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Storage Losses of Maize in Four Different Storage Methods in Thangrong Gewog, Mongar Dzongkhag

Karma Dorji[o], Kinley Wangmo[p], Sujan Pradhan[o], Dorji Rinchen[q]

ABSTRACT

Several maize storage technologies are made available and recommended to the farmers in the villages by different agencies to reduce post-harvest losses. This study aimed to evaluate the storage losses of maize mainly to insect and fungal damages in four different storage methods for a maximum of five months storage period in Thangrong, Mongar dzongkhag (district). Freshly harvested maize was shelled, dried, weighed and stored under four different storage methods and replicated three times for each storage method. Moisture content, physiological weight loss, insect and fungal damages were the storage quality parameters assessed monthly until five months of storage. All the storage methods maintained the moisture content within the range recommended for the safe storage of maize (12-14 %). The physiological loss of weight (PLW) was the lowest at 0.10 % for the maize grain stored in super bag and the highest at 0.30 % was observed in grains stored in curing and storage shed over the four-month storage period. Traditional storage and silos resulted in PLW of 0.20 % and 0.16 %, respectively. Overall insect damage (sum for five months) of 2.54 % in the traditional storage was the highest reported among the storage methods followed by 1.79 % for grains stored in curing and storage sheds. Insect damage of 0.64 % for super bag and 0.27 % for silo stored maize grains were observed. Fungal damaged grain ranged from a low of 0.19 % for curing and storage shed to a high of 0.31 % for super bag stored maize grains. Overall storage losses (sum for five months) to insects and fungal diseases were in the range of 0.51-2.80 % with the highest being observed in traditional storage and the lowest in silo storage. All the storage methods evaluated maintained good quality maize grains with minimal damage till five months of storage. The existing improved storage technologies could help in the safe storage of maize grains if stored after proper drying. It is recommended to conduct a similar comparative study for the maize harvested and stored in the summer months and also at a different location to validate the results.

Keywords: *Maize; Storage methods; Storage losses; Insect damages; Fungal damages*

1. Introduction

Maize (*Zea mays*) also known as corn is the staple food of many Bhutanese, especially in the eastern and southern dzongkhags. Maize dominated the total cereals cultivation area of Bhutan

Corresponding author: karmadorjimoaf@gmail.com
[o] National Post Harvest Centre, Paro, Department of Agriculture, Ministry of Agriculture and Forests
[p] National Post Harvest Sub-centre, Lingmethang, Department of Agriculture, Ministry of Agriculture and Forests
[q] Agriculture Production Division, Department of Agriculture, Ministry of Agriculture and Forests

with 46.3 % for the year 2015 (PPD, 2015). In the same year, the share of maize production among cereal crops was 45 %. Mongar, Tashigang, Dagana, Samdrup Jongkhar, Sarpang, Pemagatshel, Tsirang and Zhemgang are major maize producing dzongkhags in Bhutan (PPD, 2015). It is also cultivated in small quantities in other dzongkhags of Bhutan for self-consumption and as a cash crop in recent years. In 2017, total maize production was recorded at 94,051 Mt from 66,043 acres of land with the highest production in the dzongkhags of Mongar, Tashigang, Samdrup Jongkhar, Samtse, Tsirang, Dagana and Pema Gatshel (NSB, 2018). Maize production was reported to be 55,259 Mt and 46,235 Mt in the year 2018 and 2019, respectively (RSD, 2020). Despite the huge production of maize in the country, the loss at the post-production storage phase is estimated to be high according to informal sources and an unpublished report from the field (NPHC, 2016). The major reason cited was the lack of proper and appropriate storage technologies for long term storage of maize and the easy attack of maize by insects and fungal infections due to improper storage technology. Additionally, poor knowledge of safe moisture content requirements for storage, improper drying and not sorting the grains before storage result in poor storage quality.

The major post-harvest losses of crops are due to poor methods of harvesting and handling, use of inappropriate containers while packaging, poor storage conditions, and poor transportation and distribution system (Kiaya, 2014). According to Basappa (2004), the important factors leading to storage losses are long-duration storage using traditional methods, inadequate knowledge, poor storage structures, non-availability of separate godowns and damage by rodents, insects, and dampness of storage environment and storage of improperly dried grains. Among the several factors affecting the storage life of maize, the use of an improved storage system that is clean with good ventilation for proper circulation of air and additional features to protect from rodents and wild animals will significantly reduce storage losses in maize. The growers should also ensure that only the properly dried maize with a recommended moisture content of 14 % or below should be stored to deter fungal and mould growth.

The post-harvest loss of cereals in Sub-Saharan Africa ranged between 5-40 % with an estimated worth of around $4 billion (Zorya, Morgan, Diaz Rios, Hodges et al., 2011). Losses of cereal crops in developing countries are estimated to be as high as 25% of the total production. The maximum losses of 50-60% of cereal grain occur during the storage period due to the lack of proper storage management and structures (Kumar & Kalita, 2017). Meronuck’s 1987 report (as cited in Suleiman & Kurt, 2015) indicates that losses of maize in various storage facilities in undeveloped tropical countries are in the range of 15-25%. As per the findings from the farm survey on maize impact study by Shrestra, Katwal, and Ghalley (2006), the overall post-harvest loss in maize in Bhutan was reported to be 20%. Additionally, the post-harvest loss was 26% higher among the farmers growing traditional varieties compared to those who adopted modern varieties. This annual post-harvest loss in monetary terms was valued at Nu.181 million for Nu.10/kg.

The storage losses are classified into two main categories namely, biotic and abiotic factors. Biotic factors are insects, rodents, pests and fungi while abiotic factors refer to temperature, humidity and other environmental factors. However, the storage losses are caused due to the combined effect of both biotic and abiotic factors. Temperature, humidity and moisture content of the crops are the driving force behind the cause of many storage problems such as insect infestation and fungal growth in the stored crops. Most of the storage moulds grow rapidly at a temperature between 20-40 °C and relative humidity of 70 % and above (Kumar & Kalita., 2017). Minimizing the post-harvest losses would increase the amount of food available for human consumption and enhance global food security. In addition, crop production contributes a significant proportion of typical incomes in certain regions of the world and reducing food loss can directly increase the real incomes of producers.

The preliminary study to determine the post-harvest storage losses of maize was conducted in three Dzongkhags of Bhutan; Chhukha (west), Dagana (south-central) and Mongar (east) in the year 2019. That study was conducted to obtain the baseline data on post-harvest storage losses of maize in Bhutan and at the end of six months of storage, the total mean storage losses were 16.18%, 38.21% and 23.83% for Chhukha, Dagana and Mongar, respectively (Dorji, Tshering, & Lhamo, 2020). A survey study carried out in Nepal reported insects as the major cause of maize storage loss with 62% of the respondents' expressing insects as its cause while 39% of the respondents presumed the storage losses to be between 10-20% (Bhandari, Achhami, Karki, Bhandari et al., 2015). In continuation to the above study, it was found to be of utmost importance to compare the storage losses of maize in different storage methods disseminated by different agencies amongst the communities - traditional storage method, super bags, silos and NPHC curing and storage shed. This study was conducted to compare the storage losses of maize in different existing storage methods in Bawcholing, Thangrong Gewog, Mongar.

2. Materials and Method

2.1 Experimental design

The experiment was set up at Bawcholing village, Thangrong Gewog under Mongar Dzongkhag. Thangrong (Mongar), Karmaling (Dagana) and Sampheling (Chhukha) are the places that were initially selected by the Food and Agriculture Organizations (FAO) as a pilot sites for carrying out agriculture and post-harvest related programs under one of their projects. Accordingly, the improved curing and storage shed that was designed by National Post Harvest Centre (NPHC) was constructed at these sites. The sites at Chhukha and Dagana could not be included in the current study due to the COVID-19 situation that resulted in the two sites being labelled under red zones. Thangrong Gewog was selected as the site for study since maize is abundantly cultivated in the gewog and also as all the storage methods were readily available for the study. The study site is located at an altitude of 1361 masl.

Maize was harvested in February 2021, shelled and it was dried in the sun as practised by the farmers till the average moisture content of 12 % was achieved. The experiment was immediately started after the desired moisture level of 12 % for safe storage was achieved in February. The moisture content of maize for storage is recommended to be between 12-14% (FAO, 1992). The data collection was carried out monthly and continued till August 2021.

The following four different storage methods were evaluated.

Storage method 1: A metal silo designed and fabricated by the Agriculture Machinery Centre (AMC) was borrowed for the study. The silos were made out of a galvanized iron sheet and had a capacity of 500 kg. It has an opening from the top to put in the grains with a lid to close the storage. Twenty kilograms of maize grains were weighed and put into three silos. It was covered with the lid and the silos were placed in the basement of the house.

Storage method 2: Super grain bags are airtight plastic bag imported from Grainpro which comes with a zipper. Super grain bags were collected from National Plant Protection Centre. The capacity of the bag was 25 kg. The three replicated bags were filled with 20 kg each of maize grains, tied with a zip lock and kept in the basement of the house.

Storage method 3: Maize curing and storage shed was designed and constructed by the NPHC. The dimensions of the structure are 5m × 4m and raised by 2m from the ground. The sides of the structure have a mesh to protect from insects and pests with full aeration for good airflow.

The roof is covered with a corrugated galvanized iron sheet. Twenty kilograms of maize grains were put into the aerated gunny bags and placed in different corners of the shed.

Storage method 4: This is the farmer's traditional method which was used as one of the treatments. This method consists of filling the shelled maize grains in the gunny bags and keeping them in the corners of rooms, basement and attic of the house. Gunny bags were filled with 20 kg each of maize grains and stored in the basement of the house as practised. Grains that were free of insect and fungal damage were used for the storage study. For uniformity, maize grains were checked for moisture content and maize grains from the same lot with equal moisture content were stored in the storage methods. Each storage type had three replications.

A separate lot of 5 kg of maize in each replication for the four storage methods was stored to determine the change in physiological weight loss of the maize grains during the storage period. Traditional maize variety *Ashom barmu* was used during the storage study.

2.2 Determination of moisture content of maize grains

The moisture content of maize grain was measured using the portable digital moisture tester (A-Grain, India). The hopper of the moisture meter was filled with the maize sample and then the handle was released to transfer the samples into the sample holder. The measuring button was pressed for a few seconds and the moisture content displayed on the screen was recorded. The moisture of grain was checked before storage and from there on the moisture content of grains was recorded from all the samples during the monthly data collection.

2.3 Determination of physiological weight loss of grains

A separate lot of maize kept in each of the storage methods for determining the physiological weight loss was measured monthly. Weight was measured using the digital weighing balance. After the measurement of weight, the samples were put back in their respective storage methods for checking weight in the subsequent months. The physiological weight loss of the grain was converted into percentage as follows;

$$\text{Physiological weight loss (\%)} = \frac{\text{Weight at the time of monitoring}}{\text{Initial weight of the grains}} * 100 \qquad \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

2.4 Determination of storage damages/losses

One kilogram of maize grains was sampled for all the replications (three replications) from different corners of the traditional bag, super bag, silos, and improved shed. Damages by insects and fungi were recorded as the main grain loss parameters in different storage methods. The number of grains that were damaged by insects and fungal diseases from the sampled lot was counted from the sample grains and these numbers were converted into loss percentages. The monitoring and assessment of storage loss were continued for 150 days at an interval of one month each. The post-harvest storage losses of maize in each category were expressed in percentage;

$$\text{Losses to Insects damage [A](\%)} = \frac{\text{No.of insects damaged grains}}{\text{Total number of grains [C]}} * 100 \quad \text{.................} \quad (2)$$

$$\text{Losses to fungal damages [B](\%)} = \frac{\text{No.of fungal damaged grains}}{\text{Total number of grains [C]}} * 100 \quad \text{.................} \quad (3)$$

$$\text{Overall storage losses } (OSL\ in\ \%) = \frac{A+B}{C} * 100 \text{..} \quad (4)$$

Where;

OSL=Overall storage losses (%)

A= Number of insects damaged grains

B=Number of disease damaged grains

C=Total number of grains

2.5 Statistical analysis

Microsoft Excel 2016 was used to arrange the data, do basic calculations and plot figures. The post-harvest storage losses of maize in different storage methods were statistically analyzed using STAR (Statistical Tools for Agricultural Research) software. The data was arranged as per the format in STAR software and it was imported into the software. One-way ANOVA test was carried out to see if there is a significant difference among the means. Duncan's Multiple Range Test was the post-hoc test carried out to determine the significance between storage means (P<0.05).

3. Results and Discussion

3.1 Moisture content, physiological weight loss and percent of insect and fungal damaged grains after one month in storage

At the end of one month in storage, the moisture content of maize grains from different storage methods ranged from 10.53 to 11.30 % and there was no significant difference (Table 1). The average moisture content of the grain was 12.3 % at the time of storage but was observed to be reduced in all the storage methods after one month which is due to the loss of moisture and other substrates during the storage period. A significantly lower physiological loss of weight (PLW) of 0.1 % was recorded for the maize samples stored in the super bags compared to grains from other storage methods after one month in storage. The lower weight loss from the super bag was obviously due to the low permeability of the bag that minimized the air and water vapour movement thus retaining its weight. Traditional, silos and sheds had more free air movement and resulted in the physiological loss of weight in the range of 0.36-0.47 %. Insect infested grain of 0.1 % in the traditional storage method was the highest recorded among the grain samples among four storage methods compared to 0.03-0.05 % for grains from the other storage methods but not statistically significant. Fungal infected grains were 0.03 %, 0.07 % and 0.05 % for grains stored in traditional methods, super bag and improved shed, respectively while no fungal infection was observed in the silo stored grains. The overall damage (sum of insect damage and fungal damage) of 0.13 % in the traditional storage method was the highest followed by 0.1 % for super bag and curing and storage shed while overall damage was just reported 0.03 % for silo stored grains. At the end of one month, the overall damage was very minimum from all the storage methods.

Table 1. Moisture content, physiological weight loss and percent of insect and fungal damaged grains after one month in storage

Storage method	Moisture content (%)	Physiological weight loss (%)	Insect damages (%)	Fungal damages (%)	Overall storage losses (%)
Traditional	10.53	0.36a	0.1	0.03	0.13
Super bag	11.30	0.10b	0.03	0.07	0.1
Silo	10.93	0.47a	0.03	0.0	0.03
Curing & storage shed	10.90	0.45a	0.05	0.05	0.1
S.E.	0.12	0.05	0.01	0.01	-
P- value	0.17	0.006	0.39	0.48	

Means in the column with different letters are significantly different between storage methods at $P < 0.05$ by Duncan's post-hoc test.

3.2 Moisture content, physiological weight loss and percent of insect and fungal damaged grains after two months in storage

After two months in storage, the moisture content was significantly higher in grains from silos (12.6 %) and super bag (12.5 %) followed by 11.87 % for traditional stored grains and 11.30 % for curing and storage shed grains (Table 2). The enclosed nature of silo and super bag probably retained slightly higher moisture content while higher moisture loss in traditional storage and curing and storage shed resulted in higher physiological loss of weight. There was no statistically significant difference in insect and fungal damaged grains with an overall storage loss in the range of 0.06-0.2 %. Similar to one month after storage, overall storage loss was highest in traditional storage methods after two months of storage at 0.2 %.

Table 2. Moisture content, physiological weight loss and percent of insect and fungal damaged grains after two months in storage

Storage method	Moisture content (%)	Physiological weight loss (%)	Insect damages (%)	Fungal damages (%)	Overall storage losses (%)
Traditional	11.87b	0.4a	0.1	0.1	0.2
Super bag	12.50a	0.1b	0.03	0.03	0.06
Silo	12.60a	0.0b	0.03	0.1	0.13
Curing & storage shed	11.30c	0.6a	0.07	0.03	0.1
S.E.	0.16	0.07	0.01	0.01	-
P value	0.00	0.006	0.36	0.11	

Means in the column with different letters are significantly different between storage methods at $P < 0.05$ by Duncan's post-hoc test.

3.3 Moisture content, physiological weight loss and percent of insect and fungal damaged grains after three months in storage

There was no significant difference in the moisture content of maize grains after three months of storage in four storage methods (12.03-12.97 %). Physiological loss of weight was 0.03 % for grains stored in traditional, and curing and storage shed while the physiological weight loss was nil for the other two methods of storage. The curing and storage shed has free air movement within its environment since it is a structure constructed outside and protected only by a wire mesh from the sides. This probably caused some weight losses from the grains stored in the curing and storage shed while physiological weight losses were not recorded from the other storage methods due to the enclosed status of the product in the basement room. In the third month, no insect damage was reported from the grains stored in traditional and silo storage while super bag, curing and storage shed reported insect damage of 0.03 % and 0.07 %, respectively. Grains stored in the curing and storage shed reported no fungal damage while other methods resulted in grain damage of 0.07-0.13 %. The overall storage damage was the highest at 0.16 % in super bag followed by 0.1 % for traditional storage. Except for grains from the super bag the traditional storage method still resulted in a slightly higher overall storage damage of grains. Silo storage and curing and storage shed resulted in an overall storage loss of 0.07 % (Table 3).

Table 3. Moisture content, physiological weight loss and percent of insect and fungal damaged grains after three months in storage

Storage method	Moisture content (%)	Physiological weight loss (%)	Insect damages (%)	Fungal damages (%)	Overall storage losses (%)
Traditional	12.17	0.03	0.0	0.1a	0.1
Super bag	12.53	0.00	0.03	0.13a	0.16
Silo	12.97	0.00	0.0	0.07ab	0.07
Curing & storage shed	12.03	0.03	0.07	0.0b	0.07
S.E.	0.15	0.01	0.01	0.01	-
P-value	0.12	0.59	0.56	0.02	

Means in the column with different letters are significantly different between storage methods at $P < 0.05$ by Duncan's post-hoc test.

3.4 Moisture content, physiological weight loss and percent of insect and fungal damaged grains after four months of storage

There was a significant difference in moisture content of maize grains after four months in storage. The lowest moisture content of 12.8 % was recorded for grains stored in silos. The fourth month of storage was in the months of June-July and due to the increased summer temperature, the silo which is made up of galvanized sheets could have absorbed heat and caused the moisture content to reduce slightly. The moisture content in general increased for grains from all storage types due to the wet season that has set in. Physiological loss of weight ranged from 0.13 %-0.20 % for three storage methods while it was nil for traditional stored grains without any significant differences. Gunny bags that were used in the traditional storage method helped absorb moisture easily and could have led to zero physiological weight loss. Silos did not result in any insect damage while the highest damage of 0.2 % was reported from grains stored in super bags followed by 0.1 % from traditional and curing and storage sheds. Fungal damage was reported only from traditional storage in the fourth month of storage. Overall damage in the fourth month of storage was 0.2 % for super bag storage, 0.13 % for traditional storage and 0.1 % for curing and storage shed. No damage was reported for the maize stored in silos in the fourth month of storage. Similar to the first three months of storage, the overall storage loss was slightly higher in the traditional storage method except for super bag grains.

Table 4. Moisture content, physiological weight loss and percent of insect and fungal damaged grains after four months of storage

Storage method	Moisture content (%)	Physiological weight loss (%)	Insect damages (%)	Fungal damages (%)	Overall storage losses (%)
Traditional	13.77a	0.00	0.1b	0.03	0.13
Super bag	13.43ab	0.20	0.2a	0.00	0.2
Silo	12.80c	0.17	0.0c	0.00	0.0
Curing & storage shed	13.23bc	0.13	0.1b	0.00	0.1
S.E.	0.12	0.04	0.02	0.01	-
P-value	0.01	0.36	0.008	0.44	

Means in the column with different letters are significantly different between storage methods at $P < 0.05$ by Duncan's post-hoc test.

3.5 Moisture content and percent of insect and fungal damaged grains after five months in storage

At the end of five months in storage, the moisture content of maize increased between 12.77 to 14 % with significant differences among the storage methods but within the recommended range for safe storage of maize (Table 5). The wet monsoon season in August could have increased the humidity around the atmosphere and led to an increase in moisture content. Similarly, the wet monsoon season possibly increased the humidity in the air and resulted in grains absorbing more moisture to have zero physiological weight losses. The highest degree of insect infestation was observed in maize from traditional storage samples at 2.24 % followed by 1.5 % in curing and storage shed. The insect infestation of 0.21% and 0.35 % for silo and super bag was the lowest among the storage treatments. Fungal damaged grains were in the range of 0.07 % to 0.11 % for super bag, silo and curing and storage shed while it was not observed for traditional storage samples. The overall storage losses to insect and fungal infestation are between 0.28 % to 2.24 %. After five months of storage, the overall storage losses were highest at 2.24 % for the traditional storage method. From the data, it can be seen that all three storage types resulted in lower overall storage losses compared to the traditional method and if stored after proper drying, grains could be stored well without significant quantity losses for five months.

Table 5. Moisture content and percent of insect and fungal infected grains after five months under different storage methods

Storage method	Moisture content (%)	Insect infested grains (%)	Fungal infected grains (%)	Overall storage losses (%)
Traditional	13.93a	2.24a	0.0b	2.24
Super bag	13.60b	0.35c	0.08a	0.43
Silo	12.77c	0.21c	0.07a	0.28
Curing & storage shed	14.00a	1.50b	0.11a	1.61
S.E.	0.15	0.25	0.0.01	-
P- value	0.000	0.000	0.01	

Means in the column with different letters are significantly different between storage methods at $P < 0.05$ by Duncan's post-hoc test.

3.6 Average moisture content of maize grains over five months storage period

The average moisture content of maize grains over the five months storage period in different storage methods is shown in Figure 1. The highest moisture content of 12.67 % was recorded in grains from super bag followed by 12.45 % for the traditional method and 12.41 % for silo storage. It was observed that the more enclosed the storage type, the higher the moisture content. The lowest average moisture content during the five months storage period was in curing and storage shed maize grains at 12.29 %. The low moisture content in the curing and storage shed is due to the higher ventilation of the shed leading to higher moisture removal from the grains. The moisture content in general increased during the storage period for the maize from all types of storage methods due to the increase in relative humidity during the monsoon season. The moisture content of maize remained with minimal change in some of the hermetic containers while it decreased in the woven bag and aerated containers over seven months of storage (Baributsa, Bakoye, Ibrahim, & Murdock, 2020). It was observed that all the storage methods maintained the moisture level at the recommended range during the five months of storage duration. The moisture content of maize for storage is recommended to be between 12-14% (FAO, 1992). The moisture content of 13 % is also recommended for maize storage in the extension manual on quality maize seed production through the community-based seed production approach in Bhutan (Katwal, Dorji, & Wangdi, 2009).

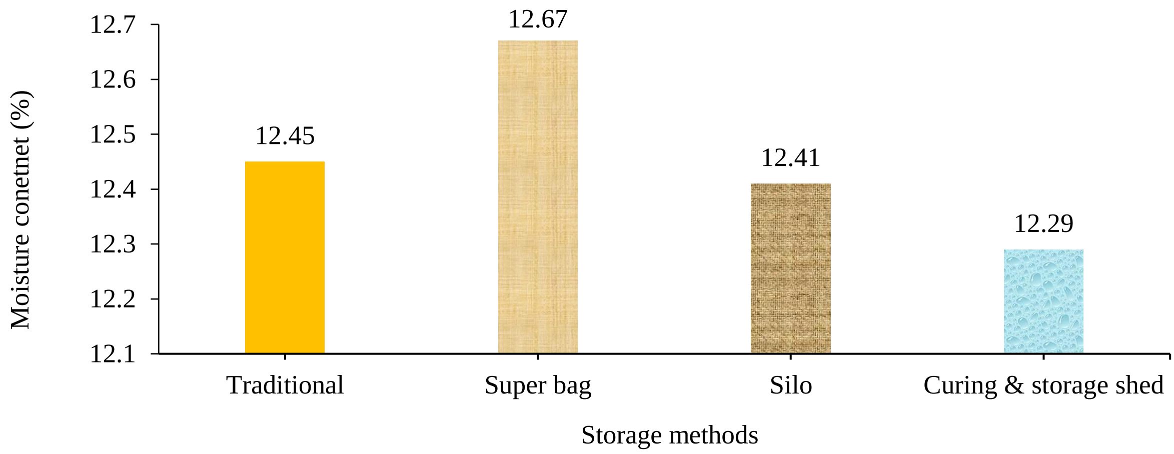

Figure 1. Average (mean) moisture content (%) of maize grains stored under different storage methods over the five months storage period

3.7 Average physiological weight loss over four months storage period

The four-month average physiological loss of weight was the lowest at 0.10 % for the maize grain stored in the super bag (Figure 2). The lowest physiological weight loss from the super bag is directly linked to the high moisture content of grains reported for this grain sample. The barrier property of the super bag probably led to minimal water loss from the grains resulting in lower physiological weight loss. The highest PLW of 0.30 % was observed from the grain stored in the curing and storage shed due to adequate ventilation that caused moisture removal. Traditional storage and silos resulted in average PLW of 0.20 % and 0.16 %, respectively during the four-month storage period.

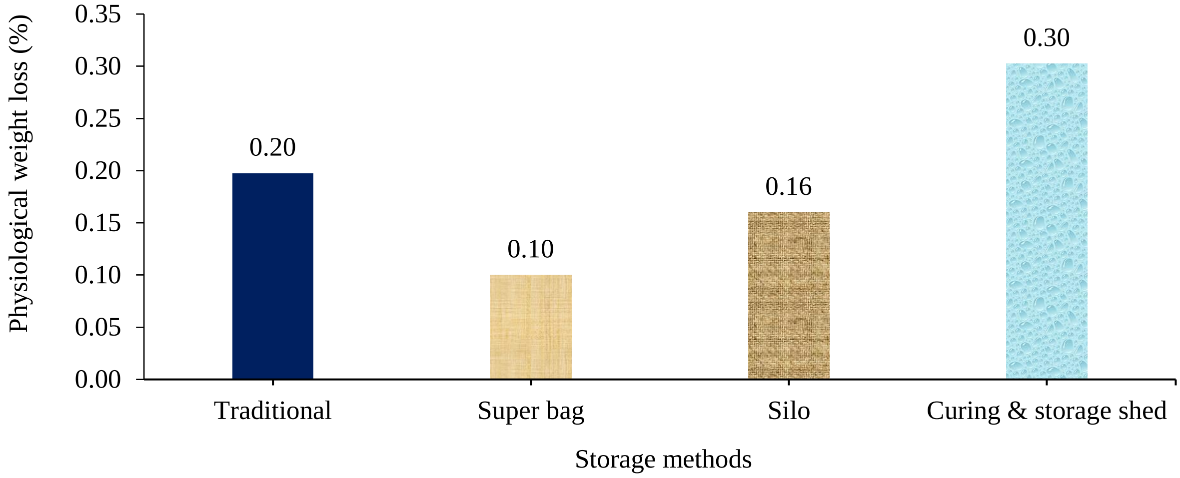

Figure 2. Mean physiological loss of weight (%) of maize grains stored under different storage methods over the four months of the storage period

3.8 Overall storage losses

After five months in storage, the highest overall insect damage of 2.54 % **was** observed in the maize stored in the traditional storage method followed by 1.79 % for the maize grains from curing and storage sheds (Figure 3). The insect damages were 0.64 % and 0.27 % for the super bag and silo storage, respectively. The higher damages in traditional, curing and storage shed could be due to the good airflow that is required for insects to thrive while the slightly enclosed nature of maize in the silo and super bag deterred insects to an extent. Fungal damages, in general, were quite low for maize grains from all the storage methods (0.19 to 0.31 %). It is believed that proper drying of maize and bringing the moisture to recommended levels before storage helped in keeping the fungal and mould growth to a very minimal level. The overall storage losses to insect and fungal damages were highest for traditional storage method grains at 2.80 % followed by 1.98 % for curing and storage shed while super bag and silo stored grains recorded 0.95 % and 0.51 %, respectively after five months of storage. In general, the overall damage of maize grain was observed quite low irrespective of storage methods for the five-month storage period. Based on the findings from this study, maize grains harvested in February (late winter to early spring) could be stored without maximum losses to insect and fungal damages in all kinds of storage methods if grains are harvested at the right maturity stage and properly dried before storage and if only good quality grains are put into storage.

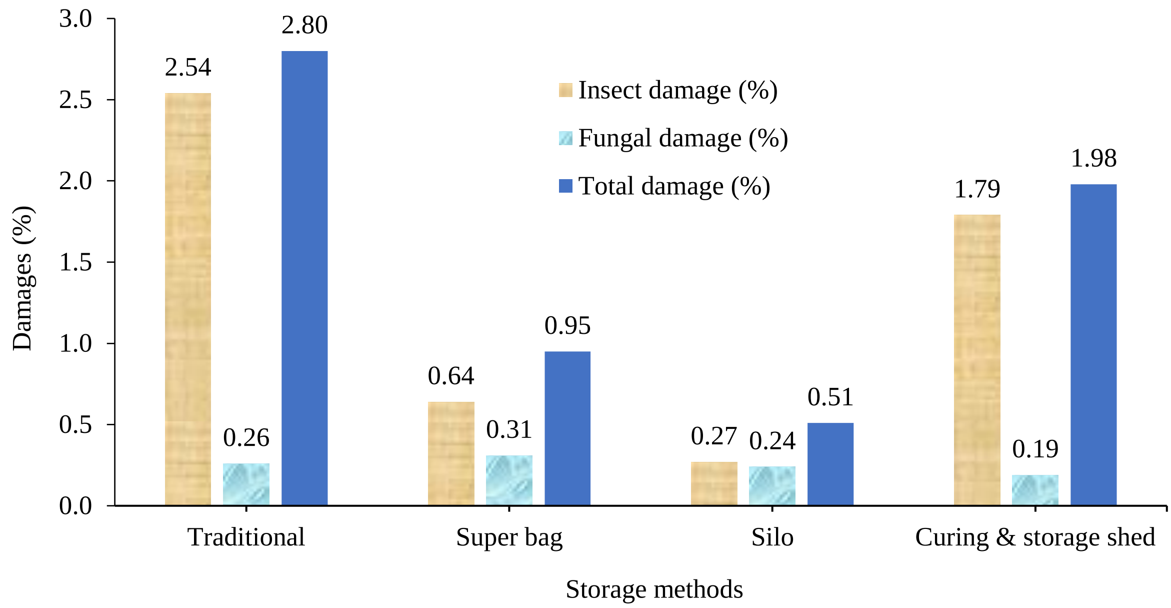

Figure 3. Total maize grain damage by insects and fungi throughout the five-month storage period under different storage methods

The trend for overall storage losses of grains over five months storage period is shown in figure 4. The overall storage losses of grain were slightly higher from the traditional storage method except for months three and four where super bag recorded slightly higher overall storage loss. Silo storage recorded the least overall storage loss during the storage period.

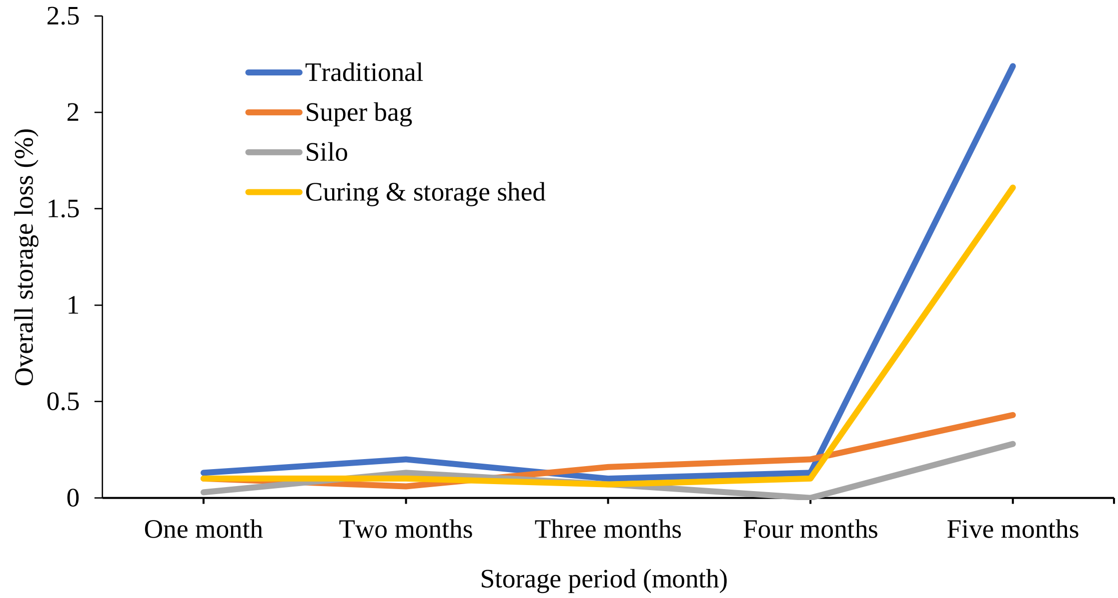

Figure 4. Overall storage losses of grains under different storage methods over the five months storage period

4. Conclusion

The moisture content of the grains remained within the recommended range for safe storage in all the storage methods over the five month storage period. Physiological weight loss was slightly higher for grains stored in curing and storage shed and traditional method while lower physiological weight loss was observed in grains stored in the super bag. Generally, insect damages were higher than damages from fungal diseases except for silo storage in some months. The lowest insect damage was reported in grains from silos while curing and storage shed reported the lowest fungal damage. The minimum overall storage losses were observed in the grain from silo storage compared to the highest that was recorded for the traditional method of storage after five months in storage. Silo could be useful for maize storage if placed under cool conditions away from direct sunlight and heat and grains. All the storage methods performed similarly in storing the grains for five months without alarming differences in losses. The storage losses in maize could be significantly reduced by adopting the four different storage methods. However, adequate awareness programs have to be instituted on these approaches like proper drying of maize grains before storage and keeping the storage bags, silos and sheds in the cool condition away from direct heat and sunlight. To validate these findings, it is recommended that a repeat of the study be carried out to evaluate these storage methods for the maize crops harvested and stored during summer.

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