses (fresh milk) is 3% dry season and 6.8% rain season ($p<0.05$). The study by Lore *et al.* (2005) reported 1.5% milk spoilage at the processors due to electric failure in Tanzania. Similarly, Lore *et al.* (2005) and Minten *et al.* (2021) reported 2% milk losses at the processors in Ethiopia.

Table 5: Wilcoxon signed-rank test results of post-harvest milk losses per supply chain

	Groups compared	n	Mean milk losses (%)	T-statistic	z-value	Sig. (2-tailed)
Processors	Dry season	23	2.981	186	2.451	**0.014****
	Rain season	23	6.761			
	At collection - Dry season	23	1.686	120	2.06	**0.039****
	At collection - Rain season	23	3.129			
	At storage - Dry season	23	0.881	81	0.672	0.501
	At storage - Rain season	23	2.335			
	At transport - Dry season	23	0.414	44	0.392	0.695
	At transport - Rain season	23	1.297			

*****, **, * are significance levels at 1%, 5%, and 10% respectively**

3.4 Determination of extent of milk losses by regions

The extent of milk losses was also measured by one-way analysis of variance (ANOVA) to determine the variation of milk losses across the studied regions i.e., Dodoma, Iringa, Kagera, Morogoro and Tanga. Therefore, the F-Test was used to determine differences between the regions based on the proportional of post-harvest-milk losses along the milk supply chain. The F-test results (Table 6) show a significant difference ($p \leq 0.001$) in relation to household's fresh milk losses. The average post-harvest milk losses at the household level was 10.1%, whereby regions in descending order the losses are 20.7%, 13.5%, 6.7%, 5.6% and 3.8% for Dodoma, Morogoro, Iringa, Kagera and Tanga respectively. Mostly, respondents reported the loss to be caused by marketing challenges i.e., they have to travel long distances to market their products, also the absence or lack of nearby milk collection centre and/or milk processing plants to assure their collection and value addition through processing. Again, farmers reported that milk handling in most households was not properly done because some of them lack skills on milk handling procedures as a result milk losses occurs in most households. The above challenges were supported by DLFOs in Kondoa, Kyerwa, Mufindi, Mvomero DCs and Bukoba MC who reported that education of the milk supply chain actors, enabling environments including infrastructures; milk handling facilities and market stability have justifiable effects on milk losses in their areas. According to Zegeye & Teklehaymanot (2016) milk handling facilities, storage, marketing and training of the milk supply chain actors have implications on post-harvest milk losses. In addition, Table 6 shows significant difference at the retail level between milk losses of fresh milk (UHT) ($p<0.05$), mtindi and yoghurt ($p<0.01$) and regions. The total milk losses at retails are 0.45% for fresh milk (UHT), 0.59% for mtindi and 0.04% for yoghurt. For the case of MCCs though not statistically significant at the $p \leq 0.05$ level ($p=0.067$) but out of the 4.4% recorded total losses at MCCs, in Iringa was 19.1% followed by Morogoro (5%), Tanga (1%), and Kagera (0.4%). For example, Figure 3 represents some of the cases of milk spoilage observed during enquiry at Asari Farm milk collection point in Iringa Region which lead to a loss of thousand litres of milk due to inadequate supply of electricity. The only source of electricity at Asari Farm was generator (Appendix I) which seems to be expensive because of high fuel consumption. Therefore, failure to get alternative source of energy at the farm, existence in milk business is questionable as asserted one of the Farm owner:

> *During the wet season, milk is abundant, leading to very low market prices that don't cover production costs. Sometimes, I feel compelled to either spill the milk or feed it to the calves because the market prices are so discouraging. Additionally, cooling the milk is expensive since I rely on a fuel-powered generator. Despite my efforts to obtain alternative energy from Tanzania Electric Supply Company Limited (TANESCO), the process is complex and has been unsuccessful. Given these challenges, I am uncertain about the future of my business (*Farm owner, Mufindi DC - Iringa. 25/03/2022).

Generally, the results conform to what was reported by (FAO, 2011) that, in SSA post-harvest loss is about 17%. Further, the above results conform to what Melesse *et al.* (2014) reported that, in Ethiopia post-harvest milk losses vary between different geographical locations. The losses is high in areas with poor milk handling infrastructures for collection and storage, lack of market, inadequate processing and poor transport to market (Zegeye and Teklehaymanot, 2016). Based on the study results the second hypothesis which stated that "there is no significant difference of milk losses between regions" is rejected.

Figure 3: About a thousand litres of milk spoiled due to inadequate electricity supply at Asari Farm collection point on 25.03.2022 in Itandula Ward, Mufindi DC, Iringa - Tanzania.

Table 6: Variation of Milk Losses by regions

	Regions	n	Mean milk losses (%)	Sum of squares between and within groups		df	Mean Square	F	Sig.
Households - Fresh milk	Dodoma	74	20.706	Between Groups	14517.429	4	3629.357	16.967	**0.000*** **
	Iringa	74	6.731	Within Groups	78075.290	365	213.905		
	Kagera	74	5.596						
	Morogoro	74	13.533						
	Tanga	74	3.753						
	Total	**370**	10.064	**Total**	**92592.719**	**369**			
Farms - Fresh milk	Dodoma	3	13.657	Between Groups	176.835	4	44.209	1.371	0.265
	Iringa	5	4.425	Within Groups	1063.919	33	32.240		
	Kagera	7	6.768						
	Morogoro	17	8.543						
	Tanga	6	8.498						
	Total	**38**	**8.071**	**Total**	**1240.754**	**37**			
MCCs	Iringa	4	19.067	Between Groups	1100.472	3	366.824	2.631	**0.067***
	Kagera	3	0.430	Within Groups	4321.469	31	139.402		
	Morogoro	12	5.005						
	Tanga	16	0.969						
	Total	**35**	**4.375**	**Total**	**5421.941**	**34**			
Hawkers/vendors - Fresh	Dodoma	10	3.925	Between Groups	801.238	4	200.309	1.917	0.123
	Iringa	6	5.053	Within Groups	4911.536	47	104.501		
	Kagera	8	3.513						
	Morogoro	13	13.605						
	Tanga	15	5.861						
	Total	**52**	**6.970**	**Total**	**5712.774**	**51**			
Hotels - Fresh milk	Dodoma	18	4.745	Between Groups	59.847	4	14.962	0.718	0.583
	Iringa	6	3.361	Within Groups	1187.033	57	20.825		
	Kagera	9	4.119						
	Morogoro	12	5.836						
	Tanga	17	3.152						
	Total	**62**	**4.294**	**Total**	**1246.881**	**61**			
Hotels – mtindi	Dodoma	18	1.458	Between Groups	82.986	4	20.746	0.406	0.803
	Iringa	6	0.000	Within Groups	2912.101	57	51.089		
	Kagera	9	2.838						
	Morogoro	12	3.542						
	Tanga	17	3.345						
	Total	**62**	**2.438**	**Total**	**2995.087**	**61**			
Hotels – Yoghurt	Dodoma	18	0.000	Between Groups	23.268	4	5.817	0.583	0.676
	Iringa	6	0.000	Within Groups	568.455	57	9.973		
	Kagera	9	0.556						
	Morogoro	12	0.000						
	Tanga	17	1.417						
	Total	62	0.469	Total	591.722	61			
Retailers - Fresh milk	Dodoma	10	0.435	Between Groups	8.690	4	2.173	3.341	**0.018** **
	Iringa	11	1.202	Within Groups	29.912	46	0.650		
	Kagera	7	0.207						
	Morogoro	12	0.234						
	Tanga	11	0.081						
	Total	**51**	**0.445**	**Total**	**38.603**	**50**			
Retailers – Mtindi	Dodoma	10	1.518	Between Groups	11.831	4	2.958	4.210	**0.005*** **
	Iringa	11	0.135	Within Groups	32.318	46	0.703		
	Kagera	7	0.459						
	Morogoro	12	0.553						
	Tanga	11	0.320						
	Total	**51**	**0.589**	**Total**	**44.150**	**50**			
Retailers – Yoghurt	Dodoma	10	0.000	Between Groups	0.233	4	0.058	6.823	**0.000*** **
	Iringa	11	0.000	Within Groups	0.393	46	0.009		
	Kagera	7	0.000						
	Morogoro	12	0.000						
	Tanga	11	0.164						
	Total	**51**	**0.035**	**Total**	**0.626**	**50**			

*****, **, * are significance levels at 1%, 5%, and 10% respectively**

Further to the above, Kruskal-Wallis test was run to determine differences in the extent of milk losses between regions at the processors level. The results show that total milk lost did not differ significantly across the studied five regions of Dodoma, Iringa, Kagera, Morogoro and Tanga [H (4) = 7.427, p = 0.115]. In addition, multiple comparisons across regions were not performed at the processors level because, the significance was greater than the critical value of $p \leq 0.05$. Even though no significance differences of losses between regions at the processors but by volume still the loss is substantial which needs something to be done particularly in areas with high loss.

Generally, based on the statistical significances observed at some of the milk supply chain nodes e.g. at the households level (F = 16.967, p = 0.000), and at the Retails (F = 3.341, p = 0.018) for fresh milk, (F = 4.210, p = 0.005) for mtindi (locally fermented/sour milk) and (F = 6.823, p = 0.000) for yoghurt, the null hypothesis which stated that "post-harvest milk loss does not significantly differ between regions" was rejected.

4.0 Conclusions and Recommendations

The study aimed to determine the extent of Tanzania's post-harvest milk losses at various milk supply chain actors in both dry and wet/rain seasons and among regions. Based on the study results it can be concluded that post-harvest milk losses vary between the rainy/wet and dry seasons as well as among the studied regions. Generally, the losses are higher during the rainy season compared to losses recorded in dry season. The variation of losses between seasons is significant at the households, processors, hotels/restaurants/milk bars and at retails while at the farms and vendors/hawkers' supply chain nodes, milk lost didn't differ significantly. In addition, at regions, the loss was significant at the households and retailers levels where, at the household level, milk losses were very high in Dodoma Region and low in Tanga Region while at the MCCs the losses were very high in Iringa and low in Kagera. Therefore, it is recommended that the Tanzanian government, through the Ministry of Livestock and Fisheries, should create awareness to the milk supply chain actors on the magnitude of the losses and the possible consequences. In addition, the government of Tanzania enforce implementation of policies and strategies or should come up with actions to minimise post-harvest milk losses along the whole milk supply chain. By doing so, productivity and economic growth per supply chain actors will increase; food security and nutrition per household and community level at large will improve; and pressure on production resources per supply chain actors will be lowered.

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