Evaluation of Organic Materials for Modified Atmosphere Production for Maize Weevil Control in Stored Maize

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Abstract

*Experiments were conducted in a laboratory and in storage structures in the field between 2008 – 2009, to assess the amount of the CO_2 and O_2 produced and the modified atmospheres produced (gas mixtures) as protectants of maize grains against the maize weevil (***Sitophilus zeamais Motsch***). 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. The MAs were produced in plastic cans (bio-generators). The measurement of the MAs produced using Riken Infrared Gas Analyzer, Model RI-550A for CO_2 and portable oxygen meter for O_2 indicated that the highest CO_2 levels were produced in fresh cow dung (25%) and fresh sugarcane (23%) following 48hr incubation period. These substrates gave the lower O_2 content (3.5% and 3.7%, respectively) compared to the dry maize stubble which resulted in lower CO_2 level (9%) and the highest O_2 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. Analysis of variances showed that application of modified atmosphere to the maize grains stored in airtight storage structures can effectively control maize weevils. 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. The gas produced from the digestion of fresh cow dung and fresh sugar cane significantly ($p<0.01$) reduced the progress of maize weevils infestation. 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. However, rate and frequency of application and economic feasibility should be studied before commercial application of the technique.*

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 cereallela* Oliv.) are the most important ones (Mekuria 1995; Abraham 1997; Emana & Assefa 1998).

Post-harvest losses of food grain due to insect pests cause significant nutritional and economic burden to farmers (Firdisa & Abraham 1998). The lack of improved grain storage structures management technologies force maize growers to sell their produces at low prices immediately after harvest (Beyene & David 2007; Emana & Assefa 1998; Abraham 2003). 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 (Arnason *et al.* 1994).

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 (Beyene & David 2007). According to Abraham (1997), 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 (Abraham 1997).

Insect pests are still the major problem in storages 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) the application of modified atmosphere and fumigant are the appropriate 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 (CO_2) and low oxygen (O_2) in air tight storage. It has long been known that decreasing the O_2 content in storage bin to less than 1.5% may become lethal for most storage insect species (Bailey & Banks 1975). More recently, it was proposed to raise the CO_2 concentration to 60% to achieve mortality of all grain pests in airtight containers (Banks & Annis 1997). It was also reported that a synergistic effect on insect mortality is exerted by exposure to a low oxygen atmosphere when CO_2 is added (Calderon & Navarro 1979). 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" (Motro *et al.* 1986). The gas mixtures 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 CO_2 and O_2 produced and consumed by composting organic materials and to identify the best organic material that can produce modified atmospheres lethal to maize weevil.

Materials and Methods

Laboratory Experiments

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 (CO_2) and oxygen (O_2) production in bio-generators (Rottos). Lots of each substrate was wetted at 60% moisture content with water and allowed to equilibrate for 48 h before measuring the CO_2 and O_2 concentration produced through anaerobic respiration. Carbon dioxide levels were measured using the Riken Infrared Gas Analyzer (Model RI-550A) and O_2 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 CO_2 level and O_2 content by passing the air samples through the two meters assisted by built in pumps after 48 h incubation period.

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).

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

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 using general linear model for percent of dead weevils, percent of damaged grain and percent of weight loss was made by SAS computer package (SAS 2004). Mean separations for significantly different parameters were done using Duncan's Multiple Range Test.

Results and Discussion

Carbon dioxide (CO_2) and Oxygen (O_2) contents of bio-generators containing organic materials wetted at 60% moisture content

The CO_2 output of fresh cow dung and chopped fresh sugarcane wetted at 60% MC were significantly higher than dry chopped maize stover wetted at the same level. Corresponding O_2 levels of the materials was significantly lower than dry chopped maize stover wetted at 60% MC (Fig.1).

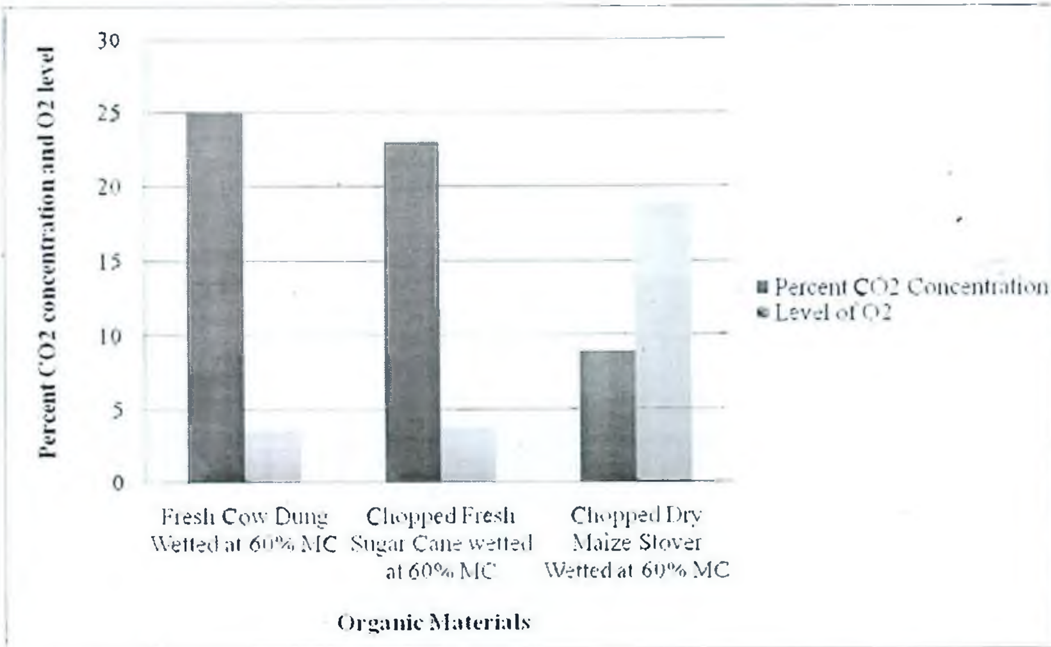

Figure 1. CO_2 and O_2 content of bio-generators obtained by composting organic materials at 60% MC after 48 h period of incubation period

Weevil Mortality, Percent number and weight of grains damaged

The results of adult weevil mortality in 2008 and 2009 in modified atmosphere treated 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 that there is a significant difference ($p<0.01$) among treatments. Modified atmospheres produced by composting fresh cow dung and fresh chopped sugarcane both wetted at 60% MC 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) who reported that storage pests were killed after 50 days of storage period using modified atmosphere with air composition of 18% CO_2 and 2.55% O_2.

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% MC and the standard check fumigant quickphose recorded the lowest percent number and weight of grains damaged and percent weight loss. However, there is no significant variation of weight losses 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. Similar result was reported by Rodriqueze *et al.* (2004) who reported no weight loss of dry corn after storage period of 150 days stored in modified atmosphere containing higher CO_2 concentration and lower O_2 level.

Germination Percentage Test

The analysis of variance for germination percentage test after eight months of storage period for maize grain in the year 2008 and 2009 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.

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% MC, which resulted in the production of high CO_2 concentration and lower O_2 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 similar to 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.

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 (+)		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 (+)		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

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