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Food Loss and Waste across the Pineapple Value Chain in Tanzania: Insights on Losses and Drivers

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***Abstract*—Food loss and waste remain a challenge along agricultural value chains, and developing countries like Tanzania face high upstream losses. This study examines food loss and waste within Tanzania's pineapple value chain, highlighting the physical and monetary losses incurred by various actors and identifying the underlying drivers. Using mixed methods, data were collected from 363 actors through surveys and interviews. Results revealed prominent physical losses, with the production stage contributing 16.27%, indicating that any measurement to reduce food loss and waste should mainly have a producer view point. The wholesaling and retailing stages observed low losses of 4.80% and 3.38%, respectively, while losses declined considerably (0.12%) at the processing stage. High monetary losses (Tsh 198.46 million) are experienced by farmers, highlighting a critical revenue gap. Regression analysis revealed that older and more experienced farmers face higher losses, while farmers with larger farms and those who attended secondary school reported lower losses. Key drivers of food loss and waste along the value chain were mainly limited market access and weather-related factors for farmers. Wholesalers and retailers associated losses with poor road and storage infrastructure, limited market access, and poor handling practices. Limited processing technologies and constrained market access were the predominant loss factors among processors. Despite lower losses reported by wholesalers and retailers, inefficiencies in logistics and quality deterioration remain. This study suggests improving market linkages, investment in road and storage infrastructure, improving postharvest practices and investing in processing technologies to reduce losses and increase economic gains among actors along the pineapple value chain.**

***Keywords*—Food loss and waste, Pineapples, Loss factors, Physical and monetary losses, Tanzania, Value chain**

I. INTRODUCTION

Globally, food loss and waste (FLW) have emerged as a major challenge because of their implications for food security, economy, and environmental sustainability [1]. FLW reduces food availability at both local and global levels, income among value chain actors, while also contributing to increased food prices [2], which together reduce overall efficiency and limit efforts towards sustainable agricultural development. Furthermore, wasted food contributes to greenhouse gas (GHG) emissions, with about 6% attributed to fruits and vegetables [3]. When food meant to be consumed is lost or wasted, it also implies wasted inputs such as land, water, energy, and fertilizer, used in food production, processing, or transportation [4]. Differences exist between developed and developing countries' FLW. In developing countries, FLW is said to be more in the upstream stages of the value chain, unlike in highly industrialized countries, where significant food waste is observed at the downstream stage of the value chain. However, Food loss assessment in developing countries is constrained by limited information on the causes, magnitude, and hotspots [5], [6]. To reduce food loss and waste, the extent of food loss and waste must be known to develop informed policies and strategies [7], [8].

Quantification and reduction of FLW have been extensively addressed, often in developed countries such as Europe and America [7], [9]. Although food is wasted across the value chain, existing studies usually emphasize the factors contributing to FLW in various agricultural value chains, focusing on specific value chain nodes such as harvesting, storage, transportation, processing, marketing, or providing overall crop loss estimates, hindering comprehensive quantification [6], [9], [10], [11]. While the focus on FLW has been increasing in the last decade, food is still being lost and wasted along the supply chain [12], and its magnitude has not been well investigated and quantified [7], [13], [14].

The Tanzanian fruits and vegetable sector offers several opportunities, employing more than 450,000 people, of which 70% are women. Despite the improvement in the industry, FLW is evident in Tanzania's horticulture sector, notably pronounced in the domestic market chain, with approximately 40% losses compared to 10% in the export market chains [15]. Pineapples in Tanzania are widely and predominantly produced by small-scale farmers in terms of area planted and harvested [16]. According to [17] harvested pineapple area was 11,631 hectares with a production of 114,263 tons in

2021. Ranked at 18th position globally and 4th position in Africa in terms of pineapple production, with 372,178.9 tons of the 28,647,865.69 metric tons produced globally in 2021 (FAOSTAT, 2023), Tanzania has observed an increase in pineapple production, which offers local, national, and export markets to the farmers. This increase has been due to growing demand in local and international markets [16].

Despite the importance of pineapples to the economy and the livelihoods of smallholder farmers, there is limited empirical data on the extent and nature of pineapple losses. Without such insights, interventions remain fragmented, resulting in missed opportunities for improvement [18]. The study by [19] establishes that pineapple losses in the Philippines can significantly reach 30-40% of total pineapple production. Such losses make loss reduction economically, environmentally, and socially crucial [20]. Quantifying losses is indispensable for planning and implementing effective interventions in a country like Tanzania, where inadequate postharvest technologies and market infrastructure is challenging. Therefore, the general objective of this study was to quantify FLW along the pineapple value chain in Tanzania and pinpoint critical loss points. Specifically, the study had two objectives:

1) To quantify physical and monetary losses along the pineapple value chain in Tanzania
2) To identify the key factors contributing to pineapple loss and waste in Tanzania.

A. State and trends in FLW

FLW occurs at all stages of the food value chain, from initial production to final consumption. However, in Africa, fruit and vegetable losses are most pronounced during the processing and distribution stages [18]. Among different food groups, losses are high in roots, tubers, and oil-producing crops, with fruits and vegetables ranking next (Fig. 1). The considerable losses in fruits and vegetables are expected due to their high perishability [19]. Globally, losses during production account for 24-30% of total FLW, while approximately 20% is observed during post-harvest handling and storage. The consumption stage is responsible for 30-35% of global food loss and waste [20]. According to [18], approximately 45% of all roots and tubers, as well as fruits and vegetables produced globally, 35% of fish and seafood, 30% of cereals, and 20% of meat, oil crops, pulses, and dairy products (including milk and eggs), respectively, are lost or wasted. [21], assert that food loss and waste at a global scale is estimated to be between 194 and 389 kilograms per person annually.

Literature highlights that the extent of FLW varies significantly by food type and by the metric used, whether calories or weight [19]. Fig. 2 represents regional food loss percentages based on various metrics. When measured by caloric content, cereals contribute the most to global FLW at 53%, followed by roots and tubers, which account for 14%, and fruits and vegetables at 13%. While meat contributes about 7% of total caloric losses, its environmental footprint is relatively high [22]. In contrast, fruits and vegetables account for 45% by weight, making them the largest share of food waste, followed by root tubers (20%). Globally, it is estimated that 20-22% of cereals, 39-44% of fruits and vegetables, 33% of root and tubers, and 24% of seafood are lost or wasted [20]. Highlighting the vulnerability of perishable food groups.

Reducing FLW has significant potential to improve food security, promote sustainable food systems, and lower economic costs along the value chain [23]. According to [9], quantifying FLW is the first important step for implementing actions and policy changes to reduce losses, and hence, necessitates a pressing need to understand where FLWs occur, their causes, and to what extent. Studies emphasize factors such as inappropriate harvesting techniques, poor quality of produce, poor handling, adverse weather and climatic conditions, infrastructure and marketing challenges, inadequate access to roads, and limited storage as the possible causes of FLW [24], [25], [26], [27], [28]. However, FLW causes are context-specific, varying from one country or region to another, and depend on the environment in which actors in the value chain operate [7], [19].

There is no consensus on how to define food loss and waste [29], [30], so differences in definitions influence the methods used to estimate and interpret food loss and waste [31], [12], [32]. This study adopts the definition by the Food and Agriculture Organisation (FAO) [19] and measures losses in the pineapple value chain as the total losses at the farm, transportation, wholesale, and retail stages, which are connected to various factors. Accordingly, to address the study objectives, the study focused on the following research questions: (i) How much pineapple (measured by volume and value), is lost or wasted at different stages of the pineapple value chain? (ii) What factors contribute to FLW along the pineapple value chain?

II. Materials And Methods

A. Study area

This study was conducted in Dar es salaam, Geita, Morogoro, and Pwani regions of Tanzania. The selection of these regions reflected their prominence in pineapple production, the prevalence of smallholder farmers, and the presence of markets.

B. Sampling

Pineapple value chain actors (pineapple producers, wholesalers, processors, and retailers) formed the targeted population. The study employed multistage sampling to select pineapple farmers. In the first stage, pineapple producing regions were identified and selected purposively. In the second stage, districts within the regions were selected based on pineapple production intensity. In the third stage, 333 farmers from the three districts (Chalinze, Geita, and Morogoro rural) were randomly selected based on probability proportional to size sampling (Table I), using Cochran's sample size determination procedure with finite population correction [33]. Further, the study involved twelve (12) wholesalers, fifteen (15) retailers, and three (3) processors from the selected districts and Dar es salaam region, resulting in a total sample size of 363 respondents.

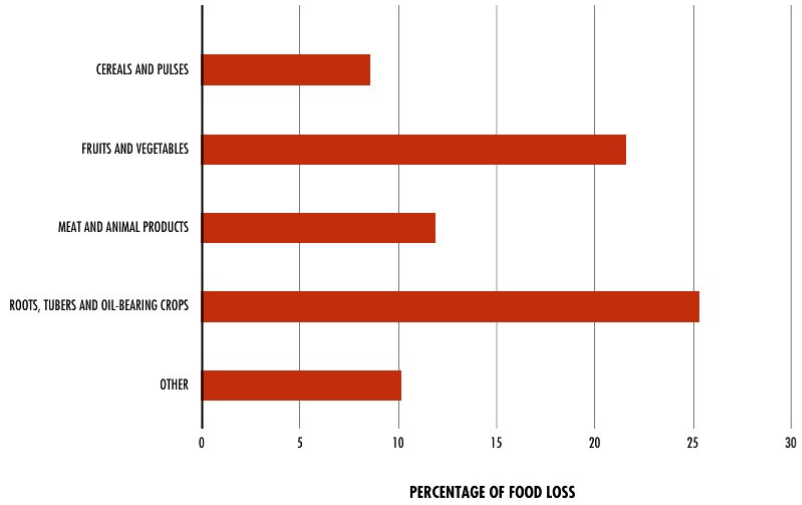


Fig. 1. FLW percentages by commodity groups from postharvest to distribution. Source: [19]

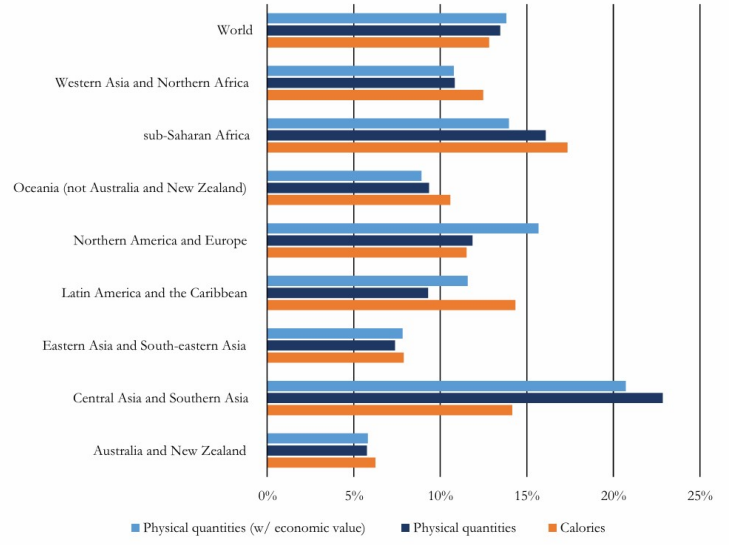


Fig. 2. Food loss percentages expressed in different metrics, 2016. Source: [19]

TABLE I. SAMPLE DISTRIBUTION OF PINEAPPLE PRODUCERS

Selected Districts	Total Farmers	Proportion	Sample (n)
Chalinze	4186	0.53	176
Geita	2450	0.31	103
Morogoro	1284	0.16	54
Total	7920	1.00	333

Source: Own data computation, 2024

C. Data collection and analysis

The study adopted a mixed-methods approach to collect data, integrating both qualitative and quantitative methods. Data were collected between February and December 2024. The study employed surveys to quantify pineapple loss and waste by collecting information on FLW through questionnaires and interviews. Participants were asked to directly evaluate the amount of FLW they incurred in their operations. According to [9], the survey is the most commonly used (38%) direct method for measuring FLW. Information regarding quantity produced, lost, or wasted, pineapple prices, and perceived FLW factors was sought. Further, triangulation was conducted through observation to complement the information provided by respondents. Secondary data were collected from FAO and government reports.

Descriptive statistics were used to summarize respondents' characteristics and to describe the extent of losses along the value chain. A multiple regression analysis was conducted to examine the relationship between farmers' demographic characteristics and pineapple losses. Further, Fractional Logit regression was estimated as a robustness check, to confirm the consistency of the findings. Physical losses at different stages were estimated using information obtained from respondents during the survey, and percentages were applied to describe losses at each stage. The physical loss estimates were calculated as the ratio of total lost or wasted pineapples to the quantity sold by farmers or sourced by traders. On the other

hand, monetary losses were calculated based on the quantities lost and average prevailing market prices. In addition, the study further employed a likert scale (where 1=not a cause, 2=minor cause, 3=moderate cause, 4=significant cause, and 5=very significant cause) to assess respondents' perception of the factors contributing to FLW across the value chain stages.

1) Regression model The dependent variable is the quantity of pineapple loss expressed as a percentage, and the independent variables include Age, gender, experience, education, farm size, and distance to the collection center/local market.

$$Y = \beta0 + \beta1X1 + \beta2X2 + \beta3X3 + \beta4X4 + \beta5X5 + \beta6X6 + \beta7X7 + \varepsilon i$$

Where, Y = Quantity of pineapple loss; X1 = Age of respondent; X2 = Gender of respondent; X3 = Experience; X4 = Education; X5 = Farm size; X6 = Distance to collection center/local market, and X7 = postharvest training. β1, β2, β3, β4, β5, β6 and β7 are the coefficients of the loss factorsβ0 = intercept; εi = error term

III. Results And Discussion

A. Social-demographic characteristics of respondents

From the research conducted, male dominance is observed at all stages of the pineapple value chain. From Table II, the majority of respondents were males, representing 78.7%, 75%, and 60% for farmers, wholesalers, and retailers, respectively. This suggests that males play a dominant role in pineapple production and marketing, unlike women, possibly due to limited access to and control of resources and market opportunities in the pineapple value chain. Most retailers (53.3%) have attained secondary school as compared to wholesalers (33.3%) and farmers (27.3%). Results further show that pineapple farmers and wholesalers are between 36-50 years of age, while the retailers are observed to be younger (20-35) years. This may result from the capital-intensive nature of production and wholesale activities, which demand substantial investments in land or cash. This could also account for the relatively lower average age observed among retailers.

It was also observed that most retailers (46.7%) have pineapple business experience of 1-5 years, unlike wholesalers (50%) and farmers (42%) who have experience of 6-10 years in the pineapple business and farming, respectively. The mean farm size was 2.694, reflecting moderate farm sizes under pineapple cultivation, characterizing pineapple farmers as smallholder farmers. Several studies have also ascertained that pineapples are predominantly grown by many small-scale farmers [34], [35]. The average distance to the collection center or local market was 2.345, suggesting that most farmers lived a moderate distance away. About 46.5% of the farmers had received post-harvest training, while none of the traders had received such training.

B. Relationship between farmers' socio-demographic characteristics and pineapple loss

The key assumptions of multiple regression were examined prior to regression analysis. According to pairwise correlation matrix (Table III), age ($r = 0.312$, $p < 0.001$) and experience ($r = 0.748$, $p < 0.001$) were significantly and positively connected with the percentage loss indicating that older and experienced farmers typically incurred higher pineapple losses. Experience was measured in terms of years a farmer has been involved in pineapple farming. Additionally, a small but statistically significant positive connection was found between pineapple losses and both distance to collection centers/markets ($r = 0.104$, $p < 0.1$) and those who received postharvest training ($r = 0.111$, $p < 0.05$). On the other hand there was a slight but significant negative relationship between pineapple loss and land size ($r = -0.146$, $p < 0.05$), suggesting that farmers who own large farms experience less losses. There was no significant relationship between dependent variable and other variables such as gender or education. Multicollinearity test show a mean Variance Inflation Factor (VIF) of 1.01, with all individual VIFs well below the critical threshold of 10, indicating no multicollinearity concerns.

TABLE II. Socio-Demographic Characteristics Of Respondents

Variable	Category	Farmers	Wholesaler	Retailer
Sex (%)	Female Male	21.6 78.7	25.0 75.0	40.0 60.0
Age (years)	20-35 36-50 Above 50	38.4 46.5 15.0	0 75.0 25.0	53.3 46.7 0
Education (%)	No formal education Primary Secondary Tertiary	13.2 57.1 27.3 2.4	0 66.7 33.3	0 46.7 53.3
Experience (years)	1-5 6-10 Above 10	35.1 42.0 22.8	8.3 50.0 41.7	46.7 33.3 20.0
Postharvest training	Yes No	46.5 53.5	0 100	0 100
Farm size (acres)	0-2 3-5 6-10 11 and above	7.2 42.9 40.2 9.6		
Distance to collection center/local market	1km and below 2-3km Above 3km	8.7 48.3 42.9		

To validate the classical linear regression assumptions, several tests were conducted after checking multicollinearity by using correlation matrix and VIF. Considering the results in Table IV, the White's test for heteroskedasticity produced a test statistic of118.28 with a p-value of 0.5015, indicating no evidence of heteroskedasticity. The Shapiro-Wilk test result ($W = 0.969$, $p = 0.166$) showed that the residuals were normally distributed as confirmed by histogram of residuals (Fig. 3), overlaid with a normal density curve. This suggests that the residuals are approximately normally distributed.

The Durbin–Watson statistic was 1.9574, suggesting no autocorrelation in the residuals. Furthermore, the Ramsey RESET test for model specification ($F = 0.33$, $p = 0.8027$) indicated no evidence of omitted variable bias. Overall, the tests confirmed that the data met the necessary assumptions for reliable multiple linear regression analysis. Additionally, the residuals-versus-fitted values plot shows a random scatter of points with no clear pattern, funnel shape, or curvature, indicating that the assumptions of linearity are reasonably met

TABLE III. PAIRWISE CORRELATIONS

Variables	-1	-2	-3	-4	-5	-6	-7	-8
(1) Percentage_los~e	1							
(2) Age	0.312***	1						
(3) Gender	0.037	0.031	1					
(4) Experience	0.748***	-0.014	-0.001	1				
(5) Education	-0.031	-0.036	-0.042	0.031	1			
(6) land_size	-0.146**	0.032	0.027	0.012	-0.033	1		
(7) distance_to_co~r	0.104*	0.054	0.08	-0.008	0.122**	0.015	1	
(8) received_post_~i	0.111**	0.069	-0.033	0.022	0.019	-0.066	-0.034	1
VIF		1.01	1.01	1	1.02	1.01	1.03	1.01
1/VIF		0.988	0.989	0.998	0.978	0.993	0.973	0.987
Mean VIF								1.01

*** $p<0.001$, ** $p<0.05$, * $p<0.1$

TABLE IV. TESTING MULTIPLE REGRESSION ASSUMPTIONS

Test	Null Hypothesis	Test Statistics	Decision
White's test	Homoscedasticity	118.28 (0.5015)	Do not reject H0
The Breusch-Godfrey Serial correlation LM Test	No autocorrelation	0.164 (0.6854)	Do not reject H0
Shapiro–Wilk	Normality of error term	0.969 (0.166)	Do not reject H0
Durbin–Watson	Independence of error term	(16, 333) = 1.9574	Do not reject H0
Ramsey RESET test	No omitted variables	0.33 (0.8027)	Do not reject H0

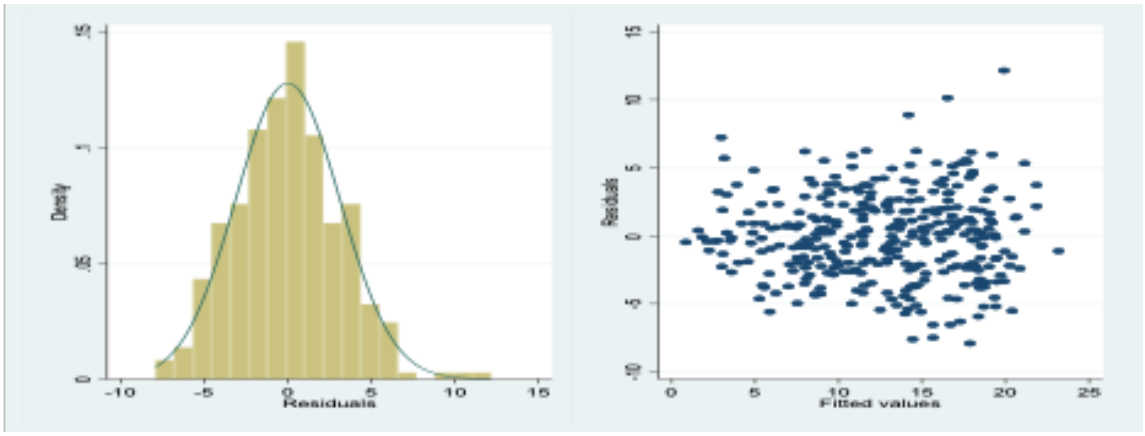


Fig. 3. Distribution of residuals

To account for the bounded nature of the dependent variable (percentage pineapple loss) the study estimated both an Ordinary Least Square (OLS) model and a Fractional Logit model as indicated in Table IV and in the Appendices1. The OLS model was retained as the primary specification because the observed loss percentages ranged from only 0.30% to 32.06%, while the Fractional Logit model served as a robustness check. The consistency of coefficient signs and significance levels across the two models indicates that the findings are robust to the estimation method. The OLS model explains 71.4% of the variation in pineapple losses (R2=0.714) and is jointly significant (F=52.81, p<0.01). Similarly, the Fractional Logit model is highly significant (Wald χ^2 =702.94, p<0.01), confirming the overall reliability of the results.

The estimates of both an Ordinary Least Square (OLS) model and a Fractional Logit model in Table IV and in the Appendices1, showed that, both age and farming experience were significantly and positively associated with pineapple loss in both models. Farmers aged 36–50 years and above 51 years experienced higher losses compared to the young farmers. Likewise, the results indicate that farmers with 6–10 years and more than 10 years of experience incur more losses than less experienced farmers. This finding suggests that old age and longer farming experience is not necessarily associated with improved post-harvest management practices. [36], did not find a connection between age and pineapple loss.

However, reported that more experienced farmers incurred lower pineapple losses. Gender has no significant effect on pineapple loss in either model, indicating that farmers' gender in the study areas does not influence pineapple losses. In contrast, Education shows mixed effects.

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Farmers with secondary education experience lower losses (-1.115, p = 0.028) than those with no formal education, indicating that secondary education may provide adequate knowledge to improve post-harvest management. However, other education levels do not show statistically significant differences. On the other hand, results revealed that land size is negatively associated with pineapple losses across both models. A slight but significant negative association (r = -0.146, p < 0.05) between pineapple loss and land size was

TABLE V. RELATIONSHIP BETWEEN FARMERS' CHARACTERISTICS AND PINEAPPLE LOSS

Frac_Loss	OLS	Fractional Logit
2.Age	2.803***	1.308***
	-0.386	-0.051
3.Age	5.162***	1.608***
	-0.539	-0.08
Gender (Male)	0.285	1.03
	-0.355	-0.034
Experience (6-10)	4.937***	1.965***
	-0.497	-0.135
Experience (10+)	11.230***	3.358***
	-0.47	-0.226
Primary Education	-0.195	0.972
	-0.487	-0.046
Secondary Education	-1.115**	0.872***
	-0.506	-0.045
College Education	-0.756	0.922
	-0.678	-0.058
University Education	-1.448	0.874
	-1.157	-0.079
Land_size (2-5)	-1.809*	0.859**
	-0.954	-0.057
Land_size (5-10)	-3.271***	0.747***
	-0.929	-0.048
Land_size (10-30)	-4.258***	0.673***
	-1.07	-0.053
distance_to_collection_centre (2-3km)	0.992	1.112*
	-0.661	-0.069
distance_to_collection_centre (Above 3km)	1.944***	1.214***
	-0.67	-0.076
Received_post_harvest_training (Yes)	0.749**	1.074**
	-0.354	-0.035
Constant	5.237***	0.056***
	-1.237	-0.006
Observations	333	333
F-test	52.81***	
Wald chi2(15)		702.94***
R-squared	0.714	
Pseudo R-squared	0.0309	
Akaike crit. (AIC)	1734.525	276.88
Bayesian crit. (BIC)	1795.455	337.81

observed. Farmers with 2–5 acres, 5–10 acres, and 10–30 acres experienced significantly fewer losses than those with smaller plots, by -1.809 ($p = 0.059$), -3.271 ($p < 0.001$), and -4.258 ($p < 0.001$), respectively. The reason could be that farmers with large pineapple farms have stronger market linkages and logistical advantages, since they are often better connected to reliable buyers and transporters, enabling them to sell their produce more efficiently and reduce post-harvest losses. Their ability to supply pineapples in bulk (for instance, filling an entire truckload) makes it easier for transporters and traders to collect produce directly from the farm or nearby collecting centers, thereby minimizing delays and spoilage compared to small-scale farmers. The same results were observed by [37] that farmers with small farms incurred higher losses, and [36], who suggested that the bigger the area, the greater the harvested amount, and the smaller the chance of losses.

Additionally, findings indicate that the distance to collection centers positively influences pineapple losses. Farms located more than 3 km away have significantly higher losses (1.944, $p = 0.004$), whereas those within 2–3 km do not differ significantly. This suggests that a longer transportation distance, which is also attributed to poor road infrastructure, contributes to greater losses. [37], reported the same results in their study, which assessed handling practices and loss factors in the pineapple value chain in the Philippines. A small but statistically significant positive connection was found between pineapple loss and those who have received post-harvest training in both models. While this may seem unexpected, this result may indicate that trained farmers are more aware of postharvest losses and therefore report them more properly, leading to higher perceived losses compared to untrained farmers.

Based on the models' results, Fractional Logit results closely mirror the OLS estimates in terms of coefficient direction and statistical significance. This consistency in the study's results is strong and supports the use of the OLS model as the main specification, despite the dependent variable being expressed as a percentage.

C. Abbreviations and Acronyms

Information on quantity harvested/procured, losses, prices, and revenues is provided in Table V, all referring to the 2023/2024 season. Pineapple losses comprised of losses during harvest and handling as well as transportation for all actors. At the production stage for example, include all losses incurred by farmers from harvest to the point of transaction between farmers and traders, as well as transportation losses for those who transport pineapples to collection centers or markets. The physical losses (expressed in percentages) represent stage-specific loss as a share of the quantity handled at that stage as depicted in Figure 4. The results indicate that farmers incur losses of up to 16.27%, which include losses during harvest and handling (15.71%) and transportation (0.56%), compared to the total loss reported by wholesalers (4,80%), retailers (3.38%), and processors (0.12%), indicating that losses at the production stage are greater than at other stages. Transportation loss at wholesalers is observed to be low 0.39%, despite wholesalers handling more pineapples than retailers, who reported a higher transportation loss (1.15%). Processors reported no transportation losses.

The total physical loss accounts for 24.57%, which is the sum of stage-specific loss across the value chain. This result is considerably lower than those reported by [37] (47.82%) and [25] (30-40%). It should be noted that the low processing-stage loss estimate is a result of little pineapple processing taking place due to the low number of processors present in the study areas. The identified processors were the only one available in the study areas during the study period. The processors identified in Geita is a group of fifteen (15) producers that came together and formed a pineapple processing group where they process pineapple into wine and hence in this study the group has been termed as a single processor. Likewise, in Morogoro only one processor (Fumbo Enterprise) processing dried pineapple alongside other fruits was identified. In Pwani region, this study included the only large processing company (Sayona) that is operating in the study area. However, it was observed that this company also does not process a large quantity of pineapples. Therefore, the low processing stage loss estimates (0.12%) should be interpreted cautiously because only a few processors were included. The estimates therefore provide empirical insights specifically to the pineapple rather than a statistically representative conclusion to the wider processing sector in Tanzania

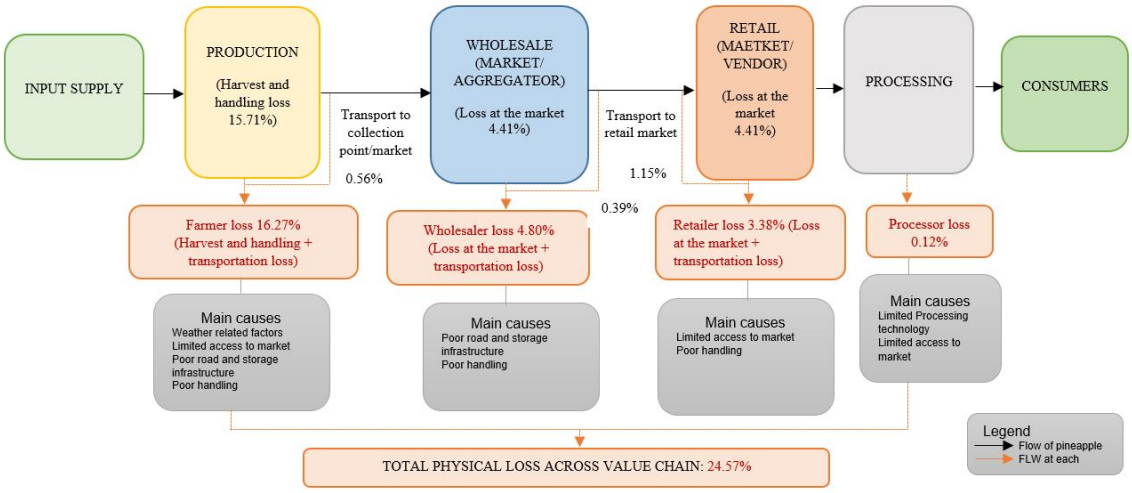


Fig. 4. FLW across the pineapple value chain

Most of the pineapple losses at the market are due to poor infrastructure (limited storage) and poor handling, which cause pineapple breakage or bruising. About 4.41 percent of pineapples get lost at the wholesale market, and it was mentioned that unmarketable pineapples due to loss are collected and taken to the dump site. Likewise, price is sometimes reduced if the pineapples are of low quality. This calls for enhanced market infrastructure by expanding space to improve handling and minimize congestion. Retailers experience a loss of 2.23 percent during marketing. Unlike in developed countries, where retailers are well-established stores and supermarkets, in developing countries, particularly in Tanzania, most retailers do not have well-established stands at the market. Hence, most of them sell pineapples along the roads with poor or little cover from the sun or rain. Lack of shade and bruises are the common reasons for pineapple waste at the retail stage. About 0.12% of

pineapples are lost during processing, primarily reported by small-scale processors who face limited processing technology and market access. It could also be noted that fewer losses could be associated with a small proportion of pineapples being processed.

In addition to survey data, field observation contextualized observed loss details during transportation. That is, while farmers incur transportation loss due to poor transportation and poor roads, especially during the rainy season, wholesalers who are usually the holders of the shipment incur loss during transportation resulting from poor loading, vehicle breakdown, or during the rainy season, where the lorries may stack for some days due to poor road conditions or due to rainfall if pineapples are not well covered during transportation.

D. Monetary losses across different stages of the value chain

To estimate the monetary value of the occurred pineapple losses, physical losses were multiplied by the average selling price at each stage (Table V). The prices and monetary values are presented in terms of Tanzanian Shillings (Tsh). Farmers reported a harvest of 1,613,975 measured in numbers (pieces) of which 261,134 pineapples were lost due to different reasons, and their value in monetary terms was Tsh 198,461,840. The

TABLE VI. FLW ANALYSIS ALONG THE PINEAPPLE VALUE CHAIN

Variable	Farmers	Wholesaler	Retailer	Processor
Quantity harvested or procured	1,613,975	263,000	13,200	50,800
Quantity lost at harvest and handling	253,586	11,550	291	59
Transportation loss	7,548	1,025	152	-
Quantity sold	1,352,841	250,425	12,757	50,741
Total loss	261,134	12,575	443	59
Average market price	760	1,200	1,400	2,000
Average revenue obtained	1,028,159,160	300,510,000	17,859,800	101,482,000
Lost value	198,461,840	15,090,000	620,200	118,000
Potential revenue	1,226,621,000	315,600,000	18,480,000	101,600,000

Source: Field data (2024)

quantity of pineapples lost at the wholesaler was 12,575 pieces, valued at Tsh 15,090,000. The total loss at the retailer was estimated to be 443 pineapples, representing a lost value of Tsh 620,200. The quantity sold by farmers was 1,352,841 pineapples, valued at Tsh 1,028,159,160. The quantity sold by wholesalers was 250,425 pineapples, equivalent to Tsh 300,510,000, and that for retailers was 12,757 pineapples at a value of Tsh 17,859,800. The results show that in the absence of losses, Wholesalers could have generated a potential revenue of Tsh 1,560,701,000, and retailers could have generated Tsh 18,480,000. Figure 5 shows that farmers lose more in terms of income, with a potential value estimated to be Tsh 1,226,621,000, followed by wholesalers (Tsh 315,600,000), and retailers Tsh 18,480,000, making the production stage the most critical loss point, followed by marketing (wholesalers and retailers).

Summary results on FLW in the pineapple value chain are presented in Table VI. The production stage is observed to be the critical loss point where food loss is most significant in magnitude, contributing 66.23% of the total chain loss; thus, it is highly impacting food security and significantly influences the economic performance of the supply chain [38]. It should

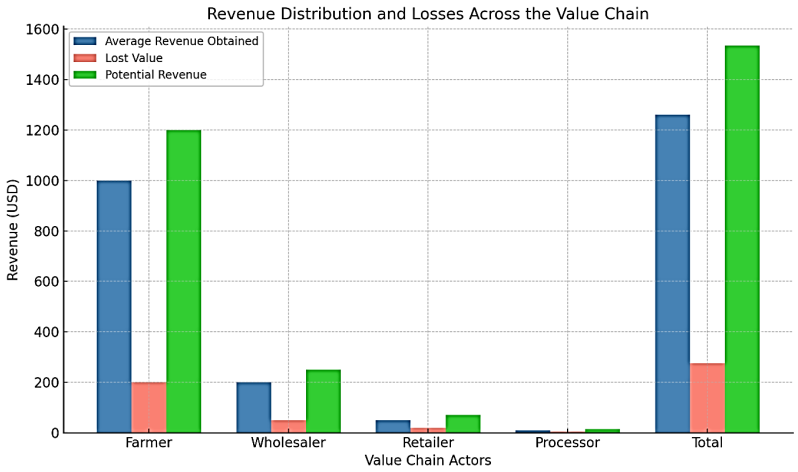


TABLE VII. SUMMARY OF TOTAL FLW ACROSS THE VALUE CHAIN

Value chain stage	Physical Loss (%)	Contribution to total value chain loss (%)	Monetary loss (Million Tsh)
Production	16.27%	66.23%	198.46
Wholesaler	4.80%	19.54%	15.09
Retailer	3.38%	13.76%	0.62
Processing	0.12%	0.48%	0.12
Total value chain	24.57%	100%	274.29

Source: Field data (2024)

be noted that, while the estimates show losses occurring at various stages of the pineapple value chain,

Fig. 5. Revenue distribution and losses across the pineapple value chain

information on FLW was collected based on the perception of the respondents (value chain actors). Hence, there may be recall bias regarding the pineapples harvested or procured and the actual pineapple losses. This is so because actors did not normally keep records of both physical and monetary losses. It is vital to conduct actual loss measurements to confirm these results and effectively implement tailored solutions to minimize these losses.

E. Perceived FLW factors

Using a five-point Likert scale, the mean perception scores of respondents regarding the factors contributing to FLW across the pineapple value chain were identified (Table VII). The main causes identified in this study are the most commonly reported by the value chain actors at each stage. The average scores highlighted limited market access, weather-related factors, and inadequate road and storage infrastructure for farmers. [18] and [21] also pointed out that a large amount of FLW in less developed countries occurs in upstream stages and is mainly due to severe climate and environmental conditions, inadequate infrastructure, and underinvestment in farming, storage, and processing. Wholesalers rated higher poor infrastructure (4.25) and poor handling practices (4.08), reflecting the logistical and management challenges they encounter during the transportation and marketing of pineapples. Retailers regard limited access to market (3.93) and poor handling (3.67) as the most significant causes of FLW.

TABLE VIII. KEY FACTORS CONTRIBUTING TO FLW IN PINEAPPLE VALUE CHAIN

FLW factors	Farmers	Wholesalers	Retailers	Processors
Poor road and storage infrastructure	3.82	4.25	3.13	4.00
Poor handling practices	3.52	4.08	3.67	2.67
Limited access to market	4.26	3.42	3.93	4.33
Limited processing technology	3.03	3.50	2.80	4.33
Weather-related factors	3.95	3.67	3.67	1.67

Source: Field data (2024)

Processors pointed out that limited processing technology and market access are key challenges, particularly for small-scale processors who depend on low processing technology.

Generally, the results indicate that limited market access, poor infrastructure, and inadequate handling are viewed as predominant FLW factors throughout the value chain. Likewise, [31] found that inadequate infrastructure and inefficient farming methods contribute to food losses, which subsequently affect incomes. This study also observed that pineapple value chain actors lose significant income due to FLW.

IV. CONCLUSION

The findings from this study provide evidence on the extent of food loss and waste and the factors influencing losses along the pineapple value chain in Tanzania. Based on the descriptive results, men dominate in pineapple production and marketing activities; however, regression results show that gender is not significantly associated with pineapple losses. Instead, farmer age, experience, and distance to collection centers or markets were found to influence losses, whereas larger farm size was linked to reduced pineapple losses. Evidence from the analysis suggests that the production stage is the most critical loss point, accounting for 66.23% of the total losses along the chain. This suggests that, the any measurement to reduce food loss and waste should mainly have a producer view point.

Although wholesalers and retailers reported relatively lower losses, interviews revealed persistent challenges related to logistics and handling practices. Key contributing factors

to food loss and waste include limited access to markets, inadequate transport and storage infrastructure, and poor handling practices. To address these challenges the study recommends first, improving market linkages, investment in infrastructure, improving harvest and postharvest practices. Second, the government should promote the establishment of processing centers at the downstream to reduce losses at the production stage that results from limited access to markets. Likewise, private investment should be encouraged to invest in appropriate facilities such as cold storage to help value chain actors to store their pineapples after harvest and during selling. This will help to improve performance and livelihoods in the value chain, as well as enhancing sustainable pineapple production in Tanzania.

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