

## Hermetic and Conventional Storage Systems for Control of *Callosobruchus maculatus* in Cowpea in Nigeria

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	<p><i>Post-harvest losses caused by storage insect pests remain a major constraint to cowpea production in sub-Saharan Africa, with <i>Callosobruchus maculatus</i> as the most destructive species. This study evaluated the effectiveness of different storage structures in managing bean weevil infestation and reducing grain losses under laboratory conditions at Nnamdi Azikiwe University, Awka, Nigeria. The storage structures assessed were hermetic bag, jute bag, metal bin, and plastic bag. The experiment was arranged in a Completely Randomized Design with three replications, and data were collected at regular intervals.</i></p> <p><i>Results showed significant differences (<math>P &lt; 0.05</math>) among storage structures. The hermetic bag recorded the lowest grain damage (0.51–0.68%), weevil population (0.80–0.82), and weight loss (3.56%). In contrast, the plastic bag had the highest grain damage (13.85%), weevil population (4.90), and weight loss (26.95%), while jute bag and metal bins showed intermediate values.</i></p> <p><i>The effectiveness of the hermetic bag is attributed to oxygen depletion and carbon dioxide accumulation, which suppress insect survival and reproduction. The study highlights hermetic storage as an effective approach for reducing post-harvest losses.</i></p> <p><b>Keywords:</b> postharvest losses, bean weevil, insect infestation, grain damage, weight loss, oxygen depletion</p>

### Introduction

Cowpea (*Vigna unguiculata* L. Walp.) is a key grain legume in sub-Saharan Africa, valued for its protein content, drought tolerance, and ability to fix atmospheric nitrogen, which improves soil fertility and reduces fertilizer use (Boukar et al., 2016).

However, post-harvest losses during storage remain a major constraint, mainly due to insect pests. The cowpea bruchid, *Callosobruchus maculatus* (Fabricius), is the most destructive storage pest. Infestation often begins in the field but intensifies in storage, where larvae feed on cotyledons, causing seed damage, weight loss, reduced germination, and grain deterioration (Sanon et al., 2011; Hajam et al., 2022).

Losses in West Africa range from 10% to over 50% depending on storage conditions (Bamaiyi et al., 2006; Sanon et al., 2011), forcing farmers to sell immediately

after harvest at low prices (Murdock et al., 2003; Hajam et al., 2022).

Conventional storage systems such as jute bags, polypropylene sacks, and metal containers are widely used but are highly susceptible to infestation due to oxygen and moisture exchange that supports insect survival and reproduction (Ofuya & Lale, 2001).

Hermetic storage technologies reduce oxygen and increase carbon dioxide, disrupting insect respiration and reproduction, thereby suppressing pest populations and preserving grain quality (Baoua et al., 2012; Murdock & Baoua, 2014; Murdock et al., 2003).

Botanical insecticides such as *Aframomum melegueta* and *Piper guineense* have also shown effectiveness against *C. maculatus*, supporting integrated pest management

approaches (Okeke & Ejete, 2025). However, storage structure remains a key factor influencing losses in smallholder systems in Nigeria.

Therefore, this study evaluates hermetic and conventional storage systems in reducing *C. maculatus* infestation, grain damage, weevil population, and weight loss in stored cowpea under laboratory conditions.

## 2. Materials and Methods

### 2.1 Study Area

The experiment was conducted at Nnamdi Azikiwe University, Awka, Nigeria, under controlled laboratory conditions. The study area lies within the humid tropical rainforest zone of southeastern Nigeria, characterized by relatively high temperature and humidity, which favour the development and proliferation of stored-product insect pests such as the bean weevil (*Callosobruchus maculatus*). The study was designed to simulate typical farmer storage conditions commonly practiced in the region.

### 2.2 Experimental Design and Treatments

The experiment was arranged in a Completely Randomized Design (CRD) with three replications to ensure uniform exposure of treatments to environmental conditions and to minimize experimental bias. Four storage structures were evaluated based on their effectiveness in protecting stored beans from insect infestation. These included a hermetic bag (50 kg capacity), jute bag (50 kg capacity), normal plastic bag (20 kg capacity), and metal bin (50 kg capacity). Treatments were randomly assigned within the experimental setup.

### 2.3 Sample Collection and Preparation

Clean, healthy, and uninfested cowpea seeds (*Vigna unguiculata*) were obtained from a local market/farm source and manually sorted to remove debris, broken seeds, and any pre-existing insect infestation. A uniform quantity of five kilograms of seeds was weighed for each treatment using a digital weighing balance. The seeds were then introduced into their respective storage structures under hygienic conditions to prevent initial contamination.

### 2.4 Storage Conditions

All treatments were stored under ambient laboratory room conditions, simulating typical on-farm and household storage environments in Nigeria. The storage structures were kept in a well-ventilated space, protected from direct sunlight and moisture. No chemical insecticides or fumigants were applied throughout the study period in order to evaluate the natural protective efficiency of each storage structure.

## 2.5 Environmental Monitoring

Temperature and relative humidity (RH) of the storage environment were monitored daily using a calibrated thermo-hygrometer. Measurements were taken at a consistent time each day to ensure uniformity. These environmental parameters were recorded to assess their influence on insect development and storage performance.

## 2.6 Data Collection

Data were collected at 2, 4, and 6 months after the commencement of storage. The following parameters were evaluated:

- **Seed damage percentage:** Determined by counting the number of damaged seeds relative to the total number sampled.
- **Number of exit holes:** Recorded as an indicator of adult emergence and feeding activity of *C. maculatus*.
- **Weevil population:** Determined by counting the number of live and dead insects present in each storage structure.
- **Weight loss:** Calculated by comparing the initial and final weights of the seeds using standard methods.

All sampling and measurements were carried out consistently across treatments and sampling periods.

## 2.7 Data Analysis

Data obtained were tested for normality prior to analysis. Where necessary, square root transformation was applied to stabilize variance. The data were subjected to one-way Analysis of Variance (ANOVA) using GenStat statistical software. Treatment means were separated using the Least Significant Difference (LSD) test at a 5% level of significance ( $P < 0.05$ ).

## 3. RESULTS AND DISCUSSION

### 3.1 Grain Damage

Grain damage differed significantly ( $P < 0.05$ ) among the storage structures, indicating that storage method strongly influenced the extent of damage caused by the bean weevil (*Callosobruchus maculatus*). As shown in Table 1, the hermetic bag consistently recorded the lowest grain damage across all storage periods (0.68%, 0.57%, and 0.51% at 2, 4, and 6 months, respectively), demonstrating its superior protective capacity.

In contrast, the highest grain damage was observed in the normal plastic bag, increasing from 12.18% at 2 months to 13.85% at 6 months. The jute bag and metal bin recorded intermediate levels of damage, with values rising to 9.17%

and 7.89%, respectively, at 6 months. This trend suggests progressive insect infestation and population build-up in non-hermetic storage systems.

The effectiveness of the hermetic bag can be attributed to the modification of the internal storage atmosphere. Reduced oxygen levels and increased carbon dioxide concentration inhibit insect respiration, feeding, and reproduction. This observation is consistent with earlier studies which reported that hermetic storage systems significantly suppress infestation by *C. maculatus* and reduce grain damage in stored cowpea (Murdock et al., 2003; Baoua et al., 2012).

The higher grain damage observed in jute and normal plastic bags may be due to their permeability, which allows free air exchange and creates favourable conditions for insect growth and reproduction. Similar findings have been reported by Sanon et al. (2011), who observed rapid population increase of *C. maculatus* and significant grain

damage in non-hermetic storage systems. Likewise, Bawa et al. (2025) reported that conventional storage methods in tropical environments are highly susceptible to bruchid infestation due to poor sealing and continuous oxygen availability.

Furthermore, studies on hermetic storage technologies such as SuperGrain and PICS bags have demonstrated significant reductions in insect damage and preservation of grain quality during storage (Baoua et al., 2014; Murdock and Baoua, 2014). These findings support the results of the present study, where hermetic storage effectively minimized grain damage compared to other storage structures.

Overall, the results confirm that hermetic storage is highly effective in reducing grain damage caused by *Callosobruchus maculatus*, while conventional storage structures such as jute bags, plastic bags, and metal bins remain more susceptible to infestation and damage.

**Grain damage (%) by *Callosobruchus maculatus* in different storage structures**

Storage structure	2 months	4 months	6 months
Hermetic bag	0.68a	0.57a	0.51a
Jute bag	7.33bc	4.04ab	9.17c
Metal bin	6.50abc	3.10a	7.89bc
Normal plastic bag	12.18c	6.92b	13.85d
LSD (0.05)	5.511	3.002	4.701

### 3.2 Weevil Population

The weevil population varied significantly ( $P < 0.05$ ) among the different storage structures, indicating that storage method played a critical role in influencing the population dynamics of *Callosobruchus maculatus*. As shown in Table 2, the hermetic bag consistently recorded the lowest weevil population across all storage periods, with values of 0.82, 0.80, and 0.82 at 2, 4, and 6 months, respectively. This demonstrates the strong suppressive effect of hermetic storage on insect survival and reproduction.

In contrast, the highest weevil population was observed in the normal plastic bag, increasing from 3.91 at 2 months to 4.90 at 6 months. The jute bag and metal bin showed intermediate infestation levels, with populations rising to 3.78 and 3.16, respectively, at 6 months. The gradual increase in weevil population in these storage structures indicates continuous reproduction and reinfestation due to favourable environmental conditions.

The significantly lower population observed in the hermetic bag can be attributed to oxygen depletion and carbon dioxide accumulation within the sealed environment. These conditions interfere with insect respiration, inhibit

oviposition, and ultimately reduce survival rates of *C. maculatus*. Similar findings have been reported by Murdock and Baoua (2014), who explained that hermetic storage systems function by creating modified atmospheres that suppress insect development and population growth.

Furthermore, Baoua et al. (2012) reported that hermetic storage technologies such as triple-layer bags effectively reduce the population of *C. maculatus* by limiting oxygen availability, thereby preventing larval development and adult emergence. This supports the low weevil population observed in the hermetic bag in the present study.

The higher weevil populations recorded in jute and normal plastic bags may be due to their permeability, which allows continuous oxygen supply and facilitates insect feeding and reproduction. This observation agrees with Murdock et al. (2003), who reported that *C. maculatus* rapidly proliferates in poorly sealed storage systems, leading to severe infestation and grain deterioration.

Similarly, Bawa et al. (2011) reported that non-hermetic storage systems are more susceptible to insect population build-up due to unrestricted air exchange, which promotes insect survival and multiplication. The relatively moderate population observed in the metal bin suggests that although

it offers some level of protection, it may not be completely airtight, thereby allowing limited insect activity.

Overall, the results demonstrate that hermetic storage is highly effective in suppressing the population of

*Callosobruchus maculatus*, while conventional storage structures such as jute bags, plastic bags, and metal bins remain more prone to infestation and population build-up.

**Table 2: Number of weevils (*Callosobruchus maculatus*) in different storage structures**

Storage structure	2months	4months	6months
Hermetic bag	0.82a	0.80a	0.82a
Jute bag	2.40bc	1.55ab	3.78c
Metal bin	1.80ab	1.36ab	3.16c
Normal plastic bag	3.91c	2.66b	4.90d
LSD(0.05)	1.512	0.481	0.898

### 3.3 Weight Loss

Weight loss differed significantly ( $P < 0.05$ ) among the storage structures, indicating that storage method had a strong influence on the extent of damage caused by *Callosobruchus maculatus*. As shown in Table 3, the hermetic bag recorded the lowest weight loss (3.56%), which was significantly lower than those observed in all other storage structures. This highlights the effectiveness of hermetic storage in preserving grain quality during storage.

In contrast, the highest weight loss was recorded in the normal plastic bag (26.95%), followed by the jute bag (19.99%) and metal bin (18.16%). The high level of weight loss in these storage structures can be attributed to increased insect feeding activity, development, and population build-up over time. As infestation progresses, larval feeding within the grains leads to substantial loss in dry matter, resulting in reduced grain weight and quality.

The minimal weight loss observed in the hermetic bag can be explained by its airtight nature, which restricts oxygen availability and leads to the accumulation of carbon dioxide. These conditions suppress insect metabolism, feeding activity, and reproduction, thereby minimizing grain deterioration. Similar observations were reported by

Baoua et al. (2012), who found that hermetic storage significantly reduced weight loss in cowpea by effectively controlling *C. maculatus* infestation.

Furthermore, Murdock and Baoua (2014) explained that hermetic storage technologies function by creating a modified atmosphere that disrupts insect physiological processes, thereby preventing population growth and subsequent grain damage. This mechanism directly contributes to reduced weight loss in hermetically stored grains.

The higher weight loss observed in jute and normal plastic bags is consistent with findings by Murdock et al. (2003), who reported that conventional storage systems allow continuous insect activity, leading to severe grain deterioration. Similarly, Bawa et al. (2011) noted that non-hermetic storage conditions favour insect survival and feeding, resulting in increased weight loss during storage.

Although the metal bin showed slightly lower weight loss compared to jute and plastic bags, the values were still significantly higher than those recorded in the hermetic bag. This suggests that the metal bin used in the study may not have been completely airtight, allowing limited insect activity and grain damage.

**Table 3: Percentage weight loss by Beans weevil (*Callosobruchus maculatus*) in different storage structure**

Storage structure	Weight loss (%)
Hermetic bag	3.56a
Jute bag	19.99c
Metal bin	18.16c
Normal plastic bag	26.95d
LSD (0.05)	5.896

### Conclusion

This study demonstrated clear differences in the performance of storage structures in protecting cowpea grains from *Callosobruchus maculatus* infestation under laboratory conditions in Nigeria. Among the storage methods evaluated, the hermetic bag consistently provided the best protection by maintaining very low levels of grain

damage, suppressing weevil population growth, and minimizing weight loss throughout the storage period.

In contrast, the normal plastic bag recorded the highest levels of infestation and grain deterioration, followed by the jute bag and metal bin, which showed moderate effectiveness but were still susceptible to insect activity. The superior performance of the hermetic bag can be linked

to its ability to restrict oxygen exchange, thereby creating an unfavorable environment for insect survival and reproduction during storage.

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