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Studies on organic materials for the production of modified atmosphere for maize weevil control in stored maize

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Abstract

The production of modified atmospheres (MAs) by composting fresh cow dung, chopped fresh sugarcane and chopped dry maize stubble each wetted at 60% moisture content was studied. These substrates gave the lower O₂ content (3.5% and 3.7%, respectively) compared to the dry maize stubble which resulted in lower CO₂ level (9%) and the highest O₂ content (19%). The efficacy of the MAs produced by these substrates was also studied in simulated storage structures in the field by letting the produced gas mixtures to storage structures containing 3 quintals of weevil susceptible BH-540 maize variety. Significantly ($p < 0.01$) higher mean numbers of weevils mortality and lower mean number and weight of damaged grains and weight losses were recorded in maize grains treated with Quickphose (fumigant standard check) and modified atmospheres from fresh cow dung and fresh sugarcane. Germination test did not show any variation among the treatments. The result of this study showed that the gas from biological digestion of fresh cow dung and chopped sugar cane can be used as control option for maize storage pest in airtight storages.

Keywords: Maize weevils, fresh cow dung, fresh chopped sugar cane, dry maize stubble wetted at 60% MC, chemical, plastic seal.

1. Introduction

Many insect pests are known to cause heavy losses to stored maize in Ethiopia, however, the maize weevils (*Sitophilus zeamais* Mostchulsky) and the Angoumois grain moth (*Sitotroga cerealella* Oliv.) are the most important ones^[13, 1, 10].

Post-harvest losses of food grain due to insect pests cause significant nutritional and economic burden to farmers^[11]. The lack of improved grain storage structures management technologies force maize growers to sell their produce at low prices immediately after harvest^[6, 10, 2]. These problems have been aggravated as traditional varieties have been replaced by high yielding and improved varieties, which are generally more susceptible to storage insect damage than those of local varieties^[3].

In Ethiopia, due to maize weevil about 20% storage losses and 25% price reduction for the damaged grains were reported for maize, resulting in large income losses with value ratio not greater than one^[6]. According to Abraham^[1], insect pests in the store cause over 16% loss on maize around Bako.

Despite heavy losses incurred in storage, much attention has not been given to research on stored product^[1].

Insect pests are still the major problem in storage which necessitated continued search for effective and less hazardous control methods. Among these methods, the use of modified atmospheres (MA) in storage containers has lately attracted considerable interest. In the report of Caldron and Navarro (1980)^[8] the application of modified atmosphere and fumigant are the appropriate measure for the bulk storage of maize. The technique of modified atmosphere consists of storing grain in hermetically plastic sealed bags and supplying gas with sufficient carbon dioxide (CO₂) and low oxygen (O₂) in air tight storage. It has long been known that decreasing the O₂ content in storage bin to less than 1.5% may become lethal for most storage insect species^[4]. More recently, it was proposed to raise the CO₂ concentration to 60% to achieve mortality of all grain pests in airtight containers^[5]. It was also reported that a synergistic effect on insect mortality is exerted by

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exposure to a low oxygen atmosphere when CO₂ is added [8]. There is an indication that such gas mixtures can be obtained by composting, that is “controlled aerobic bio-degradation of a mass of organic materials” [13]. The gas mixture produced is transferred to small bins and maintained until the mortality of the insects in the stored grains is achieved. Therefore, experiment was done to determine the quantity of CO₂ and O₂ produced and consumed by composting organic materials and to identify the best organic material that can produce modified atmospheres lethal to maize weevil.

2. Materials and Methods

2.1 Laboratory Experiments

Experiments were conducted in a laboratory and in storage structures in the field between 2008 – 2009, to assess the amount of the CO₂ and O₂ produced and the modified atmospheres produced (gas mixture) as protectants of maize grains against the maize weevil (*Sitophilus zeamais* Motsch). Fresh cow dung, fresh chopped sugarcane and chopped dry maize stover were tested in a laboratory trial at Bako Agricultural Research Center (BARC) for carbon dioxide (CO₂) and oxygen (O₂) production in bio-generators (Rottos). A good amount of each substrate was made wet at 60% moisture content with water and allowed to equilibrate for 48 h before measuring the CO₂ and O₂ concentration produced through anaerobic respiration. Carbon dioxide levels were measured using the Riken Infrared Gas Analyzer (Model RI-550A) and O₂ content by a portable oxygen meter.

Air samples were withdrawn from the bio-generators through air sampling tubes fitted to each bio-generator. As the two instruments were connected, air samples were analyzed for CO₂ level and O₂ content by passing the air samples through the two meters assisted by built in pumps after 48 h incubation period.

2.2 Field Experiments

Hermetic storage structures that were internally sealed with plastic material, each having a capacity of three quintals of maize, were constructed from bamboo and internally plastered with mud. The bio-generators containing fresh cow dung, fresh chopped sugar cane and chopped dry maize stover were

connected to the hermetic storage structures through plastic hose to transfer the modified atmospheres produced in the degradation process. Quickphose and untreated check were also included. To each storage structures, three quintals of maize grain were added and left open for a month to allow natural infestation. After a month, the mouth of the plastics used to seal the storage was sealed and connected to the bio-generators after equilibrating for 14 days. Sample tubes were also fitted to these hermetic storage structures to withdraw 1.5 kg of grain for evaluation at two months interval for eight months storage period. Each treatment was replicated three times and arranged in randomized complete block design (RCBD). Data on the mean number of dead adult weevils, number and weight of grains damaged and percent weight loss were recorded. Percent weight loss was calculated by the formula of Boxall (1996) [7].

$$\% \text{ weight loss} = \frac{(\text{Wu} \times \text{Nd}) - (\text{Wd} \times \text{Nu})}{\text{Wu} (\text{Nu} \times \text{Nd})} \times 100$$

Where: Wu = Weight of undamaged grains
Wd = Weight of grain damaged
Nu = Number of undamaged grains
Nd = Number of damaged grains

Analysis of variance of the variables for percent of dead weevils, percent of damaged grain and percent of weight loss was made by SAS (version 9) computer package. Mean comparison for significantly different parameters were done using Duncan's Multiple Range Test (P<0.01).

3. Results and Discussion

Carbon dioxide (CO₂) and Oxygen (O₂) contents of bio-generators containing organic materials wetted at 60% moisture content

The CO₂ output of fresh cow dung and chopped fresh sugarcane wetted at 60% moisture content was significantly higher than dry chopped maize stover wetted at the same level. Corresponding O₂ level of the materials was significantly lower than dry chopped maize stover wetted at 60% moisture content (Fig.1).

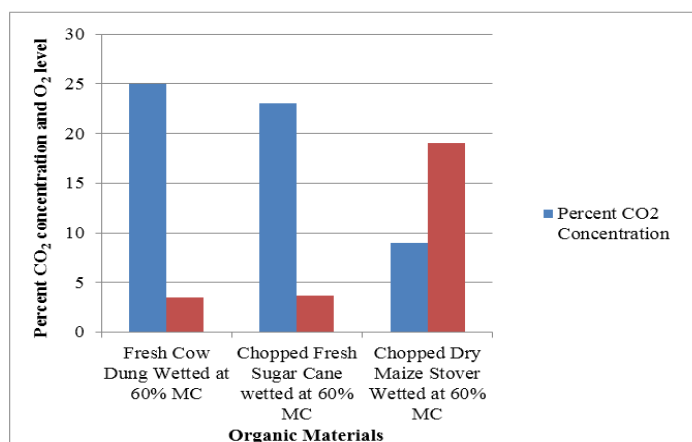


Fig 1: CO₂ and O₂ content of bio-generators obtained by composting organic materials at 60% moisture content after 48 h period of incubation period

3.1 Weevil Mortality, Percent number and weight of grains damaged

The results of adult weevil mortality in 2008 and 2009 in modified atmosphere treated grain are presented in Table 1 and 2, respectively. The analysis of variance for mean number of dead weevils over eight months of storage period showed a significant difference ($p < 0.01$) among treatments. Modified atmospheres produced by composting fresh cow dung and fresh chopped sugarcane both wetted at 60% moisture content caused the highest adult weevil mortality followed by quickphose fumigant. The difference between the untreated check and plastic sealed storage structures in adult weevil mortality was non-significant. Similar results were reported by Rodriqueze *et al.* (2004) [14] who reported that storage pests were killed after 50 days of storage period using modified atmosphere with air composition of 18% CO₂ and 2.55% O₂.

Analysis of variance for number and weight of grains damaged and percent weight loss during 2008 and 2009 showed significant differences ($p < 0.01$) among the different treatments. As indicated in Tables 1 and 2 for both years, significantly highest percent number and weight of grains damaged and percent weight loss were

observed in the untreated check and plastic sealing.

But, the modified atmospheres produced from fresh cow dung, fresh chopped sugarcane both at 60% moisture content and the standard check fumigant quickphose were recorded for the lowest percent number and weight of grains damaged and percent weight loss. However, there was no significant variation of weight loss among modified atmosphere treatments and standard chemical (quickphose) in terms of percent number and weight of grains damaged and percent weight loss. This indicates that there is similar control efficacy between the standard chemical and modified atmosphere treatments. Similarly, Rodriqueze *et al.* (2004) [14] reported no weight loss in dry corn after storage period of 150 days stored in modified atmosphere containing higher CO₂ concentration and lower O₂ level.

3.2 Germination Percentage Test

The analysis of variance for germination percentage test showed non-significant differences among treatments. This shows that application of modified atmospheres produced by composting organic materials to the stored maize grains had no effect on seed viability and hence causing no problem of using the produce as seed source.

Table 1: Adult mortality, percent number and weight of grains damage as affected by modified atmospheres produced by degradation of organic materials in simulated storage structures in the field at Bako (2008)

Treatment Number	Treatments	Number of dead weevils	Percent			
			Number of grains damaged	Weight of grains damaged	Weight loss	Germination
1	Untreated check	59c	40.39a	29.65a	12.11a	97.00
2	Fresh Cow dung wetted at 60% MC	359.3a	1.423c	3.857cd	0.605c	96.23
3	Fresh chopped sugarcane wetted at 60% MC	322.7a	1.987c	4.327cd	0.693c	96.22
4	Dry maize stubble wetted at 60% MC	186.3b	8.57b	7.863c	1.343b	97.01
5	Quickphose (Standard check)	263.3ab	1.287c	1.817d	0.472c	97.00
6	Plastic seal only	81c	38.007a	24.52a	11.92a	95.97
	SE (\pm)	35.302	1.4	1.925	0.273	Non-sig.
	CV (%)	26.36	21.55	29.5	32.11	2.4

Values followed by the same letter within a column are not statistically different at 0.01 probability level

Table 2: Adult mortality, percent number and weight of grains damage as affected by modified atmospheres produced by degradation of organic materials in simulated storage structures in the field at Bako (2009)

Treatment Number	Treatments	Number of dead weevils	Percent			
			Number of grains damaged	Weight of grains damaged	Weight loss	Germination
1	Untreated check	63c	35.74a	29.65a	16.33a	97.02
2	Fresh Cow dung wetted at 60% MC	348a	1.55c	2.11d	0.706c	97.00
3	Fresh chopped sugarcane wetted at 60% MC	326.7a	1.64c	2.32d	0.853c	96.36
4	Dry maize stubble wetted at 60% MC	175.3bc	8.477b	7.77c	1.465b	97.04
5	Quickphose (Standard check)	212ab	1.19c	1.69d	0.663c	96.99
6	Plastic seal only	96c	34.08a	26.36a	12.94a	96.72
	SE (\pm)	39.473	1.07	1.638	0.226	Non-sig.
	CV (%)	30.66	17.66	26.87	28.38	3.6

Values followed by the same letter within a column are not statistically different at 0.01 probability level

The result of this study identified some effective organic materials for the production of modified atmospheres lethal to the maize weevil. The outstanding ones were fresh cow dung and fresh chopped sugar cane both wetted at 60% moisture content, which resulted in the production of high CO₂ concentration and lower O₂ level. Moreover, they resulted in the highest mean number of adult weevil mortality, lower percent number and weights of grains damaged as well as lower percent weight loss compared to the other treatments. Their performance was significantly at par with the standard fumigant insecticide quickphose. Hence, with further study to determine and quantify the best amount and rate of applications, fresh cow dung and fresh chopped sugarcane could be potential materials to produce modified atmospheres lethal to stored maize insect pests to be used as an integral component of integrated storage insect pest management.

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