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ORIGINAL ARTICLE

Effect of different storage methods on the storability of wheat grain

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ABSTRACT

Information on post-harvest storage of wheat grain in Ethiopia using different storage methods is not well documented. Therefore, the present study was conducted to evaluate the effects of hermetic storage methods on the performance of stored wheat with full factorial design with triplicate. The experiment consisted of six storage methods namely; metal silos, Purdue Improved Grain Storage bag (PICS), Super GrainPro bag, Plastic drum, Triplex applied to wheat in Plastic drum, and polypropylene bag as control. Percentage of grain damage, weight loss, thousand kernel weight, bulk density, live insect counts, dead insect counts, moisture content and water activity were determined after one year of storage. The ANOVA was determined by factorial using R software. Results indicated that storage methods such as PICS, Super GrainPro bags, Triplex applied to drum plastic, and plastic drums led to a significantly ($P<0.05$) lower levels of insect infestation, moisture content, and water activity compared to the control and the metal silo. Moisture content and water activity were significantly ($P<0.05$) higher in the metal silo compared to other hermetic storage methods and the control. The percentage of weight loss and percentage of grain damage were significantly ($P<0.05$) lower in hermetic storage containers compared to the control. Hermetic storage methods including triplex powder applied to plastic drum can extended the stored wheat for a year with a minimum damage and loss of wheat grain.

Key words: Hermetic storage, Wheat, Weight loss, Insect damage, Triplex powder.

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1. Introduction

Cereals (wheat, rice, maize, sorghum, millet, barley, rye, etc.) are common members of the grass family (*a* monocot family *Poaceae*, known as *Gramineae*), have long, thin stalks and good source of carbohydrates, protein, fiber (Sarwar, 2013, Saeid, 2017), starch, energy, micronutrients, especially magnesium and zinc (Sarwar, 2013), fat, ash, fiber, and vitamins minerals (Saeid, 2017).

Wheat (*Triticum aestivum*) is the most widely produced grain and staple food crops in the world (Saeid, 2017). In developing countries, wheat accounts more than 90% of food produced and about 70% of the caloric intake of the people (Kumar & Kalita, 2017). In Ethiopia, wheat is the common and staple grain which is grown next to maize and teff (Dessalegn, Solomon, Gebre Kristos, et al., 2017) and over 90 million population of the country is used it as source of food (Sector et al., 2017).

Preservation of wheat is important to enhance food security by prolong the storability of the cereals after harvested. However, due to poor storage methods there has been a significant (5-26%) wheat grain postharvest losses (Dubale, 2019). Each year, 25–33% of the world's grain crop is lost during storage. In Ethiopia, traditional storage methods are used to keep 49% of the grain crops all these have a severe impact on the world's food security (Alemayehu et al., 2023). Insect infestination is one of the big challenges during wheat grain storage. When wheat grain is stored after harvest without proper storage, insects can damage and even destroy food components (Martin et al., 2015). In addition to insect infestation, mold growth, birds and termites are also factors that facilitate the post-harvest loss of the wheat. This causes not only price discard in markets, less nutritious due to high grain damage (Chattha et al., 2015). That is why many researchers reported in developing nations like Ethiopia, post-harvest management of agricultural products is a big concern (Alemayehu et al., 2023).

In Ethiopia, people have been using different traditional methods to preserve their commodities such as "Gota'', "Gotera'' and poly propylene bags (Kasahun Olana, 2021). However, storability of the grain cannot be extended rather the loss is significantly high due to insects or weevils.

Other alternatives had been used to reduce the loss of wheat grain like synthetic chemicals which are not safe for human health and environment. Thus, recently there are different storage methods to reduce the above problems without the addition of chemicals and are environmentally safe (Worku et al., 2019). The storability of the grain can be prolonged using different hermetic storage methods (Chattha et al., 2015, Hocking., 2003). Thus, looking for safe storage could be best alternative in order to keep the grain from grain damage and weight loss by using hermetic storage methods such as (super GrainPro bag, Purdue improved crop storage bag, metal silo, and plastic drum) and integration method or triplex applied to drum plastic (Martin et al., 2015, Kalsa et al., 2019).

Furthermore, Kalsa et al., (2019) conducted a research on hermetic storage methods on the grain damage and weigh loos for six months storage and similarly Worku et al., (2019) on physicochemical properties of stored wheat. However, little research is conducted on the storability of wheat grain by evaluating the performance of hermetic storage methods beyond six month storage time. Thus, the objective of this research was focused on evaluating the storability of wheat grain using different hermetic storage methods in a period of a year.

2. Materials and methods

2.1. Raw material collection, preparation and experimental site

Wheat grain of *kakaba* variety was obtained from the Ethiopian Seed Enterprise, Bahir Dar Center, Ethiopia that was harvested in 2018. The wheat grain was cleaned to remove broken kernels, chaffs, dusts, then stored for one year (February, 2018 – February, 2019) in different storage methods under ambient conditions with (temperature of 24.6±0.6ºC and relative humidity of 48.2±10.4%, obtained from Ethiopian Meteorology Agency, Bahir Dar branch) at the food engineering laboratories in the faculty of chemical and food Engineering, Bahir Dar institute of technology, Bahir Dar University.

2.2. Experimental Design

Completely randomized design (CRD) was used in this study. The storage methods in six levels (Metal Silo, Purdue Improved Grain Storage Bag, Super GrainPro Bag, Plastic Drum, Plastic Drum with Triplex powder at rate of 0.25% (w/w), and Polypropylene Bag). The entire experiment was conducted in triplicate, and the total runs were 18.

2.2.1 Sampling

One kilogram of wheat sample was taken from each storage methods at the top, bottom and middle to avoid biasness.

2.3. Experimental Analysis

The analysis of the experiment was done using standard methods.

2.3.1. Grain damage and Weight loss (%)

Using the count approach, the proportion of wheat grain damage was estimated (Martin et al 2015). A thirty-gram sieved wheat sample was taken, and the damaged and undamaged wheat samples were separated, with just the insect-damaged region weighing and the number of kernels in each category determined. Damage percent was calculated as followed in equation (1).

$$Insect\ Damaged\ Grain\ (\%) = \frac{ND}{ND+NU} \times 100 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where, ND= number of damaged grains, NU= number of undamaged grains

Weight loss percent was calculated using the following equation as described by (Demissie et al., 2008) and (Kalsa et al. 2019).

$$Weight\ Loss\ (\%) = \times \frac{(WUN \times D)-(WDN \times U)}{WU \times (ND+NU)} 1\times 00 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Where WU= Weight of undamaged kernels,

WD = Weight of damaged kernels

2.3.2. Bulk density

Bulk density was measured, according to the method used by (Kalsa et al., 2019). The sieved wheat grain sample from each treatment was added to the fixed flask of 400ml volume, and the weight was measured using an analytical balance at the precision of 0.1g.

$$Bulk\ Desnsity\ (\frac{kg}{m^3}) = \frac{Mass}{Volume} \text{ ....(3)}$$

To avoid the variation of bulk density (in the above equations) with moisture contents, weights were adjusted to the standard moisture content (13%) using the following equation.

$$Adusted\ Bulk\ Density\ (kg/m3) = \frac{100-MC}{87} \times Bulk\ Density \text{ .... (4)}$$

Where MC the moisture content of wheat

2.3.3. Thousand Kernel Weight (Gram)

A thousand kernel weight of each sample was measured according to the method used by (Kalsa et al., 2019). A total of 1000 of wheat grains were manually counted and measured in analytical balance. The weight of each sample was adjusted to the standard moisture content using the equation (4) as described in section 2.3.2.

2.3.4. Number of Live and Dead Insects

The number of live and dead insects was measured according to the method used by (Kalsa et al., 2019). A five hundred gram sample from each experimental unit was sifted with sieve of mesh sizes of 4 mm (top) and 2mm (middle and bottom pan were used. Insects which were retained in 2mm and 4mm mesh sieve were counted.

2.3.5. Moisture content

The moisture content of wheat samples were measured using John Deere moisture meter (MM), SW08120 California) as described by (Hossain et al., 2016). The device has codes for different grains, before adding wheat samples from the menu wheat was selected then wheat samples were added until the coverage of the sensors and the displayed result was recorded (Hossain et al., 2016).

2.3.6. Water activity

The water activity of all wheat samples was measured by using water activity meter (AQUALAB4TE) following the procedure described by (Carter et al., 2015). Wheat samples were taken in the sample holder till the coverage of the surface of water activity meter, after a few minutes the value displayed was recorded.

2.4. Data Analysis

The Analysis of Variance (ANOVA) was conducted to determine the difference between the treatments by using R software version 4.3.3, and grain damage and Weight loss percentage were transformed square root and number of insect count was log transformed before analysis. Least significant difference (LSD) tests of significance was used to separate the means when there were significant differences at $p<0.05$.

3. RESULTS AND DISCUSSION

3.1. Grain Damage and Weight Loss Percentage

Grain damage percentage had a significant difference ($P<0.05$) among storage methods as shown in (Table 1) below. The percentage of insect damaged kernels ranged from 2.4% - 59.8%. The highest grain damage percent was measured in a polypropylene bag while the lowest was recorded in the triplex powder applied to plastic drum.

The present result is in agreement with that of Somavat et al., (2017) who reported that average insect-damaged grain percentage in a polypropylene bag was much higher than other hermetic storage methods. Kalsa et al., (2019) concluded that the grain damage percentage was highest in poly-propylene bag followed by the metal silo (9.6±0.3, 0.7±0.5) during six storage months respectively. Similar works reported that grain damage percentage in poly-propylene bags was about 50% which is significantly higher than the other hermetic storage methods like Purdue improved grain storage stored for six months (Martin et al, .2015). This could be the migration of moisture content and insects can do respiration in the polypropylene bag than hermetic bags and hermetic containers are sealed tightly which can prevent the exchange of air which is important for the respiration of biological agents.

Said. & Pradhan, (2014) studied that low oxygen and high carbon dioxide environment kill insect and mite pests and prevent aerobic fungi from growing. According to Kalsa et al., (2019) during six months, the grain damage percentage of wheat grain stored in drum plastic treated with triplex powder was (0.8±0.2) as compared with that of the metal silo and polypropylene bag (1.9±1.1,14.3±4.3) respectively. From the result it can be discussed as application of botanical plants or triplex applied to plastic drum also the potential storage method as hermetic storage methods to decrease insect damage of wheat grain. Sijabat, (2018) concluded that triplex is an effective storage method by the reduction of insect damage for stored grains and safe to health. As triplex, other plant like neem is also effective integrated insect management systems and is easily available, biodegradable, non-residual and is (Lal et al., 2017). Similarly, the values of weight loss ranged from 0.4±0.2% to 28.5.0±4.8% as shown in (Table 1) below. The lowest mean value of grain weight loss was recorded in the triplex applied to plastic drum and the highest was in a polypropylene bag. The result is in agreement with the work of Kalsa et al., (2019).As previous studies indicated that wheat grain loss of 1.0 % to 2.0% in hermetic storage methods is much lower than poly-propylene bags (Kumar & Kalita, 2017).Those authors also declared during six months storage time the minimum and maximum percentage of weight loss was 2±0.1 and 9.6±0.3 % for Purdue improved wheat grain and polypropylene bag respectively. Storage loss of wheat grain under non hermetic storage systems in Ethiopia ranges between 25% and 50% (Dessalegn, Solomon, & Chanie, 2017) due to the transfer of moisture to the stored product. Similarly Demissie et al., (2008) found that the triplex treatment is an alternative to the synthetic insecticides for reducing percentage weight losses of wheat grains as hermetic. This could be due to presentation of the respiration live insects and growth of molds (Somavat et al., 2017). Similar works reported that grain deterioration is also related to respiration of the grain itself and of the accompanying microorganisms (Górnicki, 2013).

Table 1. Effect of storage methods on the grain damage and weight loss stored for a period of a year

Storage Methods	**Grain Damage, %**	**Weight Loss, %**
Super GrainPro bag	7.1±4.3[c]	1.3±0.25
Metal silo	26.4±6.8[b]	7.1±3.0
Plastic drum	8.2±1.4[c]	24.4±0.4
Plastic drum+ Triplex treated	2.4±0.2[c]	0.4±0.2
Purdue improved crop storage	3.3±0.4[c]	0.5±0.1
Polypropylene bags	59.8±4.6[a]	28.5± 4.8
F (5, 34)	22.75	1.530
p-value	0.01	0.20
LSD	4.40	

Means within a column followed by the same letters are not significantly different at 5% level of significance

3.2. Thousand Kernel Weight (gram)

Storage methods had showed significant effects on the percentage of thousand kernel weight ($p<0.05$) as shown in (Table2). The thousand kernel weight ranged from 34.0±4.1 to 40.8±0.7 gram due to storage methods. The lowest mean value of thousand kernel weight was observed in a polypropylene bag.

Scholars find out that reduction in the thousand kernel weight in the non-hermetic storage like polypropylene bag could be the highest activity of biological agents such as molds and due to insect infestation (Martin et al., 2015).While the highest thousand kernel weight was measured in hermetic storage methods or on metal silo. This is due to probably the moisture uptake of wheat grain from the environment and due to the air leakage of metal silo.

This promotes respiration of insects and finally the moisture of the grain will have a significant effect on the thousand kernel weight of stored wheat. The present results are in agreement for hermetic storages with that of Szumiło, Rachoń, & Stankowski, (2010) the average value of thousand kernel weight is above 31(grams) this could be due to the types or species of wheat.

Table 2: Effect of storage methods on thousand kernel weight and bulk density of wheat grain stored for a period of a year

Storage methods	**Thousand kernel weight (gram)**	**Bulk density kg/m^3**
Super Grain pro bag	39.1±1.0^b	659.5±52.1
Metal Silo	40.8±0.7^a	630.7±35.3
Plastic drum	39.8±0.8^{ab}	647.1±21.6
Plastic drum +triplex treated	39.8±0.5^{ab}	625.4±16.3
Perdue Improved Crop bag	38.7±1.5^b	626.3±42.7
polypropylene bag	34.0±4.1^c	568.8±88.2
F,(5, 34)	29.14	1.10
p-value	0.01	0.39
LSD	3.51	

Means within a column followed by the same letters are not significantly different at 5% level of significance

3.3. Grain bulk density

Relatively the highest bulk density of wheat grain was recorded in Purdue Improved grain Storage bags (Table 2). This could be attributed to reduced insect and moulds damages in that container. Similar studies reported that Purdue Improved grain Storage bag can better protect wheat grains from insect damage compared with woven polypropylene sacks (Martin et al., 2015). However, the result showed that it was lower than some reported works, the value of bulk density of the wheat grain for the durum observed (802−815 kg /m^3) (Szumiło et al., 2010) stored for two months compared with all storage methods. The lowest was observed in polypropylene bag (Table2). It may be due to the consumption of wheat grains by insects and molds. The present findings agree with the conclusion made by (Protection et al., 2015) that traditional storage methods cannot preserve stored grains or stored in like poly-propylene bags the bulk density loss of stored grains is significantly higher than hermetic one. Bulk density of wheat grain can be affected by storage time and due to storage methods. As (Kalsa et al., 2019) conducted, the bulk density of the baseline of this wheat grain sample was 825.7 kg/m^{3}and it decreased to 749.9 kg/m^3 for polypropylene bag and for the hermetic storage methods 789 kg/m^3,802 kg/m^{3}were recorded for purdue improved grain storage and super grain pro bags respectively during six months of storage time. From this findings, the highest bulk density of wheat grain was observed in super grain pro bags after one year storage time (Table 2) which was lower than the reported value at six month storage time (802 kg/m^3)(Kalsa et al., 2019).

3.4 Moisture content

The present result (Table3) showed that there was a significant effects on moisture content (P=0.01) due to different storage methods. Hermetic storage methods, with the exception of the metal silo, had the lowest moisture compared to polypropylene bag. The lowest moisture content was found in triplex applied to plastic drum. In the beginning, the moisture content for all storage methods samples was 10.4% and the moisture contents slightly increased from 10.4-12 % after two storage months. At the beginning of the experiment the air leakage of the metal silo was significantly higher than the other hermetic storage methods, thus the moisture content was significantly highest in metal silo followed by polypropylene (Kalsa et al., 2019). The result of the present study is in disagreement that of (Somavat et al., 2017) in which the authors reported that grain moisture in the metal silo was 8.6% to 11.8% stored for four months. The moisture of wheat should be lower than 13% for safe storage. A similar studies also indicated that hermetic containers maintained low moisture levels of wheat during storage (Somavat et al., 2017). When the moisture content is higher than the normal, it has an adverse effect on both economic and quality of grains (Saeid, 2017).

Table3: Effect of storage methods on moisture content and water activity of wheat grain stored for a period of a year

Storage methods	Moisture (%)	Water activity
Super Grain pro bag	11.7 ± 0.3^{b}	0.49 ± 0.0^{cd}
Metal Silo	13.3 ± 1.4^{a}	0.63 ± 0.1^{a}
Plastic drum	11.46 ± 0.7^{b}	0.51 ± 0.0^{c}
Plastic drum +triplex treated	10.6 ± 0.9^{c}	0.48 ± 0.1^{cd}
Perdue Improved Crop bag	11.3 ± 0.3^{bc}	0.45 ± 0.0^{d}
polypropylene bag	11.8 ± 0.9^{b}	0.57 ± 0.0^{b}
F,(5, 34)	9.09	10.1
p-value	0.01	0.01
LSD	1.30	1.40

Means within a column followed by the same letters are not significantly different at 5% level of significance

3.5. Water activity

The effects of storage methods on water activity (aw) were significant (P=0.01) (Table 3). Water activity ranged from 0.45 to 0.63. The lowest mean value of water activity was recorded in the PICS bag whereas the highest value was in the metal silo. This could be the respiration of the insect's molds or the availability of moisture content initially in metal silo (Somavat et al., 2017). Since Purdue improved Grain storage bag is a triple bag which can prevent the store from loss by well preventing of air from outside. Similar works reported that grain water activity in poly-propylene bags was higher compared to hermetic devices(Walker et al., 2018).

3.6. Insect infestation

3.6.1 Number of live insect density

There was a significant difference on live of insects (P=0.02) among storage methods. The number of insects of wheat grain ranged from 2.1 insects to 72.6 insects per kg of grain (Table 4). A lowest value of live insect count was recorded in Purdue improved grain storage bag followed by that of a triplex dust applied to plastic drum. Hermetic bags have reduced exchanges of gasses between stored grains and the environment (Ndegwa et al., 2016).The results from the present study are also in agreement with that reported by (Martin et al., 2015) hermetic bags cannot be confortable for insects. According to Kalsa et al,.(2019) during six storage months, the lowest number of live insects were measured in hermetic storage methods in super GrainPro bags and triplex powder applied to drum plastics and Purdue improved grain storage (3±1,2±1,4±1)) respectively. Besides, earlier researches showed that applying plant leaves in powder form to hermetic storage methods have insecticidal properties (Demissie et al., 2008). A neem tree and other plant leaves have also been used as food grains protectants at farm level, and plant materials, insect species (Abbas, 2005).

During six storage periods, the maximum number of live insects were measured in a polypropylene bags and metal silos (134±34.9 and 89±13.9) respectively (Kalsa et al, .2019) and based on that authors metal silo is not efficient for killing insects due to high moisture development. High moistures favor the development of insects and molds as a result of which increased live insects. Grain storage insects need favorable conditions to increase in number (Shiferaw, 2017). This could be insects keep their living and due to respiration while the storage methods not hermetic or air tighted.

Table 4: Effect of storage methods on the densities of live insect and dead insects in wheat grain stored for a period of a year

Storage methods	Number of live insects per 0.5 kg	Number of dead insects per 0.5kg
Super Grain pro bag	14.49±2.9^{c}	86.3±0.5^{bc}
Metal Silo	41.8±3.2.0^{ab}	186.4±1.5^{d}
Plastic drum	13.4.±2.9 ^{c}	97.1±4.5^{bc}
Plastic drum +triplex treated	3.7± 2.9^{d}	91.6±1.2^{bc}
Perdue Improved Grain bag	2.2± 1.9^{d}	18.0±3.3^{c}
poly propylene bag	51.4±1.9^{a}	372.9±3.7^{a}
F,(5, 34)	14.26	14.66
p-value	0.02	0.01
LSD	0.36	0.54

Means within a column followed by the same letters are not significantly different at 5% level of significance

3.6.2. Number of dead insects

Storage methods exhibited significant differences (P=0.01) on a number of dead insects (Table 4). The number of dead insects ranged from 18.0 to 372.9 dead insects per 0.5 kg of wheat grain. The highest of a dead number of dead insects was measured in polypropylene bag and the lowest was measured in Purdue improved Grain storage bags. Next to the polypropylene dead insects were measured in the metal silo when compared to other hermetic methods. The present reports do not agree with metal silo because metal silo (Jagadeesan et al., 2014). In Perdue improved grain storage bags, the average number of dead insects was the lowest than any methods. Due to maybe it is a kind of triple bags, polypropylene in outer and two (high-density polyethylene) in the inner part which makes it is the hermetic type of storage methods. The researcher found out it is an effective method which has the same effect as super GrainPro bag storage method against insects and moulds growths on wheat grains (Michael Ndegwa, 2015).From the result it can be discussed that if there is low dead insects means that there is not much insects grow in the storage.

4. Conclusion

Polypropylene bag which was used as a control in this research showed the highest grain damage and weight loss of stored wheat compared with the other storage methods. Within the hermetic storage methods, metal silo was not effective to preserve the wheat grain due to air leakage at the beginning of the storage. However, metal silo is mechanically stronger than any other hermetic storage methods and highly recommended for smallholder farmers when the airtightness is checked. Like other hermetic storage methods, botanical plant leave powder like triplex powder applied to plastic drum can increase the storability of wheat grain. Therefore, it is the best alternative to reduce wheat grain damage and weight loss and it shall be appreciated in small farm. Hermetic storage methods can extend the storability of the wheat without or with minimum grain damage without the addition of any synthetic chemicals beyond a year. From this finding, the highest moisture content was measured on metal silo and this affected the result of thousand kernel weight and bulk density of stored grain compared with other hermetic storage methods.

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