

**ASSESSMENT OF THE PURDUE IMPROVED CROP STORAGE (PICS) BAG  
FOR MAIZE STORAGE IN GHANA****Arthur E<sup>1\*</sup>, Akowuah JO<sup>1</sup> and G Obeng-Akroff<sup>2</sup>****Emmanuel Arthur**

\*Corresponding author email: [teddyarthur72@gmail.com](mailto:teddyarthur72@gmail.com)

<sup>1</sup>Department of Agricultural and Biosystems Engineering, College of Engineering, Kwame Nkrumah University of Science and Technology, Kumasi-Ghana

<sup>2</sup>Department of Agricultural and Biosystems Engineering, Iowa State University, Ames, IA, USA



## ABSTRACT

Despite the recent introduction of improved grain storage methods and technologies, many smallholder maize farmers in Ghana still use traditional storage practices and structures for storing their maize grains after harvest. This practice contributes to the high post-harvest losses in maize grain at the smallholder level largely due to insect pest infestation. Hermetic bag storage is a proven technology effective in reducing grain damage and losses from insect pests. In this study, the efficacy of the Purdue Improved Crop Storage (PICS) bag was compared with a polypropylene (PP) bag stored with maize treated with Betallic Super EC chemical and PP bag stored with maize without Betallic treatment (Control) during a 6-month storage period. Data on grain moisture content (MC), number of live insects, insect damaged kernels (IDK) and maize weight loss were collected monthly for analysis. Grain viability and nutrient analysis were also conducted before and after storage. The results showed initial grain moisture content of 11.4% was not significantly affected in the PICS bags but increased by 1-2% in the PP bags. Purdue Improved Crop Storage (PICS) bags and Betallic treatment significantly reduced insect damage grains with mean weight loss of < 5% and 6.35 % respectively compared to the control (PP bag without Betallic) treatment with mean weight loss of 21 % over the 6-month storage period. Germination rate of sampled seeds after storage in the PICS bags (75 %) was not significantly different to the initial germination rate (78 %) compared to the control (PP bag without Betallic) treatment of 56 %. Overall, maize grains stored in the PICS bags showed no signs of deterioration as compared to grains in the PP bags. The PICS bags were superior to the PP bags in terms of other grain quality metrics assessed and the nutrient characterization such as protein and carbohydrate which had no significant difference ( $p < 0.05$ ) between the initial and the three treatments. The results showed that PICS bags can be effective in protecting maize grains during storage. Smallholder farmers are therefore encouraged to consider this technology especially for controlling insect pests of stored maize.

**Key words:** Insect pests, Polypropylene, Smallholder farmers, Purdue Improved Crop Storage bag



## INTRODUCTION

Maize is widely grown throughout the world and has the highest production compared to all other cereals with about 817 million tonnes produced annually on the average. In most African countries, maize is one of the most important staple foods [1]. In Ghana, post-harvest losses of maize occur in both the major and minor season which covers the period of April-August or September and September-December respectively especially in the middle belts of Ghana [2]. Roughly 13.8 % of food produced in the globe was lost in 2016, either through post-harvest mishandling, insect and disease infestation or simply waste at the table [3].

In sub-Saharan Africa (SSA), the dominant insect pests that attack stored maize are the larger grain borer (LGB) and the maize weevil, *Sitophilus zeamais* [4]. Losses caused by these insects include: weight loss discolouration and changes in flavour, mould formation, reduced nutritional value due to lowered protein levels and poor germination of seed due to embryo damage. As reported by Rajendran and Parveen [5], insect infestation in stored food commodities reduces quality and quantity of food available for human consumption. Live insects in grain can also cause additional problems with respiring insects producing water, CO<sub>2</sub> and heat. In instances of higher infestations, the moisture content of the grain increases and hotspots are also developed in the stored grain in the areas of high insect activity.

To protect their grains, Adejumo and Raji [6] reported that, farmers in developing countries predominantly use traditional storage techniques which include open platforms, woven baskets, pots, mud rhombus, maize cribs, bamboo storage structures, straw roofed storage structures, underground storage, polypropylene (PP) bag storage and the use of farmer's room for storage. These systems are prone to insect infestation and aflatoxin contamination. Tefera *et al.* [7] emphasized, traditional storage systems used in developing countries cannot guarantee protection against major storage pests of staple food crops like maize leading to 20-30% grain losses, particularly due to postharvest insect pests and grain pathogens. Proper storage of grains is, therefore, necessary to prevent spoilage, maintain quality and provide income assurance to farmers. All actions and measures aimed at reducing food losses along the value chain are contributing factors which enhance food security and also help to alleviate poverty among smallholder farmers in Africa [8]. Hermetic storage of grains using sealed plastic bags has proven to be the most effective for controlling insect infestations in stored grains. Hermetic bags including the Purdue Improved Crop Storage (PICS) bag in Ghana have been widely promoted among smallholder farmers, however, many of these farmers continue to rely on the traditional PP bags with or without chemical treatment for pest control management for stored grains and preservation of seeds. The effectiveness of the PICS bag in controlling *Sitophilus zeamais* was tested in Ghana and the results showed that PICS bags were effective against *S. zeamais* and can be effectively used for grain storage [9].

This study was conducted to verify the efficiency of the PICS storage bags for protecting stored maize against insect pests as compared to Polypropylene (PP) bags, which is the commonest method or practice for maize storage in Ghana. Specifically,



effect of long-term storage of maize in the PICS hermetic bags on moisture content, grain nutrient, insect mortality and grain viability were assessed.

## MATERIALS AND METHODS

A total of 450 kg of a local maize variety called *Obaatampa* (Reg. No. CV-1, P1 641711) was harvested and disinfested using a solar biomass hybrid dryer. Before putting into the storage bags, the grains were sieved to eliminate foreign materials and dead insects. Only clean and wholesome grains were used for the experiment. Fifty kilograms of clean shelled maize were weighed using an electronic balance and put into each bag (PICS, PP with Betallic super EC treatment and PP with no Betallic super EC treatment). All the bags were tightly tied and kept on pallets under room temperature conditions in the laboratory (plate 1). Before storage, the following were performed moisture content, germination, percentage usable proportion by weight, insect infestation and proximate analysis to serve as baseline information against which changing parameters were compared monthly over a six-month period. The experiments begun on 13<sup>th</sup> September, 2019 (baseline) and ended on 13<sup>th</sup> March 2020 (final).



**Plate 1: Experimental set-up in the laboratory**

### Grain moisture content

The initial moisture content of maize grains was determined using the mini GAC<sup>®</sup> plus moisture meter. To ensure uniform moisture content of 12-13% in maize samples in each of the storage bags, maize was evenly dried before storage using a solar biomass hybrid dryer. A double tube compartmentalized spear was used to draw 100g of maize samples at different depths and sides of each storage bag and subsequently from same bag for grain quality analysis. Grain samples from each bag were drawn by pushing the probe from top to bottom from four cardinal points on the storage bag and the moisture meter was used in determining the moisture content.

### Germination test

For each storage bag, 100 seeds were sampled randomly at different depths using a sampling probe. The seeds were planted in a seed pan filled with moist river sand and

replicated three times. The germination test was conducted before the trial and repeated after 6 months of storage to ascertain consistency in the trend in germination percentage. The first count was taken 3 days after planting. Germination count was carried out daily after first germination. The percentage germinated seeds were calculated using Equation 1 [10].

$$\% \text{ Germination} = \frac{\text{number of seeds germinated}}{\text{number of seeds set for germination}} \times 100\% \dots\dots\dots \text{Equation 1}$$

**Determination of insect infestation levels**

For each storage bag, 1.5 kg grains were sampled from different depths using a sampling probe. The samples for each storage bag (treatment) were sieved using 4mm sieve on to a white paper. The inert materials were then separated from the insect with the help of a spike. The insects were subjected to two types of tests. The first test was by visual inspection using the naked eye and then thoroughly examined under the magnification of a stereo microscope.

**Determination of relative damage**

One thousand grains were counted manually from sampled grains from each storage bag. The number of damaged and undamaged kernels in each subsample were visually counted and separated. The quality test was carried out using the International Grain Procurement Manual guidelines, procedure and rules. The dry weight of the damaged and undamaged grain for each subsample was then determined. The relative percentage damage of the grain over the storage period was determined by Equation 2.

$$\text{Relative damage (\%)} = \frac{\text{weight of undamaged grain (kg)}}{\text{sum of weight of damaged and undamaged (kg)}} \times 100 . \text{Equation 2}$$

**Proximate analysis**

Moisture content, ash content, crude protein content and crude fibre were determined by the methodology of the Association of Official Analytical Chemist (AOAC) [11]. Crude fat was determined based on the Soxhlet extraction method of AOAC [11]. For carbohydrate content, total percentage carbohydrate was determined as the difference between 100% and the sum of percentage crude protein, crude fat, crude fibre, moisture, and ash constituents of the sample.

**Experimental Design**

The experiment was set up in 2 × 3 Factorial using Completely Randomized Design (CRD) method. The experiment was set up to compare PICS hermetic bag for storage of maize to the existing polypropylene (PP) bag. The experiment involved assessing the effect of storage bag (PICS and PP) and storage duration (6 months’ period) under three treatments; 1) maize in PICS hermetic bag; 2) maize in PP bag with Betallic treatment and 3) the control (maize in PP bag with no Betallic). The treatments and control were replicated 3 times.



## Data Analysis

Effects of treatment conditions on insect infestation levels, grain moisture, relative damage, and germination rate were subjected to analysis of variance (ANOVA) within groups using GenStat statistical software version 12 with significant values reported at  $p < 0.05$ .

## RESULTS AND DISCUSSION

### Grain moisture

Storing maize either in the PICS bags or the PP bag with or without chemical treatment had a significant effect on grain moisture over the storage period of six months (Fig 1). With initial storage moisture content of 11.4%, grains in the PICS bags recorded the lowest mean value of 10.8% as at the sixth month whilst grains in the PP bag treated with Betallic and the control recorded 11.53% and 12.37%, respectively. Overall, grain moisture in the hermetic bag (PICS) remained relatively constant over the storage period but maize stored in the PP bags gained moisture especially the control which was heavily infested by weevils. These results are consistent with the results of other studies focused on PICS bags, which demonstrated better outcomes for grain stored in the triple bags than for grain stored in other ways [12]. According to Murdock *et al.* [13] the PICS bags' ability to create low-oxygen environments is the key to its protective nature. Williams *et al.* [14] also reported that, preventing water vapour transmission is another valuable trait of triple layer bag. Purdue Improved Crop Storage (PICS) bags were able to maintain grain moisture better than the PP bags due to the permeability of PP bags which allowed the transfer of moisture into the bags thereby resulting in the stored grains gaining moisture over the storage period. A stable moisture environment is beneficial from a farmer's perspective and according to Devereau *et al.* [15], for tropical regions, having a barrier against water vapour transmission would prevent stored maize from absorbing water when humidity is high and from losing water when it is low. Grain with low moisture content is unlikely to become badly infested by insect pests and the risk of microbiological infection is low [16].

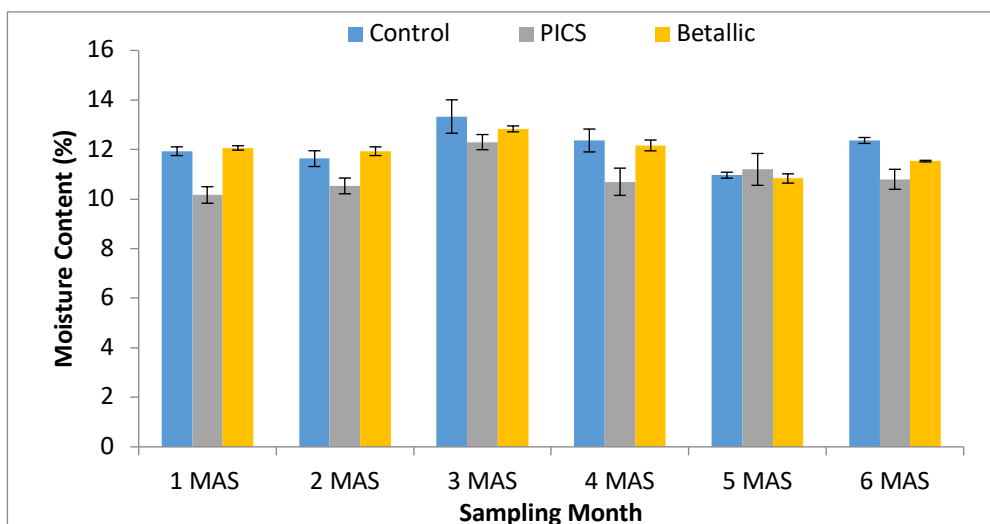


Figure 1: Moisture content of the 3 different treatments for a period of 6 months. MAS means month after storage

### Insect infestation level

The major post-harvest insect pests identified in the storage bags were *Sitophilus zeamais* (Maize weevil), *Tribolium castaneum* (Red-rust flour beetle) and *Prostephilus truncates* (Larger grain borer) with *Sitophilus zeamais* dominating in population in all the storage bags. Level of insect infestation varied greatly with type of storage bag and time. There was, therefore, a significant difference ( $p < 0.5$ ) amongst the three treatments with respect to insect infestation level. However, in the PICS bag treatment, the numbers of *Sitophilus* were not significantly different during entire storage period with an average of 0.33 live *Sitophilus* recorded at the end of storage period. A similar trend was observed with the Betallic treatment during the first 3 months where no live insects were present. But with the knock-down of the active ingredients, there was a surge in the number of *Sitophilus* that emerged with an average of 34.33 recorded on the sixth month after storage (Figure 2). The number of live *Sitophilus* was significantly higher in bags in the control treatment where a mean of 60 live insects were recorded at the sixth month of storage. This is clear indication that, PICS bag provided the best protection of stored maize grains against the maize weevil as it was able to suppress the emergence or re-emergence of the maize weevil over the six-month period compared to the PP bags with Betallic treatment and the control treatment (no Betallic) (Figure 3).

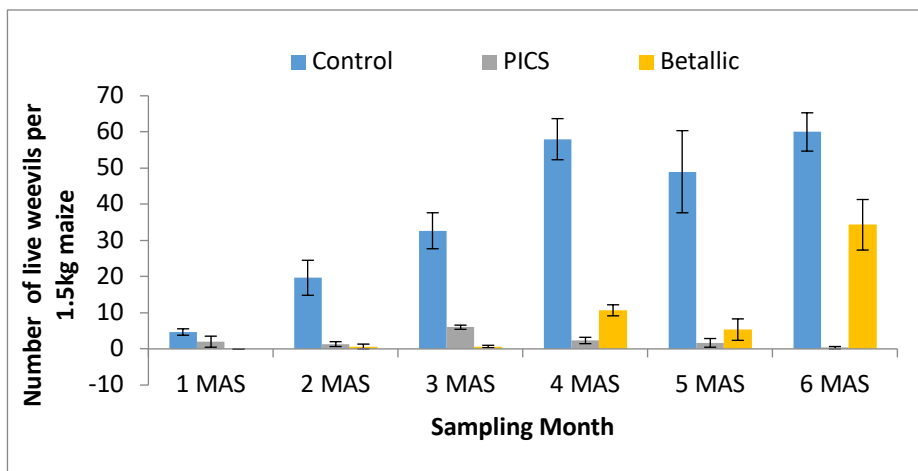
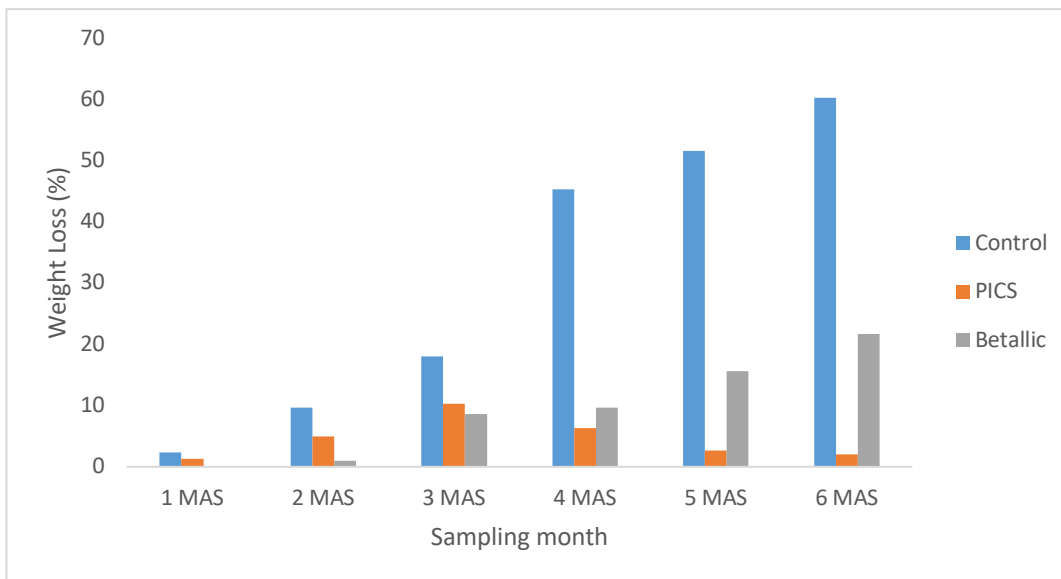


Figure 2: Number of live weevils per 1.5kg maize

### Grain weight loss due to insect damage

Insect damage to the stored maize varied greatly with time and type of treatment set-up (Fig 3). It was observed that, PICS bag and Betallic treatments significantly reduced insect damage kernels (IDK) compared to the PP bags with no treatment (control treatment). Mean weight losses of insect damaged grains was not significantly different during the entire storage period in the PICS bag treatment (Fig. 3). The number of IDK increased from 0.9% one month after storage (MAS) to 1.3% six MAS with mean weight loss  $< 5\%$  over the six months storage period. However, the Betallic treatment was quite effective only up to four months of storage where weight loss did not exceed 10%. After four months of storage, the level of insect (*Sitophilus*) present in the bag increased significantly and resulted in percentage IDK of 14.5% with a weight loss of

45.3% after four months of storage. As reported by Stathers *et al.* [17], this could be attributed to the gradual dissipation of the active ingredients in the Betallic Super EC chemical as storage time is prolonged. In the control treatment, insect damaged grains increased significantly from an average 1.5% at one MAS to 40.2% at six MAS with weight loss increasing from 2.3% to 60.3 % over the six-month storage period. This study corroborates with the study by Costa [18] who reported that, postharvest losses (including weight losses) of 59 and 54% were recorded in maize stored for 90 days in traditional PP bags in field experiments conducted in Uganda and Burkina Faso, respectively.

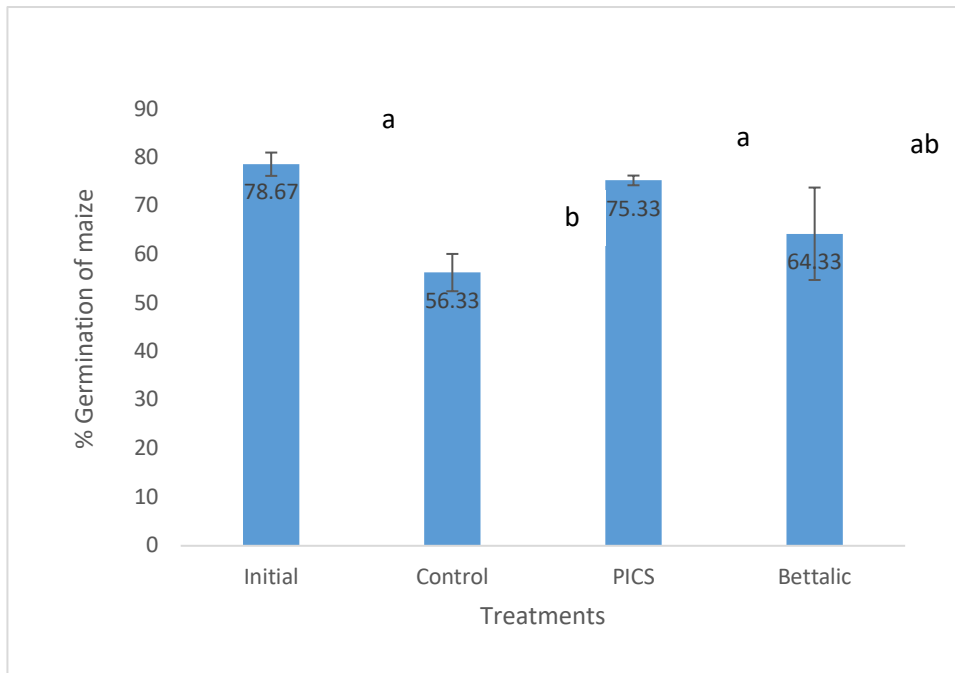


**Figure 3: Percentage weight loss**

### Germination

After six months of storage, there was no significant difference ( $p < 0.05$ ) in germination rate between the initial germination rate (78.67%), PICS bag treatment (75.33%) and the Betallic treatment (64.33%) (Figure 4). However, there was a significant difference between the control (56.3%) and the PICS bag treatment. The decrease in the germination potential in the various treatments may be attributed to the rate of insect infestations since the initial had no infestation and therefore recorded 78.67%. Likewise, the PICS which had the least infestation recorded 75.33%. The control on the other hand experienced the highest insect infestation, therefore, recorded the lowest germination percentage. This implies that increase in infestation decreases the germination potential.





**Figure 4: Percentage germination of maize. Means within the graph followed by the same letter are not significantly different at  $p < 0.05$**

#### Proximate characterization of maize grains

As shown in Table 1, there were changes in the proximate composition of the maize sample after six-months of storage. There were decreases in protein, fat and crude fibre of all the treatments after the storage period, whereas, there was an increase in moisture content, ash and carbohydrate. In Table 1, it could be seen that, with respect to moisture content, the study recorded no significant difference ( $p < 0.05$ ) between the initial and the other treatments. There was no significant difference ( $p < 0.05$ ) between the initial and the final proximate compositions for protein and carbohydrate in all the treatments.

Fat had an initial content of 4.84% which was the highest mean while the control had the lowest mean of 3.26%, however, the difference between the initial and the other treatments, was not significant ( $p < 0.05$ ).

However, analysis of variance showed a significant difference ( $p < 0.05$ ) between the initial (0.55%) and the final ash content for the various treatments Bettalic 1.12%, PICS 1.19% and control 1.13%.

Also, there was a significant difference ( $p < 0.05$ ) in the initial (0.50%) and the final results for PICS (0.18%) and Bettalic (0.12%) treatment on crude fiber, although not for the control (0.32%). The reduction in protein content of maize grains infested by *Sitophilus zeamais* suggest the intake of the grain protein nutrient as a result of high insect infestation levels over the storage period. In a similar study on nutritional depletion of maize grains, Bamaiyi *et al.* [19], reported that, protein is an important nutrient in the diet of insect pest. This buttresses the suggestion that protein is one of the nutrients affected by insect feeding.

Over the storage period, it was observed that (Table 1), moisture content of maize grains increased across the various treatment set-ups. However, it was observed that

PICS bags provided a stable environment to control moisture fluctuations. Grains stored in the PP bags with and without chemical treatment, however, had higher moisture content. This could be attributed to the metabolic activities of the insects in these bags. These metabolic activities generate heat required for chemical reactions that proceed more frequently and rapidly at very high temperatures. In effect, it releases moisture as one of the bi-products of the reaction. The result of this study is in agreement with the findings of Bamaiyi *et al.* [19] who reported surface heating dampness and increase in moisture content of stored maize in PP bags.

The reduction in fat can be attributed to insect infestation over the storage duration and this has previously been reported by Keskin and Ozkaya [20]. In a study conducted by Ijabadeniyi and Adebolu [21], a decrease in fat content and increase in the ash content of infested wheat samples stored for 6 months was attributed to increased insect population.

The infestation of *Sitophilus zeamais* which fed on the maize grains was the reason for the reduction in crude fibre as observed in Table 1 at the end of the storage period. A similar assertion to this was reported by Nwuabani *et al.* [22] who attributed the reduction in crude fiber to the increase in insect damaged kernels as a result of their feeding activities. The increase observed in ash content was due to the insect infestation and prolonged storage period as reported by Keskin and Ozkaya [20, 21].

Carbohydrate increased in grains stored in the PICS bag as protein, fat and crude fibre decreased at the end of the six months' storage period. The results are similar to those of Osipitan *et al.* [23] who reported reduction in protein and increase in starch as a result of infestation by *Sitophilus zeamais*.

## CONCLUSION

Post-harvest losses in maize due to insect infestation and lack of effective storage structure for use by farmers are a major challenge in developing countries. In this study, the results on grain moisture, grain damage due to insect infestation, germination and grain nutrients showed that, PICS hermetic bag was highly effective in preserving the initial quality characteristics of the stored maize grains. The PICS bag was able to suppress insect infestation and damage levels compared to grains treated with the Betallic and the control (untreated maize grains) stored in the PP bags. The Betallic treatment was effective at suppressing stored-product insect pest up to the fourth month of storage. Germination rates were significantly lower in infested grains stored in PP bags compared to the PICS bag. For long term storage of maize grain, PICS bags should be considered as a safe and effective method of controlling insects of stored maize at a relatively lower cost for smallholder farmers.

## ACKNOWLEDGEMENTS

My sincerest gratitude to the Foundation for Food and Agriculture Research and the Rockefeller Foundation for supporting this research.



**Table 1: Proximate analysis of maize**

	<b>Initial</b>	<b>Betallic</b>	<b>PICS</b>	<b>Control</b>	<b>LSD</b>
Moisture content	8.66a	11.06a	8.78a	11.38a	<b>ns</b>
Fat	4.84a	3.55a	3.28a	3.26a	<b>ns</b>
Ash	0.55b	1.12a	1.19a	1.13a	<b>0.23</b>
Protein	9.04a	8.77a	9.02a	8.37a	<b>ns</b>
Crude fibre	0.50a	0.12b	0.18b	0.32ab	<b>0.23</b>
Carbohydrate	76.41a	75.38a	77.55a	75.54a	<b>ns</b>

\*values followed by the same character in the same row is not significantly different at  $p < 0.05$

## REFERENCES

1. **FAO.** On-farm Post-harvest Management of Food Grains by P. Golob. A Manual for Extension Workers with Special Reference to Africa. FAO, Rome, 2009.
2. **Opit GP, Campell J, Arthur F, Amstrong P, Osekre E, Wasburn S, Baban O, McNeill S, Mbata G, Ayobami I and PV Reddy** Assessment of Maize Postharvest Losses in the Middle Belt of Ghana. 11<sup>th</sup> International Working Conference on Stored Product Protection 2014:134.
3. **Food and Agriculture Organization (FAO).** The State of Food and Agriculture. Moving Forward of Food Loss and Waste Reduction. FAO Rome, 2019.
4. **Seidu JM, Mensah GWK, Zah VK, Dankwah SAA, Kwenin WKJ and AA Mahama** The use of solar drier to control insect infestation in stored grains in Ghana. *International Journal of Biological and chemical Science.* 2010; **4**: 2397-2408.
5. **Vowotor KA, Meikle WG, Ayertey JN and RH Markham** Distribution of/and Association Between the Larger Grain Borer *Prostephanus Truncates* (Horn) (Coleoptera: Bostrichidae) and the Maize Weevil *Sitophilus Zeamais* Motschulsky (Coleoptera:Curculionidae) in Maize Stores. *Journal of Stored Products Research.* 2005; **41**: 498-512.
6. **Rajendran S and HKM Parveen** Insect Infestation in Stored Animal Products. *Journal of Stored Products Research.* 2005; **41**:1-30.
7. **Tefera T, Kanampiu F, De Groot H, Hellin J, Mugo S, Kimenju S and M Banziger** The Metal Silo: An Effective Grain Storage Technology for Reducing Post-Harvest Insect and Pathogen Losses in Maize while Improving Smallholder Farmers' Food Security in Developing Countries. *Crop Protection.* 2011;**30**: 240–245.
8. **Benimana GU, Ritho C and P Irungu** Assessment of factors affecting the decision of smallholder farmers to use alternative maize storage technologies in Gatsibo District-Rwanda. *Heliyon.* 2021; **7**: 1-8.
9. **Darfour B and KA Rosentrater** Maize in Ghana: An Overview of Cultivation to Processing. An ASABE Annual International Meeting. 2016; Paper No. 162460492: 1-16.
10. **Azadi MS and E Younesi** The Effect of Storage on Germination Characteristic and Enzyme Activity of Sorghum Seed. *Journal of Stress Physiology & Biochemistry.* 2013; **9**: 289-298.
11. **AOAC.** Official Methods of Analysis of AOAC International, 17th ed.; AOAC International: Gaithersburg, MD, USA, 2000.



12. **Baoua IB, Margam V, Amadou L and LL Murdock** Performance of Triple Bagging Hermetic Technology for Postharvest Storage of Cowpea Grain in Niger. *Journal of Stored Products Research*. 2012; **51**: 81-85.
13. **Murdock LL and IB Bauoa** On Purdue Improved Cowpea Storage (PICS) Technology: Background, Mode of Action, Future Prospects. *Journal of Stored Products Research*. 2014; **58**: 3-11.
14. **Williams SB, Murdock LL and D Baributsa** Storage of Maize in Purdue Improved Crop Storage (PICS) Bags. *PLOS ONE*. 2017; **12**: e0168624.
15. **Devereau AD, Myhara R and C Anderson** Chapter 3: Physical Factors in Post-Harvest Quality. In: Golob P, Farrell G and JE Orchard (Eds). *Crop Post-Harvest: Science and Technology: Principles and Practice*. Ames, Iowa: Blackwell Science Ltd. 2002: 62-92.
16. **Hellevang K** Corn Drying and Storage Tips. NDSU Extension Service, 2011.
17. **Stathers TE, Riwa W, Mvumi BM, Mosha R, Kitandu L, Mngara K, Kaoneka B and M Morris** Do Diatomaceous Earths have Potential as Grain Protectants for Small-Holder Farmers in Sub-Saharan Africa? The Case of Tanzania. *Crop Protection*. 2008; **27**, 44-70.
18. **Costa SJ** Reducing food losses in Sub-Saharan Africa: An 'Action Research' Evaluation Trial from Uganda and Burkina Faso. UN World Food Programme. Kampala, Uganda. 2014.
19. **Bamaiyi LJ, Onu I, Amatobi CI and MC Dike** Effect of *Callosobruchus Maculatus* Infestation on Nutritional Loss on Stored Cowpea Grains. *Archives of Phytopathology and Plant Protection*. 2006; **39**: 119-127.
20. **Keskin S and H Ozkaya** Effect of storage and insect infestation on the technological properties of wheat. *CyTA- J. Food* 2015; **13(1)**: 134–139.
21. **Ijabadeniyi AO and JT Adebolu** The effect of processing method on nutritional properties of Ogi produced from three maize varieties. *Journal of Food Agriculture and Environment*. 2005; **3**: 108–109.
22. **Nwaubani SI, Otitodun GO, Ajao SK, Opit GP, Ala AA, Omobowale MO, Ogwumike JC, Abel GI, Ogundare MO, Braimah JA, Busari SG, Olenloa AE, Kolayemi OR, McNeill SG and KE Ijeleji** Assessing efficacies of insect pest management methods for stored bagged maize preservation in storehouses located in Nigerian markets. *Journal of Stored Products Research*. 2020; **86**: 1–12.
23. **Osipitan AA, Olaifa OK and OA Lawal** Evaluation of proximate composition of maize grains infested by maize weevil (*Sitophilus zeamais L.*) (*Coleoptera: Curculionidae*). *Munis Entomology and Zoology*. 2012; **7**: 439-445.