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Hermetic storage: A technology for reducing grains losses during storage

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Abstract
Hermetic technologies are being promoted in Bihar as safer and more effective methods of grain storage on small farm holder. However, farmers and policy makers lack knowledge of their efficacy in controlling major stored grain pests. A present research was carried out to investigate the effect of hermetic bags on maize grain quality comparing with different packing materials (Plastic bags, metallic container, pusa bin) for 12 months of storage. Moisture content, lightness were recorded for 15days interval for first two months thereafter 30 days internal to till end of storage period. When the plastic bags, metallic container and earthen bin were used as the packing material, the moisture content and lightness were decreased as moisture increased from 12.07-14.67% (wb) which decreases the lightness (L) from 71.01 to 67.05. When grain was packed in metal, earthen bins and plastic bags, the reduction in viability of seed with time of storage varied with the moisture content of seed at packing. When Maize stored in super grain bags with initial moisture content of 12.07% showed satisfactory temperature, moisture content and lightness throughout the storage period resulting in better germination rate than those packed in other packaging materials like plastic bags, metallic container and mud bin with same moisture content.

Keywords: Plastic bags, gunny bags super grain bag, milling quality, moisture content

1. Introduction

Maize (*Zea mays* L.) is a one of the major grain in Bihar that provides calories and income for many households. Whereas the crop is harvested every season, substantial amount of the grain is lost to insect pests during storage because to control these pests remains a challenge to resource-poor small farm farmers. This is aggravated by lack of effective, appropriate and affordable storage technology (Baributsa *et al*., 2014) [10]. As a result of insect feeding, damage, and contamination, the volume of stored grain and quality, grain value, and marketability is reduced (Affognon *et al*., 2015) [1]. To avoid the risk of losing the harvested crop to insect pests, some farmers sell their maize early at low price while others treat it with dilute insecticidal dusts, but satisfactory protection is never achieved. The major insect pests of stored maize are the larger grain borer, *Prostephanus truncatus* (Horn), and the maize weevil, *Sitophilus zeamais* Motschulsky (DeGroote *et al*., 2013) [4]. The former is the most damaging pest, and in endemic areas causes weight loss estimated at 30% while the maize weevil causes 10-20% weight loss when untreated maize is stored in traditional structures (Likhayo *et al*., 2016) [7]. The control of stored product insect pests on smallholder farms remains a major challenge. Currently, synthetic insecticides are widely used to control insect pests of stored grains. However, less than 25% of applied insecticides achieve good results leading to misperception of in effectiveness. In addition, heavy storage damage results in reduced quantity and nutritional content, sometimes rendering the grains unfit for human consumption, and low market value. Readily available cost-effective storage devices that can reduce insect pest infestation and damage are therefore required.

Hermetic storage technologies such as the triple layer Purdue Improved Crop Storage (PICS), SuperGrain bags, GrainPro cocoons and others are being promoted as cheap and effective insecticide-free control devices against insect pests in developing countries. Use of hermetically sealed containers to control major insect pests works by limiting oxygen access to insects, fungi and other microorganisms living inside the stored grain (Fintrac, 2016) [5]. Hermetic bags have shown to be effective in controlling pests of several crops including cowpeas and maize. Most of these studies have looked at the effect of a single insect pest on stored grain. This study was therefore set out to evaluate the efficacy of the hermetic bags in protecting stored maize against the major occurring storage insect pests by simulating farmer storage conditions and practices, under ambient-conditions at Banka and Bhagalpur districts of Bihar.

Materials and Methods

Material used were, Maize grain, moisture boxes, moisture meter (Make; John Deere Model No. SW08120), electronic balance, hot air woven, plastics bag, Metallic container, Earthen bin and Super grain bag. To find the effect of varieties on storability of maize, DHM-117 variety of maize was chosen for the study.

Fig 1: Plastic bag

Fig 2: Metallic container

Fig 3: Mud bin

Fig 4: Super grain bag

The experiment was conducted in 16 villages each of Bhagalpur and Banka districts of Bihar, India. 200 kg of sieved maize of selected (DHM-117) variety was divided into 4 containers (Hermetic bag, plastic bag, metallic and mud bin). Harvested maize was cleaned, weighed and kept for storage at ambient conditions for one and half months as data related to the experiments was obtained. The initial moisture content of the Maize was determined before it was taken to storage. It was observed that, the initial moisture content of the Maize was 12.07 percent (w.b.). Thereafter the grain was poured into the pre-disinfected 5 different types of bags (Fig. 1). Plastic and gunny bags were sealed properly while super grain bag was double locked with the help of zip. Maize grains were also filled in earthen bin and covered properly. The ambient condition was 28.31 ±1 ^{0} C and 72±2% RH.

Mud bin

The Mud bin is made of soil mixed with straw and saw dust, which act as an insulation between the stored grain and the surrounding environment. These storage structures are being promoted in rural areas and have been widely adopted in India for smallholder farmers. These silos usually have capacities between 1 and 2 cubic meters. The cost of constructing a mud bin is relatively low. Material costs are low because of their local availability. In addition, advanced technologies are not required to construct these mud bins so smallholder farmers can easily fabricate them in rural villages.

Plastic bag

These are rigid hermetic structures made form plastic or glass materials respectively. Plastic hermetic structures and made thermo plastic polypropylene materials using extrusion blow moulding machines. They are mainly produced from High Density Polypropylene (HDPP). Others are made of polyvinyl chloride (PVC). As a very durable and long lasting construction material, is can be used in the production of either rigid or flexible hermetic storage structures along with other additives. The greatest quality is the provision of the hermetic environment needed as impermeably is high and largely depending on the ability of the farmer to seal the loading and the unloading points. Physical strength of the structures is guaranteed, and susceptibility to rodent attack, human pilferage, birds and other pest are not prominent with the use of plastic hermetic structures. However, the issue of moisture condensation is very prominent with plastic rigid hermetic storage materials coupled with its high cost of procurement.

Metallic containers

Hermetic metallic containers are rigid storage structures made of metallic or metallic alloy materials as shown in fig1. Metallic containers which were not naturally made for hermetic storage, but guaranteed air tight conditions were the first type of hermetic structures used for this purpose. As one of the first ever known type of hermetic storage structure used by man, it affords farmers a great advantage going into storage especially, if the structures are kept under a roof or shade. Metallic containers comes in variety of shapes and sizes depending on the choice of individual. The most common types are empty metallic drums, and other container that were originally meant for liquid and solid granular materials, as either for packaging or storage purposes. Devoured of basic design, the use is opposed to problems due to absence of loading and unloading points. Others are metallic containers, designed and built specifically for the purpose of hermetic storage crop storage such 0.5 to 5.0 tonnes metallic containers.

Hermetic bags

Hermetic bags are improved polyethylene and woven poly propylene bags designed to have high density and physical strength as well as high impermeabllity of gases/ ambient air. It provides big alternative to most rigid hermetic storage structures which their initial cost of acquisition is high. The two basic component of hermetic bags are the inner bags made of high density transparent Polyethylene bags which may be double or single depending on design and make. The transparent inner bag is purely designed to guarantee high impermeabllity of ambient atmosphere to create the desired sealed environment for a hermetic storage system. It is factual that more storage insect has the capacity to perforate bags, but it was dully considered during design in the inner bags. The outer bag is not transparent in nature but made woven polypropylene material basically designed for strength, due to handling problems and the weight of the grains that it will house. The impermeabllity of the ambient air helps in maintaining safe constant moisture levels in stored grains regardless of ambient exterior relative humidity. Hermetic bags are made of plastic material which is not a good conductor of heat, unlike metallic materials.

There were four treatments for study

T_1 Plastic bag
T_2 Metallic container
T_3 Mud bid
T_4 Super grain bag + jute bag

Measurement of Moisture Content

Hot air oven method was used to determine the initial moisture content of the selected Maize. A pre weighed Maize sample of 15 g was kept in a pre-dried and weighed moisture box in oven at 80ºC for 24 hours Ranganna (2002) [12]. The dried samples were cooled in desiccators to room temperature and then weighed using electronic balance and moisture content (w.b.) of sample which was expressed as g water/g dry matter was used for calculations.

The moisture content of sample was calculated by using following equation.

$$\text{Percent moisture content (db)} = \frac{W_1 - W_2}{W_2} \times 100 \qquad ....(i)$$

Where, W_1 = mass of original sample (g) and W_2 = mass of the sample after drying (g)

Assessment of weight loss

Maize grain loss bioassay was conducted to determine the damage caused insects to Maize stored hermetically and to serve as basis for determining the effectiveness of hermetic double bagging technology. The Thousand grain mass (TGM) method described by Boxal (1986) was used to determine dry-weight loss. A sample of 1 kg of each maize variety was taken and sieved to remove all unwanted material and to obtain a working sample. A sub-sample of the working sample was used to determine the moisture content. The moisture content was determined three times and the mean value recorded. The remaining sample was accurately weighed and the number of grains counted. This was also repeated thrice. The TGM was calculated using the formula:

$$\mathrm{TGM} = \frac{10\mathrm{W}(100 - \mathrm{MC})}{\mathrm{N}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.. \text{(ii)}$$

Where, W = weight of sample N = number of grains in sample and MC=moisture content

This was done before storage and repeated five times monthly for six months for each maize variety stored in the four different bags. At the end of each month, the percentage weight loss was determined using the formula:

$$\text{Weight loss, \%} = \frac{(\mathrm{M}_1 - \mathrm{M}_2)}{\mathrm{M}_1} \times 100 \ldots\ldots..\ldots\ldots\ldots\ldots\ldots. (iii)$$

Where M_1 = TGM of grain at the start of storage.
Mx = TGM of grain at the time x (i.e. 1, 2 or 6 months).

Colour assessment of stored grain

Colour is important to consumer as a mean of identification, as a method of judging quality and for its basic esthetic value and food is no exemption. The overall objective of colour of the food is to make it appealing and recognizable. The most common technique to assess the colour is colorimeter. There are several colour scales used in a Hunter Lab Colorimeter such as $L*$, $a*$ and $b*$ which represented the surface colour. The colour values are obtained as $L*$ is the lightness coefficient, ranging from 0 (black) to 100 (white), $a*$ is purple-red (positive $a*$ value) and blue-green (negative $a*$ value). a* and $b*$, that represents yellow (positive $b*$ value) or blue (negative $b*$ value) colour (McGuire, 1992) [8].

Assessment of germination

Good quality seeds can be maintained for long duration if proper management techniques are practiced. Most of the Indian farmers are not knowledgeable regarding the proper time to store seeds. Seeds that are to be stored need to be dry, and the moisture content should be reduced to minimum levels in order to avoid seed spoilage during storage. If the moisture content is too high, the seeds will become moldy as sealed storage does not allow moisture to evaporate. In addition, high temperatures deteriorate grain viability and accelerate seed respiration. Storing seeds at a low temperature and humidity will prevent deterioration and pest attack. It is common that stored grains will lose quality due to seed respiration, but those losses can be reduced when seeds are stored hermetically. A comparison of seed germination tests was conducted to determine the difference between the viability of seeds stored in hermetic bags compared to those stored in plastic bag, metallic container and mud bin.

Results and Discussion

Damage and weight losses

Grain damage includes scarification of the pericarp and of the periphery of the endosperm, eating out of the germ, partial or complete consumption (hollowing out) of the kernel. The damage and weight losses caused by the tunneling and feeding activities of adult insects were observed to have increased gradually in the jute and polypropylene bags as the storage period progressed while a reduction was rather experienced in the triple-layer hermetic bags. This observation confirms the findings of Murdock *et al*. 2000, who all reported little or no damage to hermetically stored grain. Super grain bag did not favour one insect species over the other. In other words, hermetic bag used in controlling loss due to insects.

Kinetics of MC Changes

The MC of maize during stored in plastic bag, metallic container, pusa bin and super grain bag were presented in Fig. 2. Kinetic studies were carried out to determine the kinetic orders and rate of changes for the MC changes of milled rice during storage in some types of plastic packaging at room temperatures. All results of the kinetics measurements were plotted as logarithms of the MC against the storage period. Graphs of MC against time were also plotted, and used in the evaluation of the kinetic order.

It can be observed from Fig. 2 that the MC of maize in all cases increased with the storage period at room temperature. The analysis of the MC rate was conducted on the first week to the eight week of storage period. The initial MC of maize before storage was 12.07±0.05 % at the average relative humidity of 72%. The rate changes of MC during storage in plastic bag, metallic container, mud bin and super grain bag packaging were 6.5×10^{-3}, 5.5×10^{-3}; and 7.3×10^{-3} for 15 days interval for first two month and 30 days interval for rest of the storage period. Whereas the highest rate of MC changes was found in without packaging which was 9.1×10^{-3} 15 days and 8.2×10^{-3} for 30 days. The MC of rice was highly increased from 10.07±0.05 % (initial MC) to 12.67±0.24% (first 15 days, and rest 30 days interval respectively) for the treatment without packaging, followed by plastic bag, metallic container, mud bin and super grain bag packaging. Once the moisture achieved the equilibrium moisture content with the surrounding environment (first 15 days of storage), the MC was slowly inclined as shown in Fig.2. On the other hand, the MC at the first 15 days of storage for super grain bag was unchanged therefore the MC increases during storage in the super grain bag was the slowest among the other treatments. This study was in line with the research carried by Muangkaeo *et al.*, (2005) [9] on the influence of packaging materials and storage time on seed viability and chemical component of Maize seed.

Colour changes during storage

Unlike the measurement of MC, the $L*$ on the Maize declined during storage in LDPE bags, metallic container and mud bin. The initial $L*$ value of Maize was 71±0.61, and this value declined for the entire sample stored in above packaging indicating the whiteness on rice kernel decreased. Many papers have reported on the changes of maize during storage. Most of the papers stated that storage had an effect on the physical and chemical of maize, including cooking quality, texture, volatile components, and color (Keawpeng and K. Venkatachalam, 2015) [6]. Unfortunately, none of those mentioned in detail on the color changes on Maize during storage. It can be observed that the lightness (L*) of Maize stored in LDPE bags, gunny bags, earthen bin decreases from of lightness (L*) from 71.01 to 68.94, 71.01 to 65.13 and 71.01 to 67.05 respectively. Analysis of the kinetic orders and rate of changes for the $L*$ value of Maize during storage showed that the rate of changes for $L*$ value followed the first-order kinetics for all of the packing materials. The rate of decreases for the $L*$ values of Maize packed in super grain bag were 9.3×10^{-3}, 7.7×10^{-3} and 8.1×10^{-3} for first 15 days, respectively. Whereas for Maize without packaging was 9.3×10^{-3} for 15 days and 8.4×10^{-3} for 30 days. The continuous decreases of $L*$ value was pronounced in metallic container, plastic bags and mud bin respectively and it can be noted that there was a correlation between the MC increases and $L*$ value decreases. This result was in line with Tamrin *et al.* (2015) [13] for Milled Rice during Storage in Plastic Packaging.

Effect on germination

Hermetic treatments preserved germination after 12 months of storage with a germination of (>85%) compared to non-hermetic treatments (<62%) There were no significant differences between the two hermetic treatments and between the two non-hermetic treatments. HGBs had the highest germination at the end of the storage period for both sites, and this can be attributed to low insect population translating to low insect damage and consequently minimal seed damage. Metallic container had a higher germination percentage compared to non-hermetic treatments. AGCD (<62%) treatments had higher germination percentages than the untreated control (<50%). There were no significant differences between sites, although MRS had higher germination percentages.

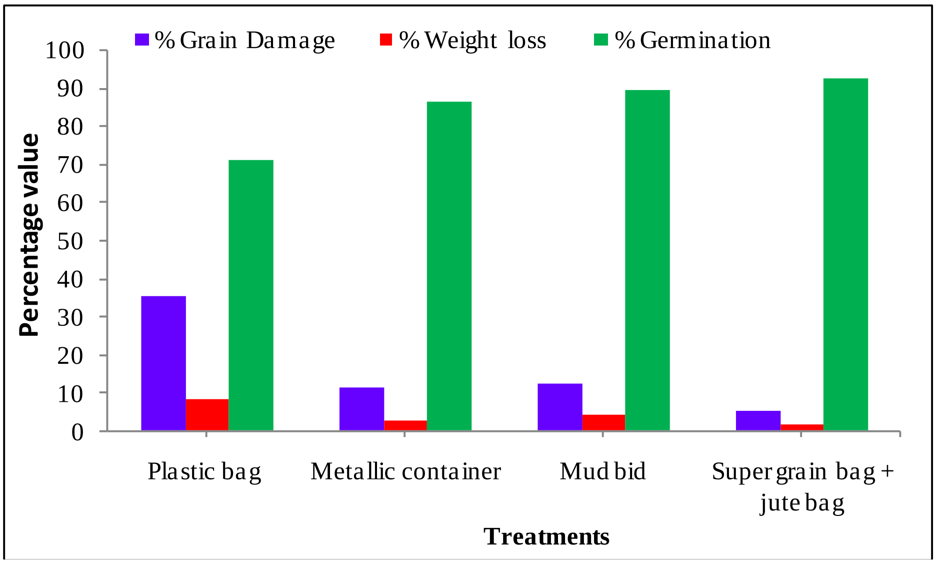

Fig 5: Percentage grain damage, weight loss and germination of miaze

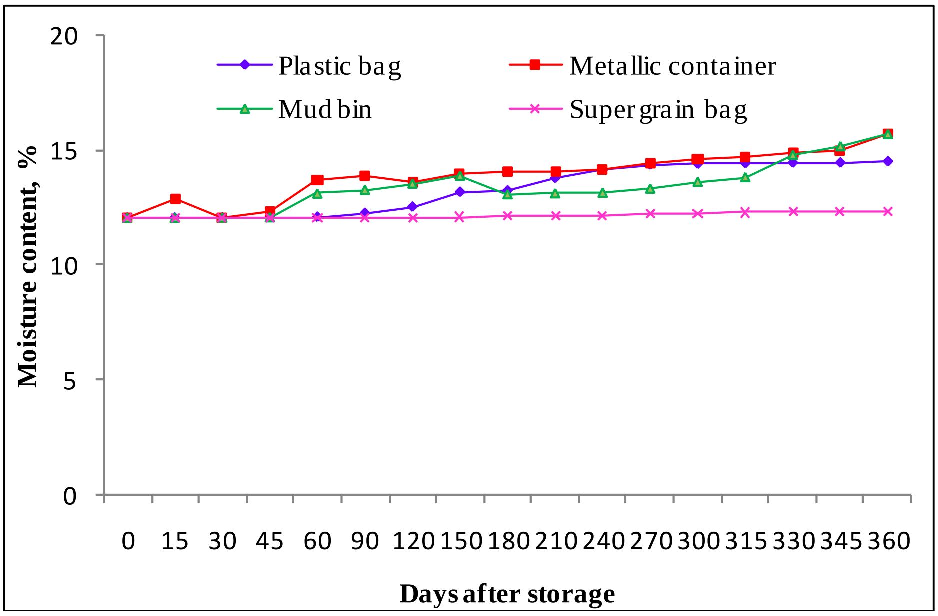

Fig 6: Moisture content changes during storage

The results corroborates to previous studies where both metal silos and hermetic bags namely Purdue Improved Crop Storage (PICS) bags (Njoroge *et al*., 2014) [11], IRRI Super bags (Ben *et al*., 2009) and GrainPro bags (Baoua *et al*., 2013) [2] managed to preserve grain quality, reduce grain damage and weight loss as compared to the conventional bag storage system like plastic bags, metallic container and mud bins.

Conclusions

The result from this trial revealed that storing grains in plastic bag, metallic container and mud bin drastically decreased seed viability, while seed stored in hermetic bags maintained seed germination. Hermetic storage technology limits the movement of air and moisture from the external environment to the stored grain, which results in reduced oxygen and moisture conditions inside the storage system. This creates an unfavorable condition for the survival and growth of insects, pests, and mold, providing an effective control. In addition, hermetic bagging technology is easy to use, involves low costs, and is readily available for smallholder farmers. However, the durability of these bags is a major concern, as they are vulnerable to punctures from sharp objects, grain, insects, and rodents while transporting or storing the grain. Punctures in the bag can sometimes be sealed by grain, but there are also chances for the air to enter the storage bag, significantly reducing its effectiveness for grain storage. However, metal silos are relatively expensive compared to other storage techniques, so smallholder farmers would require credit or a subsidy to purchase these structures.

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