Assessment of Storage Losses of Maize in Three Districts of Bhutan

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ABSTRACT

Storage loss of maize (Zea mays) in Bhutan is assumed to be high but there is insufficient data to validate it. This study was conducted in the three major maize growing districts of Bhutan covering nine locations to assess and determine the storage losses of maize in traditional method of storage in the attic floors and hanging method. The total grain loss was estimated as the sum of the percentage of grains damaged by insects and fungal diseases counted from two different storage methods and at different storage months which is estimated to be six months of storage period. At the end of six months storage, the total mean storage losses were 16.18%, 38.21% and 23.83% for Chukha, Dagana and Mongar, respectively. The damage from insect during storage was recorded at 9.11%, 36.41% and 9.81% during December while in March it increased to 14.91%, 21.99% and 15.7% for Chukha, Dagana and Mongar, respectively. Similarly, fungal damage increased from 0.95%, 8.10% and 6.50% in December to 1.27%, 16.22% and 8.03% in March for Chukha, Dagana and Mongar. There was no significant difference in losses from insect, fungal damages and total storage losses between the two storage methods. Storage losses of maize grains from insect infestation were higher compared to fungal diseases in all the study locations. Storage losses were slightly higher in the low altitude locations in all the three districts. The survey findings indicated that there is a major loss of maize during the storage with maximum losses caused by insect damage followed by fungal infection. This study recommends the design and promotion of improved storage methods and interventions in good post-harvest management to minimize losses during the storage.

Keywords: *Maize, Storage loss, Insect, Fungal*

1. Introduction

Maize (*Zea mays*) is the staple food of many Bhutanese especially in the six eastern and southern Dzongkhags of Bhutan. Maize cultivation constituted 46.3% of total cultivated area for cereals and maize constituted 45% of cereal production (MoAF, 2015). Mongar, Tashigang, Dagana, Samdrup Jongkhar, Sarpang, Pemagatshel, Tsirang and Zhemgang are major maize producing Dzongkhags in Bhutan (MoAF, 2015). It is also cultivated in small quantities in other Dzongkhags of Bhutan for self-consumption and as a cash crop in recent years.

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In the year 2017, total maize production was recorded at 94,051 MT from 66,043 acres of land with the highest production in the Dzongkags of Tashigang, Mongar, Samdrup Jongkhar, Samtse, Tsirang, Dagana and Pema Gatshel (NSB, 2018). Mongar and Tashigang recorded the highest production of 15,871 MT and 15,559 MT, respectively. With improved technologies in farming, the production of maize is increasing but the post-harvest management and technologies are still poor in the country. This leads to a high quantity of maize loss in the post-harvest stages particularly during storage. 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 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 at a price of Nu.10/kg. In an unpublished report by National Post Harvest Center (2015), the damages from insects, fungal and birds were studied in Tashigang, Tashi Yangtse, Lhuntse and Samdrup Jongkhar districts and reported to be 7.6% at the beginning of the storage.

Globally, Food and Agriculture Organization (FAO) of the United Nations predicts that 1.5 billion Mt of food are wasted or lost per year (FAO, 2019a). The food losses and waste amounts to roughly US$680 billion in industrialized nations and US$310 billion in developing countries. In another data from FAO and World Bank it was revealed that post harvest loss of cereal in Sub Saharan Africa ranged between 5-40 % with an estimated value of around $4 billion (FAO, 2019 b). Losses of cereal crops such as maize in the developing countries are estimated to be as high as 25% of the total production. Losses of 50-60% of cereal grain occur during the storage period due to lack of proper storage management and structures (Kumar & Kalita, 2017). It was reported by Meronuck (cited in Suleiman & Kurt, 2015) that losses of maize in various storage facilities in undeveloped tropical countries are in the range of 15-25%. In a survey study carried out in Nepal, 62% of the respondents expressed insects as the major cause of maize loss in storage and 39% of the respondents presumed storage losses to be between 10-20% (Bhandari et al., (2015).

In Bhutan, traditional method is still practiced for storage of maize. In traditional practice, maize is usually stored by piling in the attics or in small rooms attached to the house while some others keep the cobs hanging from ceilings of their houses. The traditional methods of storing de-husked maize in these methods were also described in a socio-economic impact assessment of maize commodity (DoA & PPD, 2018). These kinds of storage lead to favorable conditions for growth of fungal infections and storage pests thus incurring significant losses during storage. According to Basappa et al. (2005), the important factors leading to storage losses are long duration storage using traditional method, inadequate knowledge, poor storage structures, non-availability of separate godowns and damage by rodents, insects and dampness. Kiaya (2014) described poor storage conditions in general as one of the major factors contributing to post harvest losses of grains.

With conventional practice of maize storage and conditions favoring the growth of fungal pathogens and insects, it is presumed that the storage loss of maize in Bhutan is quite high.

However, the country does not have enough data to validate the storage losses in numbers. Therefore it is important to assess the total storage losses of maize through traditional storage practices in Bhutan.

This study assessed the storage losses in the two traditional storage methods commonly practiced by farmers in Bhutan. It was conducted with an objective to obtain the baseline data on the quantity of storage losses of maize in Bhutan under traditional storage methods. The survey also aimed to specifically assess the amount of grain loss due to damage by insects and fungal infections during the storage months. The data and findings from the study will provide useful information on the amount of maize loss during storage period that can be used for future interventions and remedial actions.

2. Materials and Method

2.1. Survey area, sample size and parameters studied

Storage losses of maize were conducted by surveying selected households in three districts of Bhutan; Chukha, Dagana and Mongar as shown in Table 1. A major maize growing village was selected in each Gewog and five numbers of households were randomly selected from each of these villages. A total of 30 households were surveyed from each districts (15 households for each storage method).

From each selected households, five numbers of maize cobs were randomly picked and shelled. The total number of grains, total grains damaged by insects and total grains damaged by fungal diseases were counted and recorded from each household. All the grains that have been infested by insects are counted as insect damaged grains and the grains that have been infested by fungal rots are counted as fungal damages.

Table 1.Information showing the study locations, number of households and altitudes

Districts	Gewogs	No of households surveyed		Altitude (masl)
		Storage Method 1	Storage Method 2	
Chukha	Sampheling	5	5	300-350
	Bongo	5	5	1425-1500
	Darla	5	5	1590-1700
Dagana	Karmaling	5	5	150-250
	Tshangkha	5	5	650-800
	Kana	5	5	1250-1600
Mongar	Thangrong	5	5	1400-1500
	Silambi	5	5	1850-1900
	Narang	5	5	2000-2100

The post-harvest storage losses were determined in two different traditional storage methods practiced by farmers in Bhutan. Storage method one corresponds to the practice of storing de-husked maize cobs on the attic floor of their house where as storage method two consisted of hanging the de-husked cobs from the ceilings of their houses. The survey to assess the storage losses was started three months after harvest of maize. The first survey was done in December, second in January, third in February and fourth in March. The survey was conducted three months after storage based on the preliminary survey findings undertaken by the National Post Harvest Center in 2015. This preliminary survey found that major losses occur around three months after storage due to fungal and insect infestations. These months were also selected because maize planting usually starts from March.

2.2. Determination of total storage losses to insects

The total storage loss was expressed in percent as follows;

$$(\%)\ TSL = \frac{A+B}{C} * 100 \quad (1)$$

Where,

TSL=Total storage loss (%)
A= quantity damage by insects
B=quantity damages by fungal
C=Total grain quantity

2.3. Determining the moisture content of maize grains

The shelled maize grains were filled into the measuring cup of the moisture analyzer (Portable digital moisture meter, A-Grain, India) and moisture content was measured and recorded from each sample.

2.4. Statistical analysis

The data was analyzed by one way ANOVA and the significance of treatment means were compared through Tukey's test (P<0.05) in SPSS version 16.

3. **Results and Discussion**

Findings from this study show that the major storage loss of maize was due to insect infestation. Regardless of the two storage methods used, insect infestation of grain was the major cause of storage losses. The losses due to storage insect were recorded at 14.91%, 15.79% and 21.99% for Chukha, Mongar and Dagana districts, respectively. Although fungal infections caused significant losses it was lower compared to insect infestation. The storage loss from fungal infection was recorded at 1.27%, 8.03% and 16.22% in Chukha, Mongar and Dagana Dzongkhags, respectively. The total storage losses recorded after six months of storage in storage method one was 16.18%, 23.83% and 38.21% while total storage losses in storage method two was 8.57%, 23.86% and 37.52% for Chukha, Mongar and Dagana districts respectively (Table 3). The moisture content of maize grains from the study sites was found to be at an optimum level indicating that moisture is not a major issue for maize storage in Bhutan.

3.1 Storage losses between storage methods

The findings showed that insect loss was slightly lower in storage method two compared to loss in storage method one in the surveyed gewogs, but without any significant differences. However, a slightly higher significance loss was observed in Karmaling, Kana and Thangrong Gewogs (Table 2). The slightly lower insect damage in storage method two could be due to better ventilation that resulted in free movement of air that helped reduce insect infestation.

Similarly, loss due to fungal infection was slightly lower in storage method two compared to storage method one except in Sampheling Gewog as shown in Table 2. There was no significant difference in fungal losses between the two storage methods for all the locations except in Tshangkha and Kana Gewogs. The total losses to insect and fungal were in the range of 0.31%-64.65% for storage method one and 0.22% - 59.35% in storage method two (Table 2). The high storage losses in these locations could be due to the traditional storage structures that result in favorable conditions for growth of insects and fungal pathogens. According to Katwal, Dorji and Wangdi (2009), maize grains should be stored at a temperature of 10 ˚C or lower with relative humidity levels between 45% - 55%.

Table 2. Storage losses (%) of maize between two methods of storage in December

Gewogs	(%) Insect		(%) Fungal		(%) Mean	
	Storage method 1	Storage method 2	Storage method 1	Storage method 2	Storage method 1	Storage method 2
Sampheling	22.26±9.4[a]	14.04±6.5[a]	0.79±0.6[a]	8.08±7.4[a]	23.05±9.7[a]	22.12±8.5[a]
Darla	1.61±0.7[a]	0.83±0.1[a]	1.39±1.0[a]	1.27±0.8[a]	3.01±1.6[a]	2.11±0.8[a]
Bongo	3.44±1.2[a]	3.93±1.3[a]	0.66±0.2[a]	0.34±0.1[a]	4.11±1.2[a]	4.27±1.3[a]
Tshangkha	12.90±1.7[a]	8.79±0.3[a]	4.29±0.5[a]	2.75±0.3[b]	17.20±2.1[a]	11.54±0.5[a]
Karmaling	51.18±1.0[a]	47.05±0.8[b]	13.46±0.6[a]	12.29±0.7[a]	64.65±1.5[a]	59.35±1.0[b]
Kana	45.14±0.5[a]	42.32±0.7[b]	6.56±0.3[a]	4.67±0.4[b]	51.70±0.7[a]	46.99±0.9[b]
Narang	2.66±2.0[a]	0.79±0.3[a]	19.18±10.3[a]	0.16±0.1[a]	21.85±9.7[a]	0.95±0.3[a]
Silambi	0.06±0.0[a]	0.20±0.0[a]	0.25±0.1[a]	0.02±0.0[a]	0.31±0.1[a]	0.22±0.1[a]
Thangrong	26.72±1.0[a]	14.78±1.3[b]	0.07±0.0[a]	0.16±0.1[a]	26.79±1.1[a]	14.94±1.3[b]

Means within the rows with different superscript are statistically significant at $P < 0.05$ for each category (Mean ± standard error)

3.2 Total storage losses between districts for each month

The total storage loss from insect and fungal disease was significantly high at 44.52% (storage one) and 39.30% (storage two) in Dagana compared to the other two districts in December (Table 3). The storage loss increased with increased in storage time of the maize except for a decrease in Dagana at the end of storage in March as shown in Table 3. The loss to insect was significantly higher in Dagana compared to that of Chukha and Mongar for both storage types in all the four months. The hot and humid climate of Dagana district could be the contributing factor for high damage and losses. Most of the storage molds and insects grow rapidly at the temperatures between 20-40 °C and a relative humidity of 70% and above (Kumar & Kalita, 2017). The different maize varieties cultivated by people from different districts could also be the reason for higher loss in Dagana. The post-harvest loss was reported to be 26% higher among the farmers growing traditional varieties compared to those who adopted modern varieties in a maize impact study in Bhutan (Shrestra et al., 2006).

Cao et al.,(cited in Dowell & Dowell, 2017) reported that losses of grains including maize can be as high as 20-80% within few months of storage if the insects are not controlled. Mihale et al., (cited in Suleiman & Kurt, 2015) reported that 10-50% of the maize is lost to insect pests while Bankole and Mabekoje (cited in Suleiman & Kurt, 2015) described insects and pests as a major threat to maize losses during storage and on farm.

Meronuck (cited in Suleiman & Kurtt, 2015) reported that losses of maize in various storage facilities in undeveloped tropical countries are in the range of 15-25%. In a previous study by Basappa (2006) the storage loss of maize was found to be 21.86% in Karnataka, India. The study reported long storage duration in traditional structures, insects, fungi and lack of knowledge among the farmers as some of the causes of losses. Similar to their findings, the total storage losses in this survey was 16.18%, 23.83% and 38.21% for storage method one and 8.57%, 23.86% and 37.52% for storage method two for Chukha, Mongar and Dagana districts respectively at the end of storage in March as shown in Table 3. The findings from our survey are also closer to the maize impact study conducted by Shrestra, Katwal and Ghalley (2006) where it was reported that there was an overall post-harvest loss of 20% in the farm survey on maize in Bhutan.

Table 3. Total storage loss (%) of maize in each storage types between districts for each month

District	Storage method 1				Storage method 2			
	Dec	Jan	Feb	March	Dec	Jan	Feb	March
Chukha	10.06^{b}	9.86^{b}	5.41^{c}	16.18^{b}	9.50^{b}	10.36^{b}	10.86^{b}	8.57^{c}
Dagana	44.52^{a}	57.09^{a}	70.99^{a}	38.21^{a}	39.30^{a}	56.30^{a}	68.65^{a}	37.52^{a}
Mongar	16.32^{b}	5.63^{b}	36.18^{b}	23.83^{ab}	5.37^{b}	7.12^{b}	25.96^{b}	23.86^{b}

Mean values in the same column with different superscript are significantly different between districts for each month for storage method one and two, respectively at $P<0.05$ by ANOVA

3.3 Storage losses between storage months within each Gewog

Insect, fungal and total storage loss were determined and compared between the storage months for each gewog. The grain quantity loss to both insect infestation and fungal infection differed between the gewogs. In general, Tshangkha, Karmaling and Kana Gewogs of Dagana district had a higher loss to both insect and fungal disease as shown in Table 4. This could be due to the prevailing hot and humid weather condition in these gewogs. The general trend was that grain loss increased with the increased in storage time except in few cases where it fluctuated between the storage periods. In general, the maize loss due to insect damage was higher compared to losses from fungal damage (Table 4).

Table 4. Month wise grain loss (%) in each category for each Gewog for storage method one

Gewogs	Months	Insect loss (%)	Fungal loss (%)	Total loss (%)
Tshangkha	December	12.90±1.68[b]	4.30±0.54[c]	17.20±2.16[b]
	January	20.84±3.41[ab]	6.06±0.57[bc]	26.91±3.88[ab]
	February	28.94±4.50[a]	7.57±0.63[b]	36.50±5.08[a]
	March	22.40±0.88[ab]	13.68±1.04[a]	36.08±1.08[a]
Karmaling	December	51.19±1.02[b]	13.46±0.58[b]	64.65±1.46[b]
	January	52.44±3.09[b]	18.60±1.86[a]	71.04±2.96[b]
	February	86.21±4.09[a]	0.30±0.08[c]	86.51±4.09[a]
Kana	December	45.14±0.52[c]	6.56±0.32[c]	51.70± 0.74[c]
	January	65.81±3.86[b]	7.53±0.57[c]	73.34±3.52[b]
	February	77.14±2.12[a]	12.83±1.62[b]	89.98±1.14[a]
	March	21.58±0.52[d]	18.75±1.73[a]	40.33±1.70[d]

Mean values in the same column are statistically significant between storage months for each category within Gewog at $p < 0.05$ (Mean ± standard error)

3.4 Storage losses between the Gewogs for each district (Storage method two)

Maize loss in each category was compared between the gewogs for each particular district as shown in Table 5. The gewogs for each district has been categorized as low, medium and high altitude. In Chukha district, Sampheling Gewog located in low altitude had generally higher losses due to damage from insect and fungal infection. The total losses ranged from 22.1%, 25.2%, 24.2% and 12.2% during the months of December, January, February and March respectively. The total losses in Bongo (medium altitude) was 4.28%, 4.72%, 6.21% and 10.8% while total losses in Darla (higher altitude) was 2.11%, 1.10%, 2.12% and 1.90% during the indicated months (Table 5). The results were similar for three gewogs of Dagana district with low altitude Karmaling recording higher losses in December (59.3%), January (79.4%), February (82.6%) and March (56.01%) (Table 5). Kana and Tshangkha had significantly lower losses compared to losses from Karmaling Gewog except for higher loss in Kana during February month. The higher loss in low and medium altitude gewogs could be due to the hot and humid climate that leads to favorable environment for growth of storage insects and fungal diseases. Kumar and Kalita (2017) described that most of the storage molds grow rapidly at the temperature between 20-40 °C and a relative humidity of 70% and above. In Mongar district, Thangrong (low altitude) and Narang (mid altitude) had slightly higher losses compared to Silambi Gewog (high altitude) as shown in Table 5. Total losses in December was 14.9%, 0.95% and 0.22%, while total losses in March increased to 40.84%, 27.71% and 3.03% for Thangrong, Narang and Silambi Gewogs, respectively.

Table 5. Total storage losses between Gewogs within same district for storage method two

Gewog	Total losses (%) for storage method two			
	December	January	February	March
Sampheling	22.13±8.05^{a}	25.26±10.65^{a}	24.26±8.76^{a}	12.93±3.40^{a}
Darla	2.11±0.76^{b}	1.10±0.59^{b}	2.12±0.76^{b}	1.90±0.45^{b}
Bongo	4.28±1.34^{ab}	4.72±1.22^{ab}	6.21±1.52^{ab}	10.88±2.19^{a}
Tshangkha	11.54±0.49^{c}	19.14±2.41^{c}	31.81±3.33^{b}	28.09±2.28^{b}
Karmaling	59.35±1.03^{a}	79.43±1.85^{a}	82.61±3.08^{a}	56.01±5.37^{a}
Kana	46.99±0.89^{b}	70.35±2.74^{b}	91.53±1.69^{a}	28.46±1.48^{b}
Narang	0.95±0.27^{b}	1.92±0.03^{b}	39.24±1.92^{a}	27.71±0.98^{b}
Silambi	0.22±0.09^{b}	0.42±0.10^{b}	3.15±0.33^{b}	3.03±0.31^{c}
Thangrong	14.94±1.30^{a}	19.01±5.04^{a}	35.50±1.61^{a}	40.84±0.80^{a}

Means in the same column with different superscript are statistically significant between Gewogs within same district at $P < 0.05$ (Mean ± standard error)

3.5 Moisture content of maize

Moisture content of maize sampled from storage method one was in the range of 9.28-13.98% while moisture content of maize from storage method two was in the range of 9.14-13.44% (Figure 1). The moisture content of stored maize grains was found to be within the range recommended for maize storage. This indicates that high moisture content is not a major cause of storage loss in Bhutan. According to FAO (1992), the moisture content of maize for storage is recommended to be between 12-14%. An extension manual on quality maize seed production through community based seed production approach in Bhutan also mentioned the required moisture content for maize storage to be 13% (Katwal et al., 2009). Moisture content is important to ensure good long term storage of maize grains. Generally, higher moisture content leads to increased damage from insects and fungal pathogens (Goudoungou et al., 2017). It was reported by Weinberg et al. (2008) that mold numbers in maize under hermetic storage for 75 days were found to be the lowest when the moisture content of maize was 14% and the mold numbers increased as the moisture in maize increased to 16%, 18%, 20% and 22%.

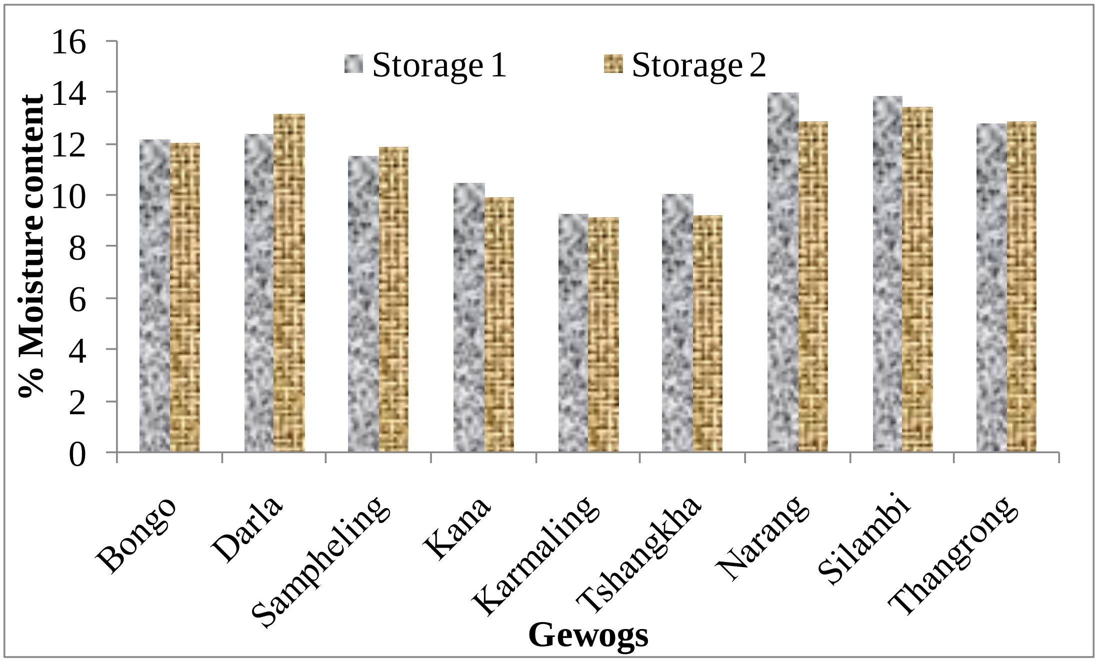

Figure 1. Moisture content (%) of maize grains stored in storage method one and storage method two in December

4. Conclusion

This study showed that there is a high quantity of loss in maize grain during storage. Storage loss was slightly higher in the storage method one but without any significant difference. This study found that the major storage loss of maize was due to insect infestation in both the storage methods surveyed in all the three districts. Regardless of the two storage methods that have been surveyed, losses due to insect infestation of grains were the major cause of storage losses. Maize grain losses due to fungal infection were lower than losses caused by insect infestations. In all the three districts, grain losses were higher in low altitude gewogs in both the traditional storage methods practiced by Bhutanese farmers. Among the three districts, Dagana had significantly higher storage losses in both the storage methods in all the surveyed months. The moisture content of maize grains from the study sites were found to be at an optimum level recommended for long term storage of maize grains.

Improved storage facilities with good ventilation and insect proof system should be designed and introduced to the farmers to minimize the storage losses. Capacity building of farmers on proper harvesting time, techniques and proper handling and storage management will help in minimizing the storage losses. It is recommended that the relevant stakeholders work together and come out with effective storage facilities to minimize storage loss of maize grains from insect and fungal infections.

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