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Determination of Postharvest Losses in Maize Production in the Upper West Region of Ghana

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Abstract

Maize is one of the most important cereal crops in Ghana; however, postharvest loss is a major setback to its production. Farmers, transporters and warehouse managers' practices along the handling chain result in major losses of the grain. Therefore, we sought, in this study, to determine the postharvest practices that caused losses in maize in of Upper West Region of Ghana. The research was in three phases:(1) A field survey where questionnaires were administered to 100 farmers, 30 transporters and 12 warehouse managers, (2) yield loss assessment that determined the per cent grain losses during harvesting, shelling and winnowing, loading and offloading, transportation, foreign debris and weevil infestation and (3) the effects of shelling methods on physical characteristics (stress crack, kernel weight and true kernel density) of maize grain. The survey revealed that majority (68%) of farmers used mechanical shelling and shelled directly into sacks without further cleaning which resulted in high foreign material in the grains. Estimated farmer handling losses were 8.33%, while transportation to the warehouses recorded losses of 0.30%, warehouse operations15.74% losses, giving total handling losses of 24.37%. An average moisture content of 10.07% was recorded at the end of a seven-month storage period and there were significant variations ($P \leq 0.05$) among communities studied. The stress cracks in manually and mechanically shelled grains recorded 29% and 6%, respectively. The average kernel weight, volume and true density for grains in the study area were 31.03 g, 23.69 cm3 and 1.31 g/cm3, respectively, which indicated maize kernels stored in the region were hard and susceptible to stress cracks during shelling. Estimated economic losses along the handling chain amounted to GH₵1,106.96. We conclude that postharvest losses are quite high and if nothing is done to reduce that, could worsen food security situation in the already challenged region of Ghana.

Keywords: Shelling and winnowing losses; loading and offloading losses; foreign material; broken grains; maize weevils; stress crack index; kernel density and moisture content.

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1. Introduction

Maize (*Zea mays L.*) is a cereal crop that is widely grown throughout the world in different agro-ecological environments. About 50 species exist worldwide and consist of different textures, colours, sizes, and shapes; the most dominate are red, yellow and white types. The most preferred are white and yellow varieties depending on the location [1]. Maize was introduced into Africa in the 1500s and has since been one of Africa's dominant food crops. Maize is one of the most important cereals produced and consumed as a staple food in Ghana with increasing production since 1965. Maize is an important staple food for more than 1.2 billion people in sub-Saharan Africa and Latin America [2, 3].Maize grains are rich in dietary fibre and calories which are good sources of energy. They are also rich in vitamins (A, C and E), carbohydrates, and essential minerals, and contain about 9% proteins [4]. Maize accounts for more than 50% of Ghana’s total cereal production [1]. Pre and postharvest losses are the major causes of food insecurity in Ghana and the world at large. The term “Postharvest loss” refers to measurable quantitative and qualitative food loss in the postharvest system [5]. This system comprises interconnected activities from the time of harvest through crop processing, marketing and food preparation, to the final decision by the consumer to eat or discard the food. Grain quality may be lost at the pre-harvest, harvest and or postharvest stages. Pre-harvest losses occur before the process of harvesting begins, and may be due to insects, weeds, rusts, and lodging. Harvest losses occur from the beginning to the completion of harvesting and are primarily caused by mechanical injury, shattering and improper methods of harvesting. Postharvest losses occur between harvest and the moment of human consumption. These include on-farm losses, during threshing/shelling, winnowing, and drying, as well as losses along the chain during transportation, storage and processing [5]. Significant losses occurred on the farm during storage, when the grain is being stored for consumption or while the farmer awaits a selling opportunity or a rise in prices [6]. Postharvest loss is the major cause of food insecurity in most developing countries, and could lead to deforestation and consequently, land degradation as more land has to be cleared for farmers to meet the increasing demand of the growing population and to make up the losses to be food secured. Food security exists when all people at all times, have physical, social and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preference for an active and healthy life [7]. A study on postharvest losses on maize at different levels of the handling chain would help to determine the extent and magnitude of losses caused by farmers, transporters and warehouse managers and factors responsible for such losses. This would also show the cumulative economic loss from harvesting to storage. The main objective of the study was, therefore, to determine the postharvest practices that cause postharvest losses and estimate the level of losses in maize production in the Upper West Region of Ghana. The specific objectives were to;

- identify the key causes of postharvest losses along the postharvest chain;
- determine the effects of threshing methods (mechanical and manual) on the physical characteristics of the grain; and
- estimate the cumulative postharvest economic losses of maize grain from the farmer to the warehouse level;

2. Materials and methods

2.1. Geographical Location of the study Area

The study was conducted in the Sissala West district of the Upper West Region of Ghana. Sissala West district is located in the North- Eastern part of Ghana. It lies approximately between Longitude 213 W to 2.36 W and Latitude 10.00 N to 11.00 N. The Administrative capital of the district is Gwollu. It covers a total Land area of 4,617.5 square kilometers [8].

2.2. Research Design

The research was carried out in three phases: Participatory Rural Appraisal, yield loss assessment, and the effects of shelling methods on physical characteristics of maize grain. These assessments were carried out over a 7-month period (January – July) in 2016, the time farmers in the study area had finished harvesting maize and were involved in postharvest handling activities and transporters carting the maize to the warehouses for reception and storage. According to MAFA [9] an average of 100 mini bags of maize per hectare was obtained from the farmer's fields in 2015/2016 farming season (the year of study). Therefore, all calculations were done with reference to the average yield per hectare. A mini bag of maize was 50kg.

2.3. Participatory Rural Appraisal (PRA)

Group discussions with 50 farmers (five (5) farmers randomly selected from each of 10 key maize producing communities) were used to determine and gather information on the single most important quality parameter that contributed to poor maize grain quality. This parameter was obtained by matrix scoring after brainstorming among the farmers and was illustrated in a problem tree.

2.4. Yield Loss Assessments

These were determined to ascertain the quantities of losses along the handling chain (farmer level, transportation level and warehouse level) of maize grain.

2.4.1. Experimental Design

The experiment was laid out in a simple Completely Randomized Design (CRD).

2.4.2. Parameters Studied

The parameters measured were harvest loss, shelling/winnowing losses, loading and offloading loss, farmer transportation from farm to farmer storage facility loss, losses due to transportation from the farmer home storage facility to the warehouses, foreign material and broken grain, weight loss due to weevil infestation and losses due to moisture content reduction.

2.4.3. Sample Size and Data Collection Procedure

A total of four (4) farmers were randomly sampled from each of the ten (10) communities for the purpose of collecting data for yield loss assessment.

2.4.4. Grain losses at the farmer level

The farmer level losses were determined at four points; harvesting, shelling/winnowing, loading and offloading and transportation to the farmer home storage facility.

2.4.5. Determination of harvesting losses

Second time harvesting was carried out in four (4) farmers farm, each cultivating one hectare, in each of the ten (10) communities sampled for the research. The area was marked out in 100 m x 100 m and second time harvesting was carried out and all lodged and standing stalk were assessed for cobs that were not harvested in the first time. The cobs harvested were manually threshed on a tarpaulin to avoid scattering of grains and the quantity obtained were measured in kilogram and expressed in percentage to represent harvesting losses as shown in the formula below;

$$HL = (Q2/Ty)100 \qquad [1]$$

Where: HL = Harvest Loss (%)

Q_2 = Quantity obtained from second time harvest (gleaned), kg.

T_Y = Total Yield (total yield is the sum of first and second time harvest quantities), kg

2.4.4. Determination of shelling and winnowing losses

Second time cleaning of the site of shelling and winnowing was performed and all available grain were collected, cleaned and weighed in kilogram. Where mechanical shelling (use of Sheller) was done, the chaff was shocked thoroughly on a tarpaulin to allow any available grain to fall off from the chaff. The site or floor was also cleaned with a broom and the grains picked, weighed and recorded. Where manual threshing was done by heaping the maize cobs on the bare ground and beating by sticks to separate the grains from the cobs, brooms were used to clean the site the second time and all available grain was picked and cleaned, and all the quantity obtained weighed in kilogram and express as a percentage of the total yield as shown in the formula below.

$$SWL = \left(\frac{Qc2}{Tyc}\right)100 \qquad [2]$$

Where: SWL = Shelling and winnowing losses (%)

Q_{C2} = Quantity obtained at second time cleaning of the shelling and winnowing site (kg).

T_{YC}= Actual Total yield (kg): The lost grain isolated from the chaff was grossed up to obtain the actual total yield.

2.4.5. Determination of loading and offloading losses

These were losses that took place at the point of loading and offloading. Grains usually dropped at the point of loading or offloading both on the farm and at home which usually is neglected as far as losses are concerned. In this case, tarpaulins were spread on the floor at the point of loading and offloading to collect grains that fell off the bags. The quantity obtained was measured in kilogram and expressed as a percentage of the total yield to be loaded.

$$\text{Loading and Offloading Losses (LOL)} = \frac{\text{Floor quantity}}{\text{Total Yield}} \times 100 \qquad [3]$$

2.4.6. Determination of losses during transportation from the farm to the farmer home storage facility

Losses during transportation from the farm to the farmer home storage facility were considered. The weight of the quantity loaded was recorded and the weight of the 'load' at offloading to the farmer home storage facility was also recorded. The difference in weight was expressed in percentage to represent the quantity loss during transportation as shown in the formula below.

$$FTL = \left(\frac{Wl - Wo}{Wl}\right)100 \qquad [4]$$

Where: FTL = Farmer transportation losses (%)

W_L = Weight of grains at loading (kg)

W_O = Weight of grains at offloading (Kg).

2.4.9. Determination of transportation losses from farmer home storage facility to warehouses (TL)

These were the losses that take place during the transportation of the grain from the producers (farmer) to the warehouses in Tumu, Wa and Tamale. These were determined by calculating the weight different at loading and reception in the warehouse by measuring the weight of the grain at loading and the weight at reception by using standing scales and the weighing bridge. The difference recorded represented losses during transportation and was expressed as a percentage of the total quantity as shown in the formula below.

$$TL = \left(\frac{Wl - Wr}{Wl}\right)100 \qquad [5]$$

Where: TL = Transportation losses from farmer to the warehouse (%)

W_L = Weight of grains at loading (kg)

Wr = Weight of grains at reception in the warehouse (Kg)

2.4.10. Determination of Warehouse Losses

Losses due to foreign materials and broken grains, weight loss due to maize weevil and losses due to moisture content reduction were considered at this stage.

2.4.10.1. Determination of losses due to foreign material and broken grains

Losses due to foreign material and broken grains were considered in this regard. 5 tons of maize (average yield per hectare in the study area) was poured into the giant cleaning machine for all foreign material to be removed. After cleaning the grains the weight was recorded and the difference in weight was calculated in percentage to represent the weight loss due to foreign material in the formula below.

$$FML = \left(\frac{Wtu - Wtc}{Wtu}\right) 100 \qquad [6]$$

Where: FML = Losses due to foreign material present (%).

Wtu = Weight of the unclean grains (before cleaning), Kg.

Wtc= Weight of the clean grains (after cleaning), Kg.

The cleaning of the bags was done in Wienco warehouse at Lamashegu in Tamale.

2.4.10.2. Determination of weight loss due weevils (Sitophilus zeamais)

This was done by randomly counting 100 undamaged and 100 damaged grains. The weights of the damaged and undamaged grains were taken using an Ohaus brand of top-loading electronic balance. Using the count and weigh method, the loss in each sample from the warehouse were assessed by substituting the values into the formula below. The percentage weight loss, according to [5] Harris and Lindblad (1978) was as follows:

$$Weight\ Loss\ (\%) = \frac{UNd - DNu}{U(Nd + Nu)} \qquad [7]$$

Where U = Weight of undamaged grains.

D = Weight of damaged grains.

Nu = Number of undamaged grains.

Nd = Number of damaged grains.

2.11. Calculation of economic Losses due to weevil (Sitophilus zeamais)

$$Economic\ Losses\ due\ to\ Weevils(GHc) = \left(\frac{YX}{100}\right)(A - B) \qquad [8]$$

Where X is the Total produce (kg)

Y is the percentage weight loss due to weevil (%).

A is the price of weevil free maize grain.

B is the price of weevil infested maize grain.

2.12. Cumulative postharvest losses

The cumulated postharvest loss was the summation of all the losses that occurred along the grain handling chain. This was calculated using the formula below;

$$Total\ Postharvest\ Losses\ (TPL) = HL + LOL + SWL + FTL + TL + FML + WL \qquad [9]$$

2.13. Effect of Shelling or Threshing Methods on the Physical Characteristics of Maize Grain

The effect of shelling methods (mechanical and manual) on the physical characteristics such as stress crack, kernel weight, kernel volume and true kernel density were considered.

2.13.1. Sample Method and Experimental Design

Four farmers were randomly selected from each of the ten farmers in each community and samples were taken for analysis for kernel weight, kernel volume and true kernel density. Completely Randomized Design (CRD) was used.

2.13.2. Maize Variety used

Pan 12 maize variety was used for the determination of the stress cracks, kernel weight, kernel volume and true kernel density as all the farmers sampled for the study were Masara farmers who cultivated pan 12.

2.13.3. Data Collection Procedure

2.13.3.1. Stress crack analysis

In determining the stress crack (SC), the two most used methods of threshing/shelling were considered. These were mechanical and manual shelling. Stress cracks were determined by using light viewing board and magnifying lens to accentuate the cracks on manually and mechanically shelled grains. Four samples of 100 intact kernels each from the two methods with no external damage were taken from each of the 10 communities and each kernel examined. Light was made to pass through the hard endosperm of the grain such that the severity of the stress crack in each kernel can be evaluated. Kernels were sorted into four categories: (1) kernel with no cracks; (2) kernel with one crack; (3) kernel with two cracks; and (4) kernel with more than two cracks. Stress cracks were expressed as a percentage, with all kernels containing one; two or more than two cracks divided by 100 kernels multiply by 100% as shown below.

$$SC = SSC + DSC + MSC \qquad [10]$$

Stress crack index (SCI) were determined by the weighted average of the stress cracks. The measurement indicates the severity of stress crack. SCI was calculated by the formula below;

$$SCI = (SSS \times 1) + (DSC \times 3) + (MSC \times 5) \quad [11]$$

Where: SSC is the percentage of kernels with only one crack,

DSC is the percentage of kernels with exactly two cracks; and MSC is the percentage of kernels with more than two cracks. The SCI can range from 0 - 500, with a high number indicating numerous multiple stress cracks in a sample, which is undesirable for most uses [10].

2.13.3.2. Determination grain moisture content

Maize grain moisture content was determined by using Aqua Boy digital moisture meter. The test was done at the farmer's gate and the warehouse during the reception and repeated in the 7th month in June at the end of storage for differences in moisture content. These were done for each of the selected farmers in the 10 communities. The moisture content was recorded in percentage.

2. 13.3.3. Determination of 100-kernel weight, kernel volume and kernel true density

The 100-kernel weight was determined for each of the four (4) sampled farmers in each of the 10 communities. The 100-kernel weight was determined from the average weight of four 100-kernel replicates from each of the 10 communities and was measured in grams. The kernel volume for each 100-kernels replicate was calculated using a helium pycnometer and was expressed in cm^3. The true kernel density was estimated by dividing the weight of the 100 sound kernels by the volume of the kernels. The true kernel density was calculated in grams per cubic centimeter.

$$Kernel\ true\ densityl = \frac{kernel\ weight\ (g)}{kernel\ volume\ \ (cm3)} \quad [12]$$

2.13.3.4. Statistical Analysis

Data collected were subjected to analysis, using Statistical Package for the Social Scientist Version 16 (SPSS 16). The community analysis of variance (ANOVA) was performed and the differences among the communities determined using Significant Minimum Difference (SMD) Test by Tukey at a level of 5% probability (P = 0.05).

3. Results and discussion

Figure 1below illustrates the major setbacks of the presence of foreign material in maize grain in a problem tree. These were categorized into causes, problem and effects.

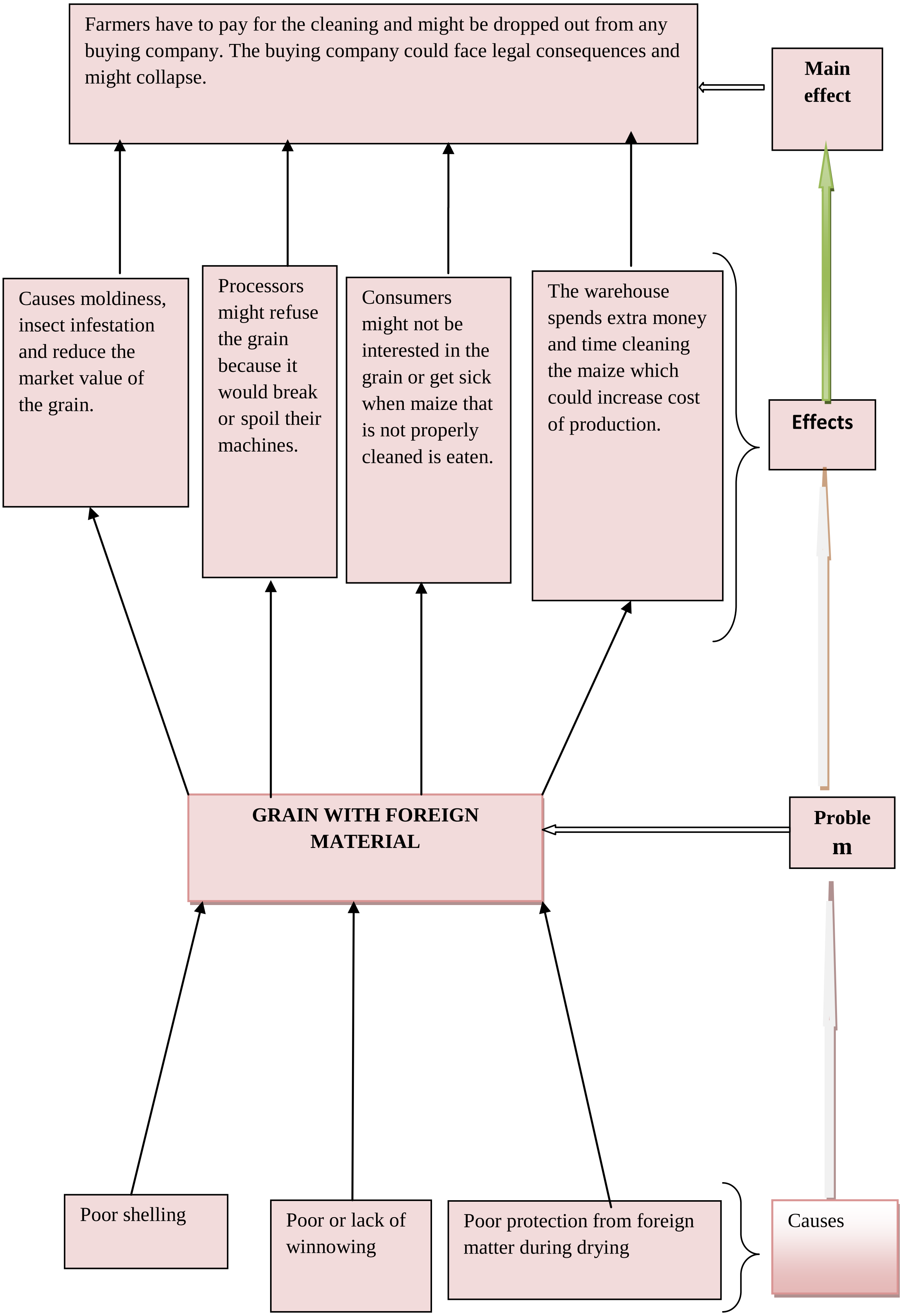

Figure 1: Illustration of foreign material in grain in a problem tree.

Group discussions with the 50 farmers revealed that foreign material in grains was the most important parameter that affected maize grain quality.Ninety per cent (90%) of the farmers ranked foreign materials in grains as the main factor that affected grain quality, 4% said moisture content affected quality, 4% said mouldiness and insect holing affected quality while 2% were uncertain. Interaction among the farmers revealed that poor shelling, poor or lack of winnowing and poor protection from foreign matter during drying were the major causes of foreign materials in maize.

Figure 2: Grain with debris (Before cleaning).

Figure 3: Grain after cleaning.

Figure 4: Foreign materials (broken grains)

Figure 5: Foreign materials (chopped cobs)

The effects of these foreign debris might have resulted in the following:

1. The presence of debris could cause moldiness, insect infestation and reduce the market value of the grain.

2. Buyers might not be interested in buying the grain as they will be buying more debris than grain.

3. Processors might refuse the grain because it would break or damagetheir machines during processing.

4. Consumers might get sick when maize that was not properly cleaned is eaten, especially when it contained metals and animal droppings.

5. Warehouses spent extra money and time cleaning the maize which could make the cost of production very high.

6. Farmers with debris in their maize had to pay for the cleaning and could alsobe dropped from any farmer association like Masara which oparates in the area of study.

7. Finally, the association could face legal consequences and might collapse.

Table 1 shows grain losses along the handling chain of maize grain. Losses at the farmer level, during transportation to the warehouse level and in the warehouse were expressed in percentages.

Table 1: Yield losses along the handling chain in the Upper West Region of Ghana

Community Name	Farmer level losses (%)				Transportation to the warehouse losses (%)	Warehouse losses (%)	
	Harvest	Shelling/ Winnowing	Farmer transportation	Loading/ offloading		Foreign materials	Weevil infestation
Zini	4.25 cd	3.75 cde	0.01 a	0.01a	0.21 b	5.34 a	14.86 b
Jeffisi	5.50 a	4.34 b	0.02 a	0.01a	0.11 b	4.25 d	8.27 c
Liplime	3.94 cd	4.00 bc	0.02 a	0.01a	0.41 b	4.72 c	10.23 d
Gwollu	4.13 cd	5.92a	0.02 a	0.01a	1.61 a	4.08 d	10.00 d
Felmou	3.71 de	3.47 ef	0.01 a	0.01a	0.21 b	4.16 d	11.61 c
Dasima	4.51 bc	4.04 bc	0.01 a	0.00a	0.03 b	5.04 b	16.89 a
Lilixia	4.11 cd	3.61 def	0.01 a	0.01a	0.23 b	5.08 b	12.25 c
Sorbelle	5.11 ab	3.87 cd	0.01 a	0.01a	0.13 b	5.08 b	11.36 c
Fatchu	4.21 cd	3.77 cde	0.01 a	0.01a	0.02 b	5.44 a	3.50 c
Bullu	3.14 e	3.29 f	0.01 a	0.01a	0.03 b	5.01 b	10.22 d
Mean	**4.26**	**4.05**	**0.01**	**0.01**	**0.30**	**4.82**	**10.92**
Cumulative losses		**8.33**			**0.30**	**15.74**	
SMD	0.61	0.35	0.011	0.009	0.42	0.22	1.1189
CV%	5.98	3.67	37.24	40.81	55.81	1.92	4.24

Harvesting is one of the key activities at the farmer level in which losses began. The highest loss was recorded in Jeffisi (5.50%) follow by Sorbelle (5.12%) and the lowest was recorded in Bullu (3.14%). The average harvest loss of 4.26% was recorded for the study area. Harvest losses varied significantly ($p \leq 0.01$) among communities in Region. Table 1above shows the harvest losses in the various communities in the Upper West Region of Ghana. Harvest losses could have occurred as a result weather (which was dry hamattan period), time of harvest and type of labour used, presence of weeds, lodging and lack of experience in harvesting. It was reported that 85% of the farmers in the study area did not control weeds before harvesting and as such impede the visibility of farmers during harvesting [11]. Harvest loss ranged from 3-6% (Table1). Similar accession was made by [12]. Preview report by SRID-MOFA in 2009 also ranged harvest losses between 5-8% [13] while IDRC (1976) pegged harvest loss at 7% [14]. Shelling and winnowing were the second point at which losses at the farmer level occurred. Gwollu had, significantly ($p \leq 0.01$), the highest shelling and winnowing losses of

5.91% while Bullu had the lowest loss (3.29%). The mean shelling and winnowing losses was 4.05% in the study area (Table 1). The Tukey's test showed that there were significant differences (p≤0.01) between communities. Shelling and winnowing in the study district accounted for 3-6%. This occurred as a result of mechanical shelling. APHLIS also ranged threshing and winnowing losses between3-5% [15]. The shelling and winnowing losses in the study area were; however, lower than the 9% reported in 2005 [12]. Loading and offloading were assessed to determine grain loss at these two points. It was revealed that the highest were recorded at Lilixia (0.01%), whilst the lowest (0.004 %.) were recorded in Dasima, however, no significant differences (P>0.01) were observed among communities. An average loss of 0.01% was recorded for the area (Table 1). Loading and offloading losses occurred as a result of holes or perforations on the sacks, often cause by rodents or when bags are poorly sewn. Losses at that point occurred when "loading boys" bang bags on each other to properly pack to avoid slippage of bags during transportation. These practices sometimes could cause the bags to burst resulting in grains falling from the sacks. Losses during transportation from the farm to farmer storage facility in the communities of the study area indicated that the highest transportation losses were recorded in Liplime, as 0.02%, while Fatchu had the lowest farmer transportation losses of 0.01%. Mean loss of 0.1% were recorded for the Region. Tukey's test revealed that there were no significant differences among communities (P>0.01).

Figure 6: Transportation of maize in a flat truck without tarpaulin.

Figure 7: An accident involving a loaded truck depicting the importance of tarpaulin in catching spilled grains.

Losses during transportation from the farmer storage facility to warehouses were assessed. It was realized that Gwollu recorded the highest loss of 1.61%, this occurred as a result of missing bags during transportation, while the lowest loss (0.02%) was recorded in Fatchu. An average of 0.01% was recorded and significant differences were observed among the communities (P≤0.01) as shown in Table 1.

Figure 8: Spilled grain from a bag of maize during transportation depicting grain loss during transportation.

Transportation loses as shown in figure 8 could be high if trucks transport the produce for a long journey without covering the bags with tarpaulin as shown in figure 6. Vehicles that transport with cover experience very low losses even if involved in an accident as depicted in figure 7. The research indicated that more foreign materials were bagged with the grains and sold to the buying companies. This happened as a result of farmers shelling the maize directly in sacks without further cleaning to remove the foreign materials. The warehouse assessment revealed that Fatchu had the highest foreign material of 5.43% while Gwollu had the lowest foreign material of 4.08%. Significant differences ($P \leq 0.01$) were observed among communities. The mean loss of 4.82% was recorded for foreign material in the district as shown in Table 1 above. The foreign material detected include broken and chipped grains, shriveled grains, corn husks/cob chaff, sand/stones and animal droppings as shown in figure2,4,5 and 11. Samples taken indicated foreign material range of 4-6% in the Region (Table 1).

Figure 9: Winnowing of maize grains threshed manually on the bare ground.

Figure 10: Photo of Masara/Wienco warehouse in Tamale with fit doors and cleaned environment.

Weight loss due to *Sitophilus zeamais*; Dasima had the highest weight loss (16.89%) while Fatchu had the lowest weight loss (3.50%). Variations among communities were significant ($P \leq 0.01$). The average weight loss by maize weevil was recorded as 10.92% in the warehouse. This might have happened as a result of untimely fumigation as the warehouse were built and operated according to standards (figure10and 12).

Figure 11: Losses due to *Sitophilus zeamais*.

Figure 12: Photo of Masara/ Wienco warehouse in Tamale showing standard roof.

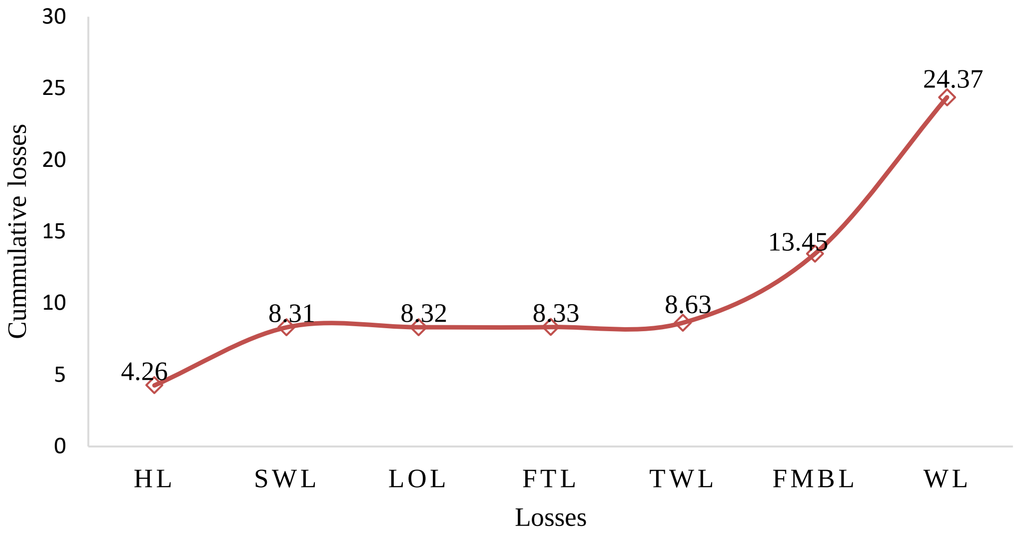

Figure 13: Cumulative grain losses along the handling chain

HL – Harvest loss; SWL – Shelling and Winnowing losses; LOL Loading and offloading losses; FTL – Farmer transportation losses; TWL – Transportation to the warehouse losses; FMBL – Foreign material and broken grain losses; and WL – Weight loss due to weevil infestation.

The cumulative grain loss along the handling chain at different handling activities revealed that the highest grain loss occurred at the warehouse (15.74%). Farmer level losses recorded (8.33%) while transportation recorded (0.30%). Loading/offloading, farmer transportation and transportation to the warehouse did not contribute significantly to cumulative loss as indicated in figure 13. Cumulative postharvest grain losses along the handling chain were estimated as 24.37%.The lower losses during transportation could have occurred as a result of majority of transporters covering the loaded grain with tarpaulin to avoid losses and contamination.

Table 2: Threshing effect on physical characteristics of the maize grain

Community Name	Moisture content (%)	True kernel density (g/cm^3)	Stress crack (%)		Stress crack index	
			Mechanical	Manual	Mechanical	Manual
Zini	10.25 a	1.27 a	5.75 a	30.25 ab	14.75 a	56.75 a
Jeffisi	10.09 b	1.35 a	5.75 a	29.00 ab	13.50 a	59.75 a
Liplime	10.37 a	1.36 a	6.00 a	30.00 ab	14.00 a	54.75 a
Gwollu	9.98 b	1.31 a	6.25 a	29.50 ab	14.00 a	57.50 a
Felmou	9.59 d	1.30 a	5.25 a	28.75 ab	14.00 a	54.25 a
Dasima	9.83 c	1.37 a	6.25 a	27.25 ab	13.50 a	57.00 a
Lilixia	9.98 b	1.31 a	6.25 a	28.25 ab	13.50 a	53.75 a
Sorbelle	10.38 a	1.32 a	6.25 a	25.50 b	14.00 a	53.50 a
Fatchu	10.10 b	1.30 a	6.25 a	31.50 a	13.25 a	50.75 a
Bullu	10.07 b	1.24 a	6.00 a	30.00 ab	13.00 a	53.00 a
Mean	**10.06**	**1.31**	**6.00**	**29.00**	**13.75**	**55.10**
SMD	0.14	0.25	1.53	4.99	4.15	12.52
CV%	0.58	8.04	10.54	7.12	12.49	9.41
P	<.0001	0.8236	0.39	0.02	0.95	0.44

The moisture content at the end of 7 months storage period indicated that Sorbelle had the highest moisture content of 10.38%, while Felmou had the lowest at 9.59%. At the end of the 7 months period an average of 10.06% moisture content was recorded which shows a decline of 0.03 % as compared to the initial average moisture content of 10.09% recorded in December 2015. Tukey's test was applied at 5% probability level and there were significant differences ($P < 0.01$) in moisture content among communities at the end of 7 months storage period (Table 2).

Stress cracks are fissures in grains which make them very fragile and susceptible to breakage and deterioration. This was carried out at an average grain moisture content of 10.09%. Felmou had the lowest stress cracks (5.25%), while Gwollu, Dasima, Lilixia, Sorbelle and Fatchu had the highest stress cracks (6.25%) for mechanically shelled grains in Sissala West district. An average stress crack of 6% was recorded for mechanically shelled grain. There were no significant differences ($P > 0.01$) among communities.

In manually shelled grains, the research shows that Fatchu had the highest stress crack (31.50%) whilst Lilixia had the lowest (25.50%) in the district. Manually shelled grains indicated significant differences ($P < 0.05$) among communities (Table 2). The stress crack index which shows the severity of the stress cracks had indicated no significant difference among communities ($P > 0.05$). Bullu had the lowest stress crack index of 13.00 as against the highest (14.75) at Zini and an average of 13.75 was recorded for mechanically shelled grains in the district as shown in table 2 above. In manually shelled grains, the stress crack index for Jeffisi was the highest (59.75) while the lowest (50.75) were recorded in Fatchu. There were no significant differences among communities ($P > 0.05$). An average of 55.10 was recorded in the district as shown in the table 2 above. Figure 14 shows the comparison of stress crack and stress crack index of manually and mechanically shelled maize grains. Manually shelled grains had the highest stress crack (29%) and index (55.10) than mechanically shelled grain of 6% and 13.75, respectively. The higher stress crack in manually shelled grain could lower the starch yield during wet milling, lower yield of flaking grits during dry milling and as well could cause non-uniform water absorption leading to overcooking or undercooking in alkaline cooking [10].

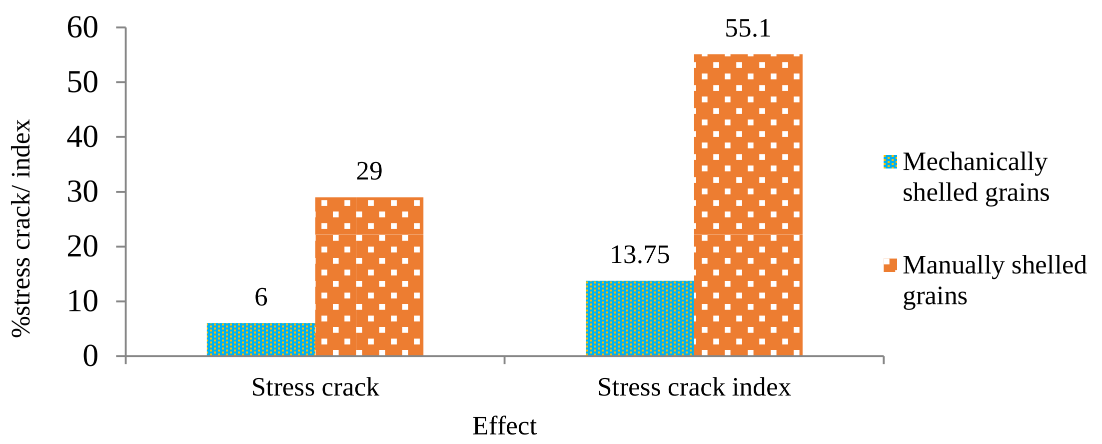

Figure 14: Comparison of stress crack/index of manually and mechanically shelled grains

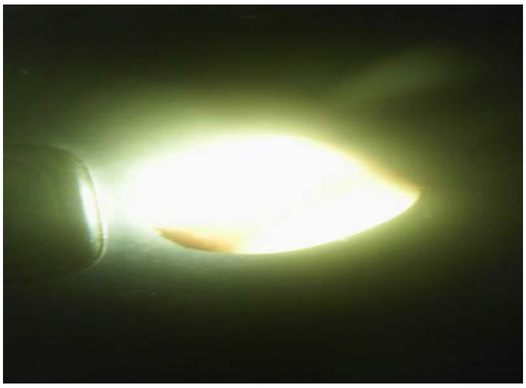

Figure 15: Grain on beam of light for stress crack determination (no damage).

Figure 16: Grain on beam of light for stress crack determination (damaged).

The True kernels density determined shows that Dasima had the highest 100-kernels weight, kernel volume and true kernel density of 38.25 g, 28 $cm^3$and 1.37 g/cm^3, while the lowest was recorded in Bullu as 21.45 g, 16.50 cm^3 and 1.24 g/cm^3, respectively. The average 100-kernels weight and volume were recorded as 31.03 g and 23.60 cm^3, respectively. The mean true kernel density was 1.31 g/cm^3 which indicated large grains in the samples which might be susceptible to stress crack. Tukey's test at 5% probability was applied and there were significant differences ($P < 0.01$) between communities in kernel weight and volume. However, there was no significant difference ($P > 0.05$) among communities for true kernel density.

Table 3: Economics of postharvest losses in Sissala West district of the upper west region

Handling Activity	Quantity loss per hectare (kg)	Cost per kg (GHc.)	Total Amount (economic losses) GHc.
	Farmer level losses		
Harvest	212.99	1.20	255.59
Shelling/winnowing.	202.30	1.20	242.76
Farmer transportation.	0.62	1.20	0.74
Loading/Offloading.	0.42	1.20	0.50
Sub total	**416.33**	**1.20**	**499.59**
	Losses during transportation to the warehouse		
Transportation to the warehouse.	14.90	1.20	17.88
Sub total	**14.90**	**1.20**	**17.88**
	Warehouse losses		
Foreign material (cleaning).	240.98	1.20	289.18
Weevil infestation.	546	0.55	300.30
Sub total			**589.48**
Grand Total			**1,106.96**

(Estimated costs as at January 2016)

Postharvest losses have an economic implication, in January 2016 a 100 kg of maize were sold in Sissala West district at GH₡ 120.00. On the other hand, 1kg of maize grain was sold at GH₡ 1.20. The farmer level has higher economic loss of at GH₡ 499.59. In January 2016, market survey revealed that weevil infested maize in Gwollu market was sold at GH₡ 65.00. Table 3 below shows the losses due to the practices long the handling chain and its corresponding economic losses in Ghana cedis (GH₵).

4. Conclusion

The points at which losses occurred along the handling chain of maize grain include harvesting, shelling and cleaning (winnowing), loading and offloading, on-farm transportation, and transportation to the warehouses. In the warehouse losses occurred as a result of foreign materials in grain and weevil infestation.

The highest losses occurred in the warehouse as 15.74%. The farmer level recorded 8.33% losses and the transportation to the warehouse had the lowest (0.30%) losses. Debris and weevil infestation resulted to the higher losses in the warehouse. The cumulative losses along the handling chain were estimated as 24.37%.

Because maize kernels in the study area were large and hard (true kernel density of 1.31g/cm^3) manually shelling (beating with sticks) made them about five time more susceptible to crack (stress crank of 29% and stress index55.10) than mechanically (sheller) shelled grains which recorded 6% and 13.75, respectively..These estimated cumulative losses could cost the already hard hit maize producer a whooping economic loss of GH₵. 1,106.96/ha, representing 34% of the cost of cultivation (GHc 3,283.52).Therefore, postharvest loss was high and if nothing is done to reduce it could worsen food security situation in that Region.

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