Hermetic storage - an ecofriendly safe storage method for long term storage of black gram

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Abstract

India is the primary origin of the black gram that is majorly cultivated in the southern part of Asian countries. About 70% of world black gram production comes from India. Black gram is more prone to insect infestation and microorganisms resulting in deterioration of grain quality. These losses can be controlled by following appropriate storage method at farmer's level. Eco-friendly, safe storage methods are demanded by the customers due to food safety, quality and environmental issues. Hermetic storage is a safe storage method, suitable for long term storage without usage of chemical pesticides. It creates an air tight environment to rapidly exterminate insect development and suppresses micro floral activity. A study was conducted to identify the suitable, cost effective storage method for safe storage of black gram at the farm level. Hermetic bags were made by using different combinations of gunny, polypropylene & storezo bags for the safe storage of black gram. The properties of packaging materials viz., thickness, and water vapour transmission rate significantly affected the quality parameters of the black gram stored in various bags. Moisture content, thousand grain mass, bulk density, insect emergence, and germination percentage of black gram stored in various bags were studied over a storage period of 12 months. Black gram stored in polypropylene and gunny bags was infested with pulse beetle by the third month of the storage period. But black gram stored in bags with hermetic bag as inner layer was not infested up to 12 months and could retain the grain quality.

1. Introduction

India is the leading producer and consumer of pulses. The total pulse production in India significantly increased to 22.14 million tons during 2016-17 which is 2.89 million tons higher than the previous production of 19.25 million tons achieved during the year 2013-14 (Anonymous, 2018). About 70% of the total production is stored by the farmers. Due to insufficient and poor storage facilities, lack of knowledge in post harvest pulse management and storage, the risk of damage due to post harvest losses are huge up to 25-50% (Lal and Verma, 2007). During storage, pulse beetle (*Callosobruchus chinensis Linn*) attacks the pulse seeds and causes about 5-10% losses. The most important factors that cause grain deterioration are the interaction of temperature and moisture, which are the determining factors in accelerating or delaying the complex degradation reactions. In India, grains are generally stored in gunny bags which are inexpensive, reusable with good inherent toughness but high permeability and low resistance to insect and rodent attack results in frequent application of pesticides to prevent infestation (Maina et al., 2016). Consumer resistance against the use of chemical fumigants in stored products and international trade treaties increase the focus to find green and residue free technology. The main objective of the study is to develop an alternative ecofriendly safe storage method for controlling bruchid infestation in stored pulses. As there are no standard methods available for storing black gram at farmer's level, the present study was carried out to monitor the quality changes of black gram when stored under hermetic condition. Hermetic bags create modified atmospheres by increasing carbon dioxide concentration and decreasing oxygen due to the respiration metabolism of insects and aerobic microorganisms present in grains. Hermetic bags are less permeable, made up of a blend of polymers with LDPE (Low-density polyethylene) as inner liner which prevents the growth of microorganism and insect attack during long term storage. Hence, hermetic, gunny and polypropylene (PP) bags were used for the storage of black gram. Moisture content, thousand grain mass, bulk density, insect emergence, and germination percentage of black gram stored in various bags were studied over a storage period of 12 months.

2. Materials and Methods

Experiment was conducted at IIFPT, Thanjavur (Tamil Nadu) for the safe storage of black gram. The black gram variety ADT-5 was procured from National Pulse Research Centre, Vamban (Tamil Nadu) with an initial moisture content of 11.5% wet basis (w.b). The initial moisture content of the black gram was determined by hot air oven method at 135°C for 2 h. The aim of the study is to evaluate the performance of hermetic bags for the safe storage of black gram. Gunny, polypropylene, hermetic storezo bags (50 kg capacity) and their combinations were used for the storage of black gram (Table 1). Here, gunny bag was considered as control for the experimentation. Each treatment was replicated thrice and the experiment was conducted for a period of 12 months. Changes in grain quality parameters were analyzed at the beginning and at the end of the storage period. The following combination of bags was used for the study as given in Table 1.

Tab. 1 Treatment of bags chosen for experiment

Treatments
T_1 - Storezo+ Polypropylene
T_2 - Storezo+ Gunny
T_3 - Storezo+ Polypropylene+ Gunny
T_4 - Polypropylene+ Gunny
T_5 – Storezo
T_6 – Polypropylene
T_7 – Gunny

Properties of packaging materials

The thickness of the different packaging materials was determined using screw gauge. The water vapour transmission rate of the gunny, polypropylene and storezo hermetic bags was determined by the method followed by Othman et al. (2017) with slight modifications. A small cup was used to determine the water vapour transmission rate of the packaging material. The packaging material was initially made into circular shape that was slightly larger than the inner diameter of the cup. Then, the cup was placed on a horizontal platform. Known amount of anhydrous Calcium Chloride as a desiccant was placed inside the cup. Subsequently, the packaging materials were placed on top of the permeability cup (Talja et al. 2007). The cup was then covered and sealed with paraffin and weighed in order to calculate the initial weight. The weight of the cup was recorded every 24 hours for 3 days. The water vapour transmission rate (WVTR) was determined using equation 1:

$$WVTR = \frac{\Delta m}{\Delta t A} \qquad \text{.........................} (1)$$

Where Δm/Δt is the moisture gain weight per unit time (g/day), A is the exposed surface area of the film (m^2)

Moisture content

The moisture content of black gram was determined by Oven-drying method (AOAC, 2005; no.930.15); ground black gram was dried at 135°C for 2 h.

Thousand grain mass (M_{1000})

The thousand grain mass was measured by weighing 1000 whole grains in a properly calibrated electronic balance.

Bulk density

It is the ratio of mass of black gram to its total volume. A 250 ml graduated cylinder filled with black gram was tapped for the seeds to consolidate. The weight and volume occupied by the black gram were recorded and the bulk density was calculated using equation 2:

$$\rho_b = \frac{W_s}{V_s} \qquad \text{.........................} (2)$$

Where ρ_b is the Bulk density (kg m^{-3}), W_s is the Weight of the sample (kg), V_s is the Volume occupied by the black gram (m^3).

True density

The true density was determined using the liquid displacement method. Here, toluene was used as a displacement liquid instead of water to prevent absorption. 10 g of black gram were immersed in 50 ml of toluene in a 100 ml graduated cylinder. The amount of toluene displaced was recorded from the graduated scale of the cylinder. The ratio of the grain weight to the true volume of displaced toluene gives the true density of the black gram.

Porosity

The porosity of the bulk grain was determined from the true and bulk density of the grains using equation 3:

$$\varepsilon = \frac{\rho_t - \rho_b}{\rho_t} X\, 100 \qquad \text{.........................} (3)$$

Where ε is the porosity (%), ρ_b is the bulk density (kg m^{-3}) and ρ_t is the true density in (kg m^{-3}).

Germination percentage

Germination is a key index to test the seed viability of stored grains. One hundred seeds of black gram were soaked in distilled water for 24 h, put on a germination paper placed inside a Petri dish, and incubated at 25°C. The filter paper was moistened every day using fresh water to facilitate germination (Gupta et al. 2010). The ratio of the number of seeds germinated after seven days of incubation to the total number of seeds kept for germination were recorded as germination percentage.

3. Results

Properties of packaging materials

The thickness of the packaging materials is expressed in terms of microns as shown in the Table 2. The water vapour transmission rate (WVTR) is the rate of water vapour permeating through the packaging material. The WVTR is determined from the slope of the regression line of the sample weight versus time and the slope is then divided by the area of the film being exposed to the transmission (Equation 1). Table 3 shows that the least WVTR was observed in Storezo hermetic bags with 1.57 g/m^2 day, followed by polypropylene and gunny bags with 6.69 and 25.85 g/m^2 day, respectively.

Tab. 2 Packaging material properties

Properties	Storezo bags	PP bags	Gunny bags
Thickness (microns)	75.21±0.95	80.41±1.91	1346.67±27.22
Water vapor transmission rate (g/m^2 day)	1.57±0.56	6.69±1.65	25.85±2.12

Grain moisture content

Black gram moisture content when stored in different bags was determined and the variations in moisture content of black gram during storage are given in the Table 3. In T_7 (gunny) and T_6 (polypropylene) bags the moisture content was increased from the initial moisture content of 11.5% to 12.57% and 12.26%, respectively, because environmental factors such as temperature and relative humidity significantly affect the black gram stored in gunny and PP bags due to its higher permeability. There was no significant difference observed in the black gram moisture content when stored in treatment T_3. Thus, the change in moisture content of stored black gram depends on the permeability of the bags used for the storage. From the study conducted in laboratory, it has been confirmed that the water vapor transmission rate of gunny bag was higher followed by polypropylene and storezo hermetic bags. Hence, less permeability in hermetic bags helps in the retention of the grain moisture content.

Thousand grain weight

The thousand grain weight of black gram stored in different bags varied from 43.22 to 41.93g. Black gram moisture content and infestation significantly affect the thousand grain mass because *Callosobruchus chinensis* feed on the endosperm portion of the black gram during infestation which results in a decrease in grain weight. The infested grains were sieved to separate grains from insects and grains dust. From the separated grains thousand grain mass was determined.

Bulk and true density

The bulk (ρ_b) and true (ρ_t) density of black gram stored in different bags are given in Table 3. The initial bulk density of black gram was 729 kg m^{-3}. After 12 months of storage period, it has been observed that maximum ρ_b was observed in the treatment T_3 with 697.42 kg m^{-3} followed by T_1 and T_5 with 688.69 and 687.54 kg m^{-3} respectively. The least bulk density was found in T_7 with 601.76 kg m^{-3}. The decrease in bulk density is due to emergence of insects from the stored black gram which results in weight loss. Thus, change in grain mass is directly proportional to bulk density.

The true density of initial black gram was recorded as1230.00 kg m^{-3}. At the end of storage period, true density decreased with the decrease in black gram moisture content. Similarly, in the infested treatments T_4, T_6 and T_7, the true density decreased to 1190.25, 1115.56 and 1108.00 kg m^{-3} respectively.

Porosity

The initial porosity of black gram was 40.73%. The porosity is inversely proportional to change in bulk density and true density of black gram. From Table 3, it has been observed that the maximum porosity was observed in the treatment T_7 with 45.69% followed by T_6 and T_4 with 44.86 and 43.80%, respectively. Hence, it is confirmed that the change in grain moisture content and insect infestation significantly affect the porosity.

Germination percentage

The initial germination percentage of black gram was 94.67%. There was significant difference ($P < 0.05$) between initial and final germination percentage of the black gram in all the treatments. After eight months of storage, the germination rate decreased in treatment T_7 followed by T_6 and T_4 with 77.67, 80.00 and 84.00 %, respectively. Maximum germination percentage was found in treatments T_3 and T_2 with 87.67% and 84.67%, respectively. Germination of black gram decreased with the increase in storage period. These changes may be due to variation in moisture content, moisture loss, and emergence of insect during storage. The germination percentage of black gram stored in PP (T_6) and gunny bags (T_7) decreased more due to emergence of insect from the stored commodity.

Insect emergence

Insect emergence from the black gram stored in various treatments was monitored regularly. *Callosobruchus chinensis* is a predominant internal feeder pest that infects pulses and affects the germination ability and nutritive value of the black gram seed during storage. No infestation was observed in the black gram stored in different treatments where hermetic bag is used as an inner layer, while black gram stored in gunny bag alone (T_7) starts to get infested from the third month of the storage period with 25.46% infestation at the end of the storage. Similarly, black gram stored with PP (T_6) and PP and gunny (T_4) got infested in the fourth and tenth month, with 19.87% and

5.16% of infestation respectively. Hence, black gram moisture content and packaging material permeability significantly affect the quality of the stored commodity.

Tab.3. Effect of different treatments of bag storage on black gram properties.

Treatments	Moisture content (w.b.%)	Thousand grains Mass (g)	Bulk density (kg m^{-3})	True density (kg m^{-3})	Porosity (%)	Germination (%)	Insect emergence (%)
Initial	11.50	43.22	729.00	1230.00	40.73	94.67	Nil
T_1	10.29	42.56	688.69	1205.00	42.85	83.67	Nil
T_2	10.55	42.83	685.12	1211.00	43.43	84.67	Nil
T_3	10.79	43.09	697.42	1224.00	43.02	87.67	Nil
T_4	11.62	42.26	668.89	1190.25	43.80	84.00	5.16
T_5	10.18	42.44	687.54	1194.48	42.44	82.33	Nil
T_6	12.26	41.97	620.66	1125.56	44.86	80.00	19.87
T_7	12.57	41.63	601.76	1108.00	45.69	77.67	25.46

4. Discussion

The *Callosobruchus chinensis* is one of the most serious pests infesting stored pulses in India. Saleem (1982) reported that *C. chinensis* causes serious damage to the pulses majorly in Bangladesh, India and many countries of the world. It causes greater damage to the pulses during storage which leads to heavy economic losses. The results coincide with the results of Mutungi et al. (2014), who report that grains stored in hermetic bags will prevent change in grain moisture content. Murdock et al. (2012) confirmed that triple layer hermetic bags are more effective in protecting grains from insect infestation. Munde (1999) reported that the increase in thousand grain mass is due to increase in moisture content for black gram. Theertha et al. (2014) found that the bulk density of black gram decreases with increase in moisture content. According to Pandiselvam et al. (2014), it is confirmed that there is a proportional relationship between grain moisture content and porosity. This might be due to increase in shape and size with respect to increase in moisture content.

Farmers in India use primitive gunny bags as a grain storage material. But within 3 months of storage period the quality of the grains gets deteriorated due to improper storage condition, which leads to insect infestation and fungal attack. To overcome these issues, the study was conducted by using storezo hermetic bag as an inner layer in multilayer bag for storage practice in godowns and at farmer's level. From the results it is evident that grain quality can be retained and insect infestation can be prevented by adopting hermetic storezo bag as an inner liner in multilayered bag storage.

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Hermetic storage of dry soybean (Glycine max): creating an effective modified atmosphere using soaked grain as O_2 depletor

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Abstract

Hermetic storage of grains and oilseed has been proposed as a solution for reducing food losses in developing countries. However, to obtain full benefit of the hermetic storage it is required to achieve a low O_2 concentration (below 2%) or high CO_2 concentration (above 20%). The gas concentration inside the hermetic container is the result of the balance between the respiration and gas exchange rates with the outside (permeability and leakage). When the grain is dry, an insufficient modification in the internal atmosphere is achieved (exchange rate higher than respiration rate), allowing insect development and, hence, grain losses. This study focuses in creating an effective modified atmosphere during the hermetic storage of dry soybean using soaked grain as O_2 depletor. Three big bags with internal polyethylene liners of 70 µm thickness were filled with 590 kg of soybean (Glycine max, with 12.5% m.c.) and sealed. Gas concentration evolution was measured during 15 days (basal condition). Later, four plastic perforated bottles filled with of 4.3 kg of soaked soybean (44% m.c.) were inserted in each bag. The bags were re-sealed and gas concentration was measured during 45 days. Results indicated that the soaked soybean acted as an O_2 depletor, reducing the gas concentration to 1% in only 8 days, and maintained below 1% during 45 days. This research indicated that a small portion of soaked grain (0.4% dry matter (d.m.)) can be used to generate an effective modified atmosphere to prevent biological activity in the entire grain mass. This is a simple and inexpensive approach to reduce food losses under low cost hermetic storage.

Keywords: food losses; pest control; controlled atmosphere; respiration; gas leakage

Introduction

Hermetic storage of grains and oilseed has been proposed as a solution for reducing food losses in developing countries. However, to obtain full benefit of the hermetic storage it is required to achieve a low O_2 concentration (below 2%) or high CO_2 concentration (above 20%) (Navarro et al., 2012). The gas concentration inside the hermetic container is the result of the balance between the respiration and gas exchange rates with the outside (permeability and leakage). When the grain is dry, an insufficient modification in the internal atmosphere is achieved (exchange rate higher than respiration rate) (Abalone et al., 2011a, 2011b), allowing insect development and, hence, grain losses.

The use of liners with gas barrier is an alternative to improve the effect of hermetic storage systems, since the O_2 entrance and CO_2 losses are strongly reduced. This creates an internal atmosphere with a higher modification level than standard liners, with potential conservation benefits (Cardoso et al., 2016). However, liners with gas barrier are expensive and it might not be affordable for family storage systems. Additionally, small perforations in the liner (as small as 1 mm) could eliminate the