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Research Article

Comparing maize storage technologies for managing post-harvest loss in Bako, Ethiopia

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Abstract

Ethiopian stored maize is expected to lose between 20 and 30% of its stock due to insect damage. To reduce these losses, Ethiopian farmers use chemically treated traditional storage structures and chemical-free Hermetic Storage Technologies (HSTs). We evaluated the storage techniques used in the area in this study. SPSS software was used to analyse the collected data, and mean differences were compared. The findings showed that after nine months of storage, maize stored in plastic containers, Purdue Improved Crop Storage (PICS) bags, chemically treated polypropylene bags, and chemically treated Goteras had grain damage of 4.83%, 5.65%, 56.83%, and 71.06%, respectively; the weight loss was 2.00%, 2.95%, 37.44%, and 56.87%. The percentage germination of maize grains stored in treated polypropylene bags and Goteras decreased from 55.33% to 48.48%, whereas maize contained in plastic containers and PICS bags dropped only slightly and was 98.83% and 95.80%, respectively. Insect development, maize grain damage, and weight loss were significantly reduced ($p < 0.05$) for plastic containers, PICS bags, chemically treated polypropylene bags, and treated Goteras. As a result, secure maize storage technology, such as hermetic storage technology, may alleviate poverty by increasing household income.

Introduction

PHL is defined as a decrease in both food quantity and quality after harvest. It is a case of crop losses that happen at all steps of the post-harvest routes, including handling, harvesting, and transportation; storing; processing; packaging; and marketing [1,2]. Says post-harvest losses are high in developing countries due to insufficient and ineffective storage structures and poor handling practices. As a result, identifying post-harvest grain management and handling practices is critical for a variety of reasons, including food security [3].

Grain storage in Sub-Saharan Africa (SSA) is managed using a variety of storage technologies. PICS bags are regarded as one of the safest and most efficient grain storage methods by small-scale farmers [4]. It has a capacity of 50 or 100 kg [5] and is constructed of three-layered bags, two gas-proof inner bags, and a much tougher open-weave polypropylene bag. These serve as a barrier between stored grain and its surroundings, preventing oxygen and moisture exchanges. The biological activity of grains' living organisms consumes oxygen and emits CO_2. They died due to a lack of oxygen. Plastic containers are high-density polyethylene containers used to transport liquids and, occasionally, store maize. It has a top opening covered with a lid, and gum is used to further seal the inlet to maintain airtightness [6]. The use of Polypropylene (PP) bags containing insecticides increases farmers' chances of storing maize in safe environments [7]. Chemically treated maize can be stored in 100 kg PP bags. Pirimiphos-methyl and permethrin are commonly used to control insect pests in stored grains [8].

It is demonstrated that farmers' indigenous knowledge of traditional storage practices can be recorded through interviews and group discussion methods [9]. Farmers in western Ethiopia's Oromia region, to our knowledge, do not use modern storage technologies to control insect pests. The vast majority of them employ low-quality traditional storage structures,

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exposing the grains to a variety of agents or situations that can result in quality and quantity loss. Farmers use grain storage structures known as "gumbi" or "gotera." Grain for consumption is frequently stored in goteras, whereas grain for the market is temporarily stored in sacks or, in some cases, in goteras [3]. Nowadays, the rising demand for pesticide-free crops emphasizes the importance of farmers evaluating pesticide-free hermetic storage systems as alternatives to synthetic chemical grain storage [10]. Plastic containers and PICS bags are promoted as cost-effective solutions for controlling insect infestations in storage.

As a result, this research was carried out in some of the most prominent maize-producing areas in the Bako area in western Ethiopia. The study's goal was to evaluate storage systems used in the area for insect pest management.

Materials and methods

Description of the research areas

From January to October 2022, surveys were conducted in the Oromia regional state's west Shewa and east Wallega zones. Based on maize production potential, the Bako Tibe district in the west Shewa zone and the Gobu Seyo and Gudaya Bila districts in the east Wallega zone were chosen for the surveys. The Bako Agricultural Research Centre (BARC) and previously published sources provided meteorological data for the study sites [11,12]. The study areas differ in elevation from 1581 to 2425 meters above sea level, with annual rainfall ranging from 830 to 1950 millimeters. The area's climate is warm and humid, with average minimum and maximum air temperatures ranging from 15 to 30 °C. The minimum, maximum, and average relative humidity values for the area are 49, 74.7, and 61.85%, respectively. Five survey locations (kebeles) were chosen from the three districts for the study. A kebele is the smallest administrative unit of a district in Ethiopia.

Sampling procedure and sample size

A multi-stage cluster sampling design was employed to determine the sample size for each group. A multi-stage cluster sampling design is a type of design used when a population is large and scattered. Multi-stage cluster sampling was used because it gave all households in the selected kebeles equal chances. From the 3 districts of the study areas (Bako Tibe, Gobu Seyo, and Gudaya Bila), the 5 kebeles sampled were: Chali Jima, Dambi Dima, Darbes Garado, Sombo Kejo, and Tulu Sangota. Farmers were identified and assigned to the sampled kebeles. Based on the total number of farmers in each kebele, 10% of farmers were chosen randomly, resulting in a total target population of 1250 farmers. This requires a sample size of 125 farmers for the study as a whole. Simple random sampling techniques were used to obtain one hundred twenty-five (125) maize grower respondents.

Contrasting maize storage technologies

Data collected included local farmers' storage technologies and stored maize grain insect pest management. The following storage technologies were used in the area:

1. Plastic container (hermetic storage technology).
2. PICS: triple-layer bags (hermetic storage technology).
3. Chemically treated polypropylene bag (Non-hermetic storage technology)
4. Chemically treated traditional storage materials such as gotera or gumbi (Non-hermetic storage technology)

Maize sampling from various storage structures

In each of the three study districts, maize grains were taken from farmers' storages. Half a kilogram of maize grain was collected from each of the 125 farmers chosen. Samples were taken from the top, sides, center, and bottom of the various storage structures using sampling spears and human hands. This was described in [13]. On each sampling date, from different storage structures in each kebele, samples were stored in a sampling bag. They were labeled with the necessary information and brought to the Bako national maize plant protection laboratory. The grains were collected three times from representative farmers' storages in each kebele during the third, sixth, and ninth months of storage [14]. When the sample store of choice was empty, samples were taken from the next closest store.

Evaluation of maize grain weight loss

100 grain were chosen randomly from each sample to calculate the percentage of weight loss. As described in [15], damaged (grains with characteristic holes) and undamaged grains were counted and weighed.

$$\%\ \text{Weight loss} = \frac{(W_u * N_d) - (W_d * N_u)}{W_u * (N_d + N_u)} * 100, \text{ where}$$

W_u = Weight of undamaged grains

N_u = Number of undamaged grains

W_d = Weight of damaged grains

N_d = Number of damaged grains

Evaluation of maize grain damage

The counting method was used to assess seed damage. A hundred seeds were randomly selected from each maize sample. The presence of holes or burrows in the number of insect-damaged and undamaged grains was determined using a hand lens. The percentage of insect-damaged seeds was then calculated [16].

$$\text{Insect damaged grains } (\%) = \frac{\text{Number of insect} - \text{damaged grains}}{\text{Total number of grains}} * 100$$

Maize grain germination percentage

Germination tests were performed at the end of the experiment after other parameters were collected. 30 seeds were randomly selected from each sample for the germination test. The seeds were placed in separate sterile Petri dishes

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with moistened filter paper (Whatman No. 1) and kept at room temperature. After 7 days, the number of seedlings that emerged from each Petri dish was counted and recorded. The percentage of germination was calculated [17].

$$\text{Viability index }(\%) = \frac{N_G}{T_G} * 100, \text{ where}$$

N_G = Number of grains germinated

T_G = Total number of grains tested in each Petri dish

Data analysis

The data were entered into a Microsoft Excel spreadsheet before being coded and analyzed using the Statistical Package for Social Sciences [18]. To assess the relationships between variables, a Pearson correlation was performed. Over three storage periods in the study area, a one-way ANOVA was used to test grain damage, weight loss, and germination in hermetic and traditional storage technologies. Also, when the interaction term coefficient was significant at $p < 0.05$, significant differences in the use and profitability of PICS bags were concluded.

Results and discussions

The local pest pressure on the stored maize crop

Table 1 shows that among the five kabeles, maize was significantly ($p < 0.05$) affected by insects in the field ($\chi 2$ = 24.600, df = 4, $p < 0.01$). Pests in the field harm maize crops, according to 66.7% of respondents. Local pest pressure on maize crops is high, according to 57% of respondents, both in the field and during storage. The ANOVA test confirmed that there were significant differences in local pest pressure among kebeles in maize crops in the field and during storage ($p < 0.01$). The proportion of grains damaged by storage pests varied greatly across kebeles. It ranged from 1% - 25%, as reported by more than 36% of respondents, to 26% – 50%, as indicated by 48%. In total, 16% of those polled reported grain damage from storage pests, ranging from 51 to 75%. The ANOVA test confirmed that there was a significant difference ($p < 0.05$) between kebeles in the proportion of maize damaged during storage (Table 1).

Maize is attacked by insects both on the farm and in the store. In this study, local pest pressures on the maize crop were high, both in the field and during storage (Table 1). Post-harvest losses in Africa are often between 20 and 40% [6]. In our survey, the proportion of grains damaged by storage pests varied significantly across kebeles. Estimates range from 1-25% for more than 36% of respondents, 26% – 50% for 48% of respondents, and 51% – 75% for 16% of respondents. These findings are consistent with those of [19], who discovered that 16% of respondents reported grain damage ranging from 51% to 75% due to storage pests (Table 1).

Storage technologies practiced in the area by local farmers and management of stored maize grain insect pests

Table 2 presents results on post-harvest facilities for maize from 2020 to 2022. These findings indicate that respondents produced maize that required storage for future use, including sale. Kebeles used a variety of storage methods, with the majority storing grains in traditional storage materials treated chemically (41.8%) (9.3% in Sombo Kejo, 8% in Darbes Gerado, 8.4% in Chali Jima, 5.3% in Dambi Dima, and 7.6% in Tulu Sangota). 11.1% of respondents used other storage facilities, such as plastic containers for maize storage, mostly in Sombo Kejo and Chali Jima Kebeles.

Traditional maize storage materials in the area come in a variety of shapes and sizes and are mostly made of wooden walls and grass-thatched roofs. Nowadays, crop storage is mostly done in PICS and PP bags filled with treatment. In this study, almost 47.1% of respondents used these storage materials. The chi-square test of independence confirmed that there was no significant difference in maize storage technology used in three consecutive years from 2020 to 2022 ($\chi 2$ = 3.546, df = 6, p = 0.738), and also that there was no significant difference in maize storage technology applied in all five Kabeles from 2020 to 2022 ($\chi 2$ = 12.046, df = 12, $p < 0.443$).

Developing countries have long suffered from insufficient post-harvest facilities for maize storage [20]. Farmers can increase income and reduce post-harvest losses by improving storage structures. Hermetic storage systems reduce insect-caused storage losses in cereal and legume crops. Table

Table 1: Farmers' responses about pest pressure on maize in storage in the Bako region of western Ethiopia.

	CJ	DD	DG	SK	TS	Total %	F-test	*p*-value	χ2
	N-15	N-15	N-15	N-15	N-15	N-75			
Maize crop affected by pests in the field (%)									24.6
Yes	12	20	10.7	18.7	5.3	66.7			
No	8	0	9.3	1.3	14.7	33.3			
Local pest pressure in maize crops both in the field and during storage									
Law	0.09 ± 0.09	0.00 ± 0.0	0.13 ± 0.09	0.07 ± 0.07	0.13 ± 0.09	0.08 ± 0.03	0.613	0.655	
High	0.20 ± 0.11[bc]	0.80 ± 0.11[c]	0.40 ± 0.13[a]	0.87 ± 0.09[ab]	0.60 ± 0.13	0.57 ± 0.06	5.879	0.001	
As usual	0.67 ± 0.13[b]	0.20 ± 0.11[b]	0.53 ± 0.13[a]	0.07 ± 0.07[ab]	0.27 ± 0.11	0.35 ± 0.06	4.795	0.002	
Proportion of maize damaged during storage									
1-25 %	0.60 ± 0.13	0.27 ± 0.12	0.53 ± 0.13	0.13 ± 0.09	0.27 ± 0.12	0.36 ± 0.06	2.75	0.035	
26-50 %	0.20 ± 0.11	0.67 ± 0.13	0.20 ± 0.12	0.67 ± 0.13	0.63 ± 0.13	0.48 ± 0.06	4.635	0.002	
51-75 %	0.20 ± 0.11	0.07 ± 0.07	0.27 ± 0.12	0.20 ± 0.11	0.07 ± 0.07	0.16 ± 0.04	0.873	0.483	

*Means followed by the same letter (s) within a column are significantly different at 0.05 levels. Tukey's honest significance. Kebeles: CJ= Chali Jima, DD= Dambi Dima, DG= Darbes Gerado, SK= Sombo kejo, TS= Tulu Sangota.

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2 shows maize post-harvest facilities and storage insect attack frequencies. According to these findings, respondents produced maize, which necessitated storage for future use, including sale. Most of them keep their maize in conventional containers. According to [19], traditional storage materials are used more widely in rural Africa to preserve maize. In 2020–2022, 41.8% of respondents (Table 2) plan to use traditional storage structures (gotera). Traditional storage materials come in a variety of shapes and sizes, but the majority are made of wood with thatched grass roofs.

From 2020 to 2022, 47.1% of farmers stored their grains in PICS or chemically treated PP bags, indicating a shift in crop storage (Table 2). Africa and Latin America use PICS bags [21]. A higher proportion of farmers in these areas do not use modern storage materials such as metal silos or plastic containers. This is because they are perceived to be prohibitively expensive for smallholder farmers across all kebeles and thus are not widely employed. Only 11.1% of respondents said they stored maize in plastic containers (Table 2). Furthermore, they demonstrated that, while they knew about enhanced storage technology and sophisticated storage facilities, the costs were too high and they could not afford them. Previous research identified high costs as an obstacle to new technologies [4].

Mean percent grain damage and weight loss in HST and TST over three storage periods

Grain damage (50.81 %, 65.29 %, and 71.06%), weight losses (31.61%, 50.84%, and 56.87%), and germination losses (35.9%, 46.5%, and 51.5%) of stored maize grain were all higher at 3, 6, and 9 months in this study. Grain damage was 4.83 %, 5.65 %, 56.83%, and 71.06 % in plastic containers, PICS, PP bags, and Gotera at nine months. This corresponds to weight losses of 2.00%, 2.95%, 37.4 %, and 56.87%, respectively. Maize placed in PP bags germinated at a rate of 55.33% and gotera germinated at a rate of 48.48%, respectively. Germination of maize stored in plastic containers and PICS bags dropped only slightly after nine months of storage, reaching 98.83 and 95.80 %, respectively. Chemically treated gotera had higher mean percentages of grain damage and weight losses than hermetic storage systems. These findings are consistent with those of [22], who found that the mean percentage of grain damage and weight losses due to pests under traditional farmers' storage procedures was 64.50% and 58.85%, respectively, throughout a six-month storage period.

Over a six-month storage period, the average percentage of grain damage and weight losses caused by pests in PP bags was 50.5 % and 36.3 %, respectively. In Kenya, maize stored in polypropylene sacks for six months yielded similar results [23]. In line with this study's findings, [7] found that PICS bags held up better against maize weevil attacks after 8 months of storage. PICS bags lost 2.4% – 2.9% of their weight (Table 3).

Conclusion and recommendation

The use of secure maize storage technology, such as the

Table 2: Percentage of respondents in relation to storage facilities practiced for storing maize from 2020-2022 in the Bako area, western Ethiopia.

Parameter	Hermetic		Treated with insecticides		Overall %	χ2	p-value
	PC	PICS bag	PP bag	Gotera			
Storage technologies practiced from 2020 to 2022 (%)						3.546	0.738
2020	3.1	7.6	7.6	15.1	33.4		
2021	5.3	8.0	6.7	13.3	33.3		
2022	2.7	8.9	8.4	13.3	33.3		
Overall %	11.1	24.4	22.7	41.8	100		
Storage technologies practiced per Kabeles from 2020 to 2022 (%)						12.040	0.443
CJ	3.1	2.2	6.2	8.4	20		
DD	1.8	7.1	2.7	5.3	20		
DG	1.8	5.8	4.4	8	20		
SK	2.7	4	4	9.3	20		
TS	1.8	5.3	5.3	7.6	20		
Overall %	11.1	24.4	22.7	41.8	100		

PC= Plastic Containers, PP= Polypropylene bag Kebeles: CJ= Chali Jima, DD= Dambi Dima, DG= Darbes Gerado, SK= Sombo kejo, TS= Tulu Sangota.

Table 3: Mean (± se) % grain damage, weight loss, and germination in HT and TST over three storage periods in the study area.

Parameters tested	Periods of storage per months	Storage methods			
		Hermetic		Traditional with treatment	
		Plastic containers	PICS bags	PP bags	Gotera
GD (%)	3	0.33 ± 0.33^{c}	0.60 ± 0.11^{a}	30.00 ± 0.20^{b}	50.81 ± 0.16^{abc}
	6	2.00 ± 0.47^{ce}	2.35 ± 0.25^{ab}	50.50 ± 0.41^{acd}	65.29 ± 0.12^{bde}
	9	4.83 ± 0.48^{ce}	5.65 ± 0.67^{ab}	56.83. ± 0.60^{acd}	71.06 ± 0.35^{bde}
WL (%)	3	0.33 ± 0.33^{c}	0.60 ± 0.11^{a}	15.00 ± 0.24^{b}	31.61 ± 0.30^{abc}
	6	1.00 ± 0.00^{ce}	1.30 ± 0.13^{ab}	31.05 ± 0.27^{acd}	50.84 ± 0.18^{bde}
	9	2.00 ± 0.00^{ce}	2.95 ± 0.34^{ab}	37.44 ± 0.57^{acd}	56.87 ± 0.30^{bde}
GER (%)	3	99.83 ± 0.17^{c}	99.60 ± 0.11^{a}	84.60 ± 0.14^{b}	64.13 ± 0.16^{abc}
	6	99.00 ± 0.00^{ce}	98.25 ± 0.20^{ab}	60.72 ± 0.30^{acd}	53.48 ± 0.27^{bde}
	9	98.83 ± 0.21^{ce}	95.80 ± 0.17^{ab}	55.33 ± 0.62^{acd}	48.48 ± 0.35^{bde}

*Means within the same raw followed by the same letter are significantly different at ($p < 0.05$) using Turkey's studentized range test (HSD). GD:Grain Damage; WL:Weight loss; and GER:Germination.

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PICS bag, can alleviate poverty by protecting insects from grain damage. This will provide farmers with a fair market price. Therefore, developing countries should make grain storage technology a priority. PICS bags were created to provide farmers with a chemical-free, cost-effective storage system that would allow them to obtain higher grain prices and improve their livelihoods during lean seasons. As a result, all interested parties, including partners, donors, the government, and manufacturers, should move quickly to improve existing farmers' traditional storage practices by promoting hermetic storage technologies such as PICS bags and the like in order to ensure food security and farmer income.

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References

1. Lopez-Castillo LM, Silva-Fernández SE, Winkler R, Bergvinson DJ, Arnason JT, Garcia-Lara S. Postharvest insect resistance in maize. Journal of Stored Products Research. 2018; 77: 66–76. https://doi.org/10.1016/j.jspr.2018.03.004
2. World Bank. Missing Food: The case of postharvest grain losses in sub-Saharan Africa, report No. 60371-AFR. The World Bank Washington DC. 2011. https://documents1.worldbank.org/curated/en/358461468194348132
3. Befikadu D. Factors affecting the quality of grain stored in Ethiopian traditional storage structures and opportunities for improvement. The International Journal of Sciences: Basic and Applied Research. 2019; 18:235-257; 54671479
4. Chuma T, Mudhara M, Govereh J. The effects of grain storage technologies on maize marketing behavior of smallholder farmers in Zimbabwe. Journal of Agriculture and Rural Development in the Tropics and Subtropics. 2020; 121:1–12. https://doi.org/10.17170/kobra-20191217882
5. Sheahan M, Barrett CB. Review: Food loss and waste in Sub-Saharan Africa. Food Policy. 2017 Jul;70:1-12. doi: 10.1016/j.foodpol.2017.03.012. PMID: 28839345; PMCID: PMC5555439.
6. Abass AB, Fischler M, Schneider K, Daudi S, Gasper A, Rust J, Madulu D, Kabula E. On farm comparison of different maize post harvest storage technologies in centeral Tanzanoa. Grain post harvest prevention project (GPLP) Action Research. May, 2017;1-14; 199396228
7. Mutambuki K, Affognon H, Likhayo P, Baributsa D. Evaluation of Purdue Improved Crop Storage Triple Layer Hermetic Storage Bag against Prostephanus truncatus (Horn) (Coleoptera: Bostrichidae) and Sitophilus zeamais (Motsch.) (Coleoptera: Curculionidae). Insects. 2019 Jul 12;10(7):204. doi: 10.3390/insects10070204. PMID: 31336866; PMCID: PMC6681287.
8. Jonfia-Essien W, Varro S, Villers P. Hermetic storage: a novel approach to the protection of cocoa beans. African Crop Science Journal. 2011; 18(2). DOI: 10.4314/acsj.v18i2.65797
9. Karthikeyan C, Veeraragavathatham D, Karpagam D, Ayisha FS. Traditional storage practices. Indian Journal of traditional knowledge. 2009; 8: 564–568; 55639990
10. Mubayiwa M, Mvumi BM, Stathers T, Mlambo S, Nyabako T. Field evaluation of hermetic and synthetic pesticide-based technologies in smallholder sorghum grain storage in hot and arid climates. Sci Rep. 2021 Feb 12;11(1):3692. doi: 10.1038/s41598-021-83086-3. PMID: 33580142; PMCID: PMC7881032.
11. Abdeta T, Kebede A, Dugassa J, Abera Z. Prevalence of Bovine Trypanosomosis in Gudeya Bila District, East wellega Zone of Oromia Regional State, Western Oromia, Ethiopia. African Journal of Basic & Applied Sciences. 2016; 8:336-342. DOI: 10.5829/idosi.ajbas.2016.336.342
12. Fufa N, Abera S, Demissie G. Effect of storage container and storage period on germination of maize grains in Bako, West Shewa, Ethiopia. International Journal of Agricultural Science and Food Technology. 2020; 6: 088–092. DOI: 10.17352/2455-815X.000060
13. Utono I. A survey of systems of grain storage and management of insect pests in stored grain Kebbi state. Journal of Agriculture and Veterinary Science. 2013; 3: 51–61. DOI: 10.9790/2380-0355161
14. Endshaw W, Hiruy B. The distribution, frequency of occurrence, and the status of stored faba bean insect pests in relation to food security in Farta District, North West Ethiopia. Cogent Food and Agriculture. 2020; 6: 1832400. https://doi.org/10.1080/23311932.2020.1832400
15. Hiruy B, Getu E. Status, species composition and management of stored maize grain insect pests in Hadiya and Silte zones of southern Ethiopia. Graduate theses and dissertations, Addis Ababa University, Ethiopia. 2018.
16. Shiferaw B, Prasanna BM, Hellin J, Banziger M. Crops that feed the world 6. Past successes and future challenges to the role played by maize in global food security. Food Security. 2011; 3: 307–327. DOI 10.1007/s12571-011-0140-5
17. Kader MA. A comparison of seed germination calculation formulae and the associated interpretation of resulting data. Journal and proceedings of the Royal Society of New South Wales. 2005; 138: 65–75. ISSN 0035-9173/05/020065–11
18. SPSS. SPSS Statistics for Windows, Version 26.0. IBM Corporation, Armonk, NY. 2016.
19. Midega CA, Murage AW, Pittchar JO, Khan ZR. Managing storage pests of maize: Farmers' knowledge, perceptions, and practices in western Kenya. Crop Protection. 2016; 90:142–149. DOI: 10.1016/j.cropro.2016.08.033
20. Mobolade AJ, Bunindro N, Sahoo D, Rajashekar Y. Traditional methods of food grain preservation and storage in Nigeria and India. Annals of Agricultural Sciences. 2019; 64: 196–205. https://doi.org/10.1016/j.aoas.2019.12.003
21. Manandhar A, Milindi P, Shah A. An overview of the post harvet grain storage practices of smallholder farmers in developing countries. agriculture (Switzerland) journal. 2018; 8:57. DOI: 10.3390/agriculture8040057
22. Sori W, Ayana A. Storage pests of maize and their status in the Jimma Zone, Ethiopia. African Journal of Agricultural Research. 2012; 7: 4056-4060. DOI:10.5897/AJAR11.1123
23. Njoroge AW, Affognon HD, Mutungi CM, Manono J, Lamuka PO, Murdock LL. Triple bag hermetic storage delivers a lethal punch to Prostephanus truncatus (Horn) (Coleoptera: Bostrichidae) in stored maize. Journal of Stored Products Research. 2014; 1-8. DOI : 10.1016/j.jspr.2014.02.005