Evaluation of Effect of Storage Period on Bulk density of Stored Grain Maize (Zea mays L.)

*Negasa Fufa¹, Solomon Abera² and Girma Demissie³

¹Ambo Agricultural Research Center, P.O. Box: 37, Ambo, Ethiopia
²Department of food Science and Post-Harvest Technology, Haramaya Institute of Technology, Haramaya University, P.O. Box: 138, Dire Dawa, Ethiopia
³Holleta Agricultural Research Center, P.O. Box: 31, Holleta, Ethiopia

The experiment was conducted in 2017/18 for the evaluation of effect of storage period on bulk density of stored maize grains. The experiment was replicated three times in randomized complete block designs. The treatments were three storage types (Gombisa, sack and Hermetic bag and storage periods (initial loading day, 1, 2, 3, 4, 5, and 6) months. All the data collected was subjected to analysis of variance (ANOVA) by using the PROC GLM procedure and difference among means were compared by the least significant difference (LSD). The correlation between parameters was examined using Pearson’s correlation coefficient using PROC CORR procedure of the SAS software. The result showed significant different (P<0.05) among storage periods and high bulk density 704.3 Kg/m³ was recorded in the initial first two months of storage whereas, the minimum 556.4 Kg/m³ value was obtained in 6 months. The bulk density values in each storage exhibited significant reduction as the storage periods increased reaching down to 523.3 kg/m³ for Gombisa and 573.0 Kg/m³ for Sack and Hermetic bag at the last six months of storage periods. From this study, it can be concluded that until the fourth months of storage the grains have better bulk density and also Hermetic bag storage showed better result throughout the storage periods.

Key words: - Bulk density, Hermetic bag, Maize, Storage period, Weight loss

INTRODUCTION

Maize (Zea mays L.) is the second most extensively cultivated crop next to Teff in Ethiopia and is grown under diverse agroecology’s and socioeconomic condition typically under rain-fed production (Tseke et al., 2015). During the last 10 years, average farm yield of maize increased from 1.8 to 3.7 t ha⁻¹ (205%) (Eyob, 2015). Three forth of the maize produced is consumed at the household level by the small-scale producers themselves (CSA, 2017). According to Marta et al. (2017), maize contains moisture (16.7% wet base), starch (71.3% dry base), protein (9.91% dry base), fat (4.45% dry base), ash (1.42% dry base) and crude fiber (2.66% dry base). Maize also contains pentoglycans (6.2% dry base), cellulose and lignin (3.3% dry base), total sugar (2.58% dry base) and total carotenoids (30 mg/ kg). The same authors reported that the amount of carbohydrates in maize ranges from 72-73% of kernel, whereas, protein ranges from 6-12% depending upon the varieties. Maize is also rich in functional food components, such as dietary fiber, essential fatty acid, Isoflavones, Fe mineral, β-carotene as pro-vitamin A and the essential amino acids of lysine and tryptophan (Marta et al., 2017). It can be processed into different breakfast items, food and feed ingredients and beverages for its consumption throughout the world (Chakraverty, 1988; Rajoo, 1998). So, maize is instrumental for the food security of Ethiopian households, and is the lowest cost caloric source among all major cereals, which is significant given that cereals dominate household diets in Ethiopia (CSA, 2016). For this reason, the demand for maize has been estimated to increase by 50%, from 558 million metric tons in 1995 to over 800 million metric tons in 2020 (Martinez et al., 2011). Although, agriculturalist have direct role in raising the crops yet utilization and demand of the crops still remains
the decisive factor. Therefore, to explore the potential of conventional grains, relevant machinery and equipment for processing operation is considered. Furthermore, adequate design, knowledge of physical properties of grains have paramount importance (Bhise et al., 2014). Attempts have been made by Thompson and Ross (1983) to determine packing factors and compressibility of different cereal grains. Grain densities have been found necessary in breakage susceptibility and hardness studies (Heidarbeigi et al., 2009). Test weight or density can be affected by moisture, mechanical and insect damage because all three parameters affect either the kernel volume or the bulk or kernel weight (Danping, 2015) and can be useful in sizing grain hoppers and storage facilities (Bhise et al., 2014). The same author further reported bulk density of hermetically stored maize and maize stored in polypropylene (Shumba) decreased until 12 weeks storage before increasing until the end of the trial. The bulk density of the grains in Zero Fly and polypropylene bags decreased consistently from 775 kg/m$^3$ at the start of storage to 699.0 kg/m$^3$ and 673.5 kg/m$^3$, respectively, at the end of storage. This reduction in bulk density seems to be caused or influenced by insect damage in the form of loss in dry matter or kernel (Adebayo, et al., 2017). According to (Danping, 2015), bulk and kernel density decreased for most grains including corn when the moisture content was increased. Grain damage and weight losses could result from the attacks of insects, microorganisms, rodents and birds (Nukenine, 2010; Waktole and Amsalu, 2012). However, there is little information of the work done on the effect of storage period on the bulk density which was considered in this study. Therefore, the objective of this study was to evaluate the storage period on grains density, to facilitate better grains quality and to recommend good storage periods for maize Producing farmers. Consequently, grain stored until the fourth months of storage the grains have better bulk density and also Hermetic bag storage showed better result throughout the storage periods.

**MATERIAL AND METHODS**

**Description of the Study Area**

This study was conducted at Bako Agricultural Research Center located in East Wollega Zone of the Oromia Regional State, western Ethiopia at an altitude of 1650 meters above sea level (m. a. s. l). Bako lies at 9° 6” north latitude and 37° 9” east longitude in the sub-humid ecology of the country 260 km west of Addis Ababa and 8 km away to the South from the main road to Nekemte. Average annual rainfall at this location is 1237 mm. The rainy season extends from May to October and maximum rain is received in July and August. Agroecologically, it has a warm humid climate with mean minimum, maximum and average air temperatures of 15, 30 and 23 °C respectively. The RH maximum, minimum and average of the area is (74.7, 49 and 61.85%), respectively. The major annual and perennial crops of the area include maize, sorghum, teff, nough, hot pepper, haricot bean, sweet potato, mango, banana, and sugar cane in order of importance. The study was conducted for six (6) months starting from harvesting time in December 2017 to May, 2018 at Bako National Maize Research Center.

**Experimental design**

The experiments were arranged in a factorial combination with two factors, storage types and storage period in a complete randomized design with three (3) replications. Storage types have three levels i.e. Gombisa, Sack and Hermetic bag while storage period have six levels that is (initial loading day, 1, 2, 3, 4, 5 and 6) months of storage periods. Data were collected at every two months interval, including at the start of the study making up four levels for the factor storage period. The study materials were BH-661 maize of variety harvested in December 2017 and three types of Gombisa (which is made up of wooden, thatch-roofed and mad plastered), Sack and Hermetic (which has triple layers and air tight) bag storage structures (figure 2 and 3).

**Sampling methods**

A total of 63 samples of BH-661 maize variety were collected from each of storage structures periodically starting from the beginning of the storage (initial loading day, 1, 2, 3, 4, 5, and 6) months of storage periods. The initial samples taken from each storage structure was considered as a control. Each sample was taken by inserting the compartmented spear into the grain mass straight to the maximum depth from the top, side, middle and the bottom of the storage.

**Data to be collected**

**Moisture Content**: Grain moisture content was determined by using the (AACC, 2005) standard procedures of oven-dry methods. The grain was dried at a temperature of 105°C for three hours and after removed from the oven wait to cool in a dissector and then weighed. Then, the moisture content was calculated as follows:

$$MC\% = \frac{Wi - Wf}{Wf} \times 100$$

Where $Wi$ = weight initial, $Wf$ = weight final

**Germination (%)**: Germination test was carried out according to international seed testing association standard (ISTA, 2005). This was done by using counting of 25 maize seeds from the pure seed by multi auto electric counter. The 25 pure seeds of each sample were placed in Petri dishes containing filter paper soaked with distilled water. Germination count was made every day up to the completion of germination at seven days. A seed was plume and radicle arose out up to 2mm length. Germination percentage was calculated using the formula described by (Tame, 2011).

$$G% = \frac{\text{No. of germinated seeds}}{\text{Total No. of seeds soaked}} \times 100$$
Figure 1. Map of the Study Area

Figure 2: Traditional Gombisa and Hermetic Bag storage

Figure 3: local storage used by farmers (Control)
**Grain damage (%)**: Grain damage was collected and assessed for insect-damage using a conventional ‘count and weigh’ method. Each five hundred (500g) grains were taken from initial to last storage periods and from each of the storage types and the number of insect damaged and un-damaged grain were obtained using a hand lens by searching for the presence of hole on the seeds. The percentage of insect damaged grains was calculated according to the methods used by (Wambungu et al., 2009) as follows:

\[
\text{PIDG} \, (\%) = \frac{\text{Number of insect-damaged grain}}{\text{Total number of grain}} \times 100
\]

Where, PIDG = percentage of insect-damaged grain

**Weight loss (%)**: Percent weight loss (PWL) was computed by the count and weigh method according to the procedure used by Boxall (1986) using the following equation:

\[
\text{PWL} \, (\%) = \frac{[\text{Wdg} \times \text{Ndg}) - (\text{Wsg} \times \text{Nsg})]}{\text{Wdg} \times (\text{Nsg} + \text{Ndg})} \times 100
\]

Where, WL = Weight Loss, Wdg = weight of undamaged grains, (Wsg) = weight of damaged grains, Nsg = number of undamaged grains, Nd g = number of insect damaged grains.

**Bulk density (kg/m³)**: The average bulk density of the grains was determined using the standard test weight reported by (Singh and Goswami, 1996; Bhise et al., 2014) procedure by filling a container of 500 ml with grain from a height of 150mm at a constant rate and then weighing the samples using digital electronic sensitive balance. Bulk density for each replication was calculated using the following formula:

\[
\text{Bd} \, (\text{kg/m}^3) = \frac{\text{Ws} \, (\text{kg})}{\text{Vs} \, (\text{m}^3)}
\]

Where, Bd = bulk density, Ws; is the weight of the sample in kg; and Vs is the volume occupied by the sample in m³.

![Figure 4: digital electronic sensitive balance](image)

**Data analysis technique**

All the data collected in 2017/18 were subjected to analysis of variance (ANOVA) by using the PROC GLM procedure (SAS Institute, 2004) and difference among means were compared by the Least Significant Difference at 5% level of significance (Steel and Torrie, 1980). The correlation parameters were examined using Pearson’s correlation coefficient using PROC CORR procedure of the SAS software (SAS Institute, 2004).

**RESULTS AND DISCUSSION**

**Effect of storage period on germination**

There were highly significant differences (P ≤ 0.0001) among the storage structures on germination. The highest 98.0% mean germination was recorded in the first two months and significantly dropped to 72.0% in the last six months (Table 1). Maximum mean 88.6% germination percentage was recorded in hermetic bag, whereas the minimum values, 72.0% recorded in Gombisa (Table 1). This finding is in conformity with findings by (Kaleta and Górnicki, 2013) the data revealed that the germination decreased during the storage period, and decreased as the moisture content increased. With 18 % moisture content and above the germination decreased to zero after 35 days of storage. Similarly, Befikadu et al. (2012) estimated that germination loss of grain stored in Gombisa and sack increased might be due to destruction of seed by Weevil (Sitophilus species) and Angoumois grain moth (S. cereaella). The bulk density of stored maize grains also showed significant reduction due to the length of storage time.

**Effect of storage period on damaged grain**

The percentage of damaged grain was not significantly different (p>0.05) among the storage structures during the first two months of storage. The highest 9.1% damaged grains were recorded in six months storage periods (Table 1). The highest mean values 12.3 and 9.3 of percentage of damaged grain were recorded in Gombisa and Sack (Table 2). Likewise, Befikadu et al. (2012) estimated 11.50 and 10.75% percentage of kernel damage for Gombisa and Sack respectively after 60 days of storage. Also, other authors (Tefera et al., 2011) explained 10-20% of maize grains were lost after three months of storage. He found that the problem is due to ineffective storage technologies. The mean grain damage and weight losses caused by the pests in traditional storage practices were 64.50 and 58.85%, respectively (24).

**Effect of Storage Periods on Bulk Density and Weight Loss**

Table 3 shows the interaction effect of storage structure and storage periods on bulk density in each storage. The average bulk density was the same for the first two months and it significantly by decreased 523.3 kg/m³ in Gombisa for the last six months. Similarly, grain stored in Sack and Hermetic bag exhibited significant reduction of 573.0 kg/m³ as the storage period increased. This is due to high
infestation of different weevils’ species and causes moisture and temperature increment in the storage which favors mold development to the grains stored. Correspondingly, storage period has an impact on the bulk density and the values were decreased from 704.3 kg/m³ at initial to 556.4 Kg/m³ in the six months of storage periods. This due to biochemical process undergone in the stored grains like respiration. Though, Abass et al. (2014) report the bulk density of stored grain decreased from the original value of 774.8 kg/m³ (at the start of storage) to between 741.9 and 766.7 kg/m³ at 6 weeks of storage. This might be due insect-damaged to the stored grains. High weight loss 13.8% was recorded when grain stored in Gombisa and the minimum 5.0% was recorded in hermetic bag at the last six months. Whereas, according to (Waktole and Amsalu, 2012) the mean percentage of grain damage and weight losses caused by the pests under traditional storage practices were 64.50 and 58.85%, respectively. The finding of Deepak and Prasanta (2017), 0.2% 11.8% of weight loss was recorded due to insect infestation in maize after 6 months of storage in traditional granaries in Togo and 3.2, 7.2 and 8.2% f or PICS bag, polypropylene bag and jute sack. Storage periods were positively correlated and highly significant with moisture content (r = 0.91, p<0.0001), damaged grain (r = 0.93, p<0.0001) and weight loss (r = 0.66, p<0.0001). This indicated that as the storage periods increased the weevil’s growth was favored and this increases the risk of grain damaged, weight loss, moisture development in the storage. Also, storage period was negatively correlated and significant with germination percentage (r = -0.83, p<0.0001) and bulk density (r = -0.91, p<0.0001), respectively, as reported by (Guenha et al., 2014; Bhise et al., 2014). Generally, the maize with higher moisture content undergoes an autolytic digestion (self-digestion). During autolytic digestion, breakdown of nutrients including carbohydrates to supply energy for biochemical processes takes place; due to this the bulk density of the grains decreased. Reduction in bulk density also appears to be influenced by insect damage to the grains.

### Table 1: Main effect of storage period on grain damage, weight loss, germination and bulk density

<table>
<thead>
<tr>
<th>Storage periods</th>
<th>Grain damaged (%)</th>
<th>Weight loss (%)</th>
<th>Germination (%)</th>
<th>Bulk density (kg/m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ILD</td>
<td>-</td>
<td>-</td>
<td>98.0 ±2.02</td>
<td>704.3 ±11.69</td>
</tr>
<tr>
<td>2</td>
<td>-</td>
<td>-</td>
<td>96.7 ±2.37</td>
<td>671.4 ±7.15</td>
</tr>
<tr>
<td>3</td>
<td>0.90 ±0.00</td>
<td>1.20 ±0.00</td>
<td>93.1 ±2.45</td>
<td>641.9 ±3.33</td>
</tr>
<tr>
<td>4</td>
<td>2.7±1.08</td>
<td>3.1 ±1.06</td>
<td>89.8 ±2.32</td>
<td>613.9 ±4.77</td>
</tr>
<tr>
<td>5</td>
<td>4.4 ±1.30</td>
<td>5.3 ±1.30</td>
<td>83.8 ±2.20</td>
<td>593.8 ±2.88</td>
</tr>
<tr>
<td>6</td>
<td>9.1 ±1.72</td>
<td>9.7 ±1.51</td>
<td>78.9 ±1.79</td>
<td>556.4 ±1.97</td>
</tr>
<tr>
<td>LSD (5%)</td>
<td>0.55</td>
<td>0.51</td>
<td>1.6</td>
<td>13.7</td>
</tr>
<tr>
<td>CV (%)</td>
<td>20.2</td>
<td>16.6</td>
<td>1.9</td>
<td>2.3</td>
</tr>
</tbody>
</table>

**Note:** Mean values ± standard deviation of three replicates within each column sharing similar letters were not significantly different by LSD test at P≤0.05, CV: coefficient of variation, LSD: least significant different, kg: kilo gram, m³: meter cube, ILD: initial loading date.

### Table 2: Main effect of storage structures on grain damage, weight loss, germination and bulk density

<table>
<thead>
<tr>
<th>Storage structures</th>
<th>Grain damaged (%)</th>
<th>Weight loss (%)</th>
<th>Germination (%)</th>
<th>Bulk density (kg/m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sack</td>
<td>3.3 ±1.15</td>
<td>2.8 ±0.16</td>
<td>89.3 ±1.94</td>
<td>631.6 ±3.08</td>
</tr>
<tr>
<td>Hermetic</td>
<td>2.1 ±0.67</td>
<td>1.96±0.08</td>
<td>94.2 ±1.79</td>
<td>641.8 ±5.13</td>
</tr>
<tr>
<td>LSD (5%)</td>
<td>0.39</td>
<td>0.36</td>
<td>1.1</td>
<td>1.7</td>
</tr>
<tr>
<td>CV (%)</td>
<td>20.2</td>
<td>16.6</td>
<td>1.9</td>
<td>2.3</td>
</tr>
</tbody>
</table>

**Note:** Mean values ± standard deviation of three replicates within each column sharing similar letters were not significantly different by LSD test at P≤0.05, CV: coefficient of variation, LSD: least significant different, kg: kilo gram, m³: meter cube, ILD: initial loading date.

### Table 3: Interaction effect of storage structures with storage period on bulk density and weight loss

<table>
<thead>
<tr>
<th>Storage period (months)</th>
<th>Bulk density (kg/m³)</th>
<th>Weight loss (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Gombisa Sack Hermetic</td>
<td>Gombisa Sack Hermetic</td>
</tr>
<tr>
<td>ILD</td>
<td>704.3±6.5a 704.3±7.0a 704.3±6.5a</td>
<td>- - -</td>
</tr>
<tr>
<td>1</td>
<td>701.0±5.4a 673.5±5.0a 695.7±5.50c</td>
<td>- - -</td>
</tr>
<tr>
<td>2</td>
<td>656.6±4.7g 667.7±4.45j 690.0±3.56d</td>
<td>- - -</td>
</tr>
<tr>
<td>3</td>
<td>623.3±4.8e 645.7±3.24h 656.7±3.24g</td>
<td>1.00±0.00d 1.40±0.18g 1.10±0.00g</td>
</tr>
<tr>
<td>4</td>
<td>590.0±3.50gh 623.0±3.15e 628.7±3.18f</td>
<td>3.6 ±0.65f 3.2±0.38e 2.40±0.015f</td>
</tr>
<tr>
<td>5</td>
<td>567.7±3.50l 607.0±3.05j 606.7±3.81l</td>
<td>7.6 ±1.20e 5.1±1.21d 3.30±0.53e</td>
</tr>
<tr>
<td>6</td>
<td>523.3±2.50k 573.0±3.1i 573.0±3.61j</td>
<td>13.8±1.67a 10.2±1.61b 5.00±0.53a</td>
</tr>
<tr>
<td>LSD (5%)</td>
<td>3.2</td>
<td>0.51</td>
</tr>
<tr>
<td>CV (%)</td>
<td>2.3</td>
<td>3.7</td>
</tr>
</tbody>
</table>

**Note:** Mean values ± standard deviation of three replicates within each column sharing similar letters were not significantly different by LSD test at P≤0.05, CV: coefficient of variation, LSD: least significant different, ILD: initial loading date.
CONCLUSION

Storage structure as well as storage period have an impact on the bulk density and it significantly decreased 523.3 kg/m³ in Gombisa at the last six months. The highest 13.8% mean values of weight loss were obtained in the sample taken from Gombisa and the minimum 5.0% mean value were recorded in hermetic bag in the last six months. The highest percentage of damaged was observed in Gombisa whereas, maximum 57.3 kg/m³ bulk density and 88.6% germination percentage was recorded in grains sample taken from Hermetic bag. Storage periods were positively correlated and highly significant with temperature \( r = 0.89 \), moisture content \( r = 0.91 \), damaged grain \( r = 0.93 \) and weight loss \( r = 0.66 \). As storage period increases bulk density, germination percentage decreased whereas weight loss and grain damage increased due to insect infestation and fungal attack. Grain stored until the fourth months of storage the grains have better bulk density and also Hermetic bag storage showed better result throughout the storage periods.

ACKNOWLEDGMENTS

We would like to thank Mekdes Kebede, Lemi Yadesa, Debela Diro and Geta Gelana for an endless assistance during the laboratory works.

Conflict of Interests: The authors declare that there was no conflict of interest.

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