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Alternatives to the use of phosphine fumigation in Ghana

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Abstract

Presently in Ghana, fumigation in stored products is not well developed. The Government of Ghana has started constructing warehouses for storage of agricultural commodities under the Planting for Food and Jobs policy. Stored product insect pest management strategies are changing to: meet consumer's demand for food free of chemical residues, address concerns about safety of insecticides to humans, delay insecticide resistance development in insects, and comply with stricter pesticide regulations. Phosphine is predominantly registered and used for disinfestation of stored cocoa beans against insect infestation in Ghana. Although this chemical is efficient and effective; however, continuous usage of chemicals could lead to many problems such as resistance development in insects. Chemical fumigants such as sulfuryl fluoride, Dichlorvos, chloropicrin, formaldehyde, hydrogen cyanide, and ethylene oxide are effective against stored product insect pests. There is, therefore, the need to evaluate alternatives to and integrated combinations with the use of phosphine. Furthermore, the majority of farmers in Ghana are resource-poor and have neither the means nor the skills to obtain and handle fumigants appropriately. Further, Ghana is being encouraged to adopt new methods like controlled atmosphere, use of heat treatment, electromagnetic waves, and ionized gas like cold plasma as alternate stored product insect pest control methods. This paper focuses on the advances in stored-product protection in Ghana with emphasis on alternative chemicals to supplement the widespread use of phosphine in Ghana.

Keywords: Fumigation, Alternatives, Heat, Phosphine, Integrated pest management

Introduction

In Ghana, most of the stored products produced are annually lost to insects. Infestation by stored product insects results in major damage and causes drastic economic losses to farmers (Obeng-Ofori, 2008). The control of stored product insect in most sub-Saharan African countries like Ghana is a major challenge to farmers, and storekeepers. However, fumigation is a proven technique for effective control and management of the infestation by stored grain pests. Chemical fumigants are used primarily for insect pest disinfestation (Nambi et al., 2017). The use of chemical fumigants in Ghana has increased drastically. The frequent and indiscriminate use of insecticides has resulted in the failure of these chemicals to effectively control storage insect pests (Subramanyam and Hagstrum, 1996).

Use of phosphine (PH_3), one of the most used fumigant for fumigation, has increased globally. Phosphine is a colourless, odourless, flammable gas in its pure form but is detected as distinctive garlic or fishy odour due to impurities in the mixture (Chadda, 2016). Phosphine is becoming an essential fumigant for insect protection in storage goods. But few drawbacks, such as low temperatures and relatively long exposure periods, restrict the use of phosphine (Kostyukovsky et al., 2010). Phosphine is the only fumigant currently used in Ghana, because of its low cost, ease of availability and residue-free treatment. The efficacy of fumigation depends upon the combined effect of the exposure period and phosphine concentration (Chadda, 2016).

The continued use and concentration inadequacy of phosphine fumigations have resulted in resistance among targeted insect species (Chaudhry, 2000; Benhalima et al., 2004; Collins 2006; Pimentel et al., 2010; Obeng-Ofori, 2010; Phillips et al., 2012; Chen et al., 2015; Bajracharya et al., 2016) which has caused a significant increment in the incidence of the heavy product pest infestations. The indiscrimate use of insecticides is the major reason causing these heavy infestations. There is a serious concern because the only alternative fumigant currently in general use is methyl bromide. Methyl bromide fumigation requires more equipment and skill than those needed for phosphine (Price and Mills, 1988). Due to the development of resistance to phosphine by most of the stored product pests, there is a need for searching for an alternative solution to control storage pests in Sub-Saharan Africa countries like Ghana (Obeng-Ofori, 2010). Nevertheless, Nambi et al. (2017) have noted that fumigation methods like controlled atmosphere storage, hermetic storage, and CO_2 are used for disinfestation at a commercial scale. There is little information on the use of these alternative methods in controlling insect pest in our stored commodities. Concerning that, there is an urgent need to look at the effectiveness and availabilities of alternatives to the use of phosphine fumigants in Ghana.

Uses of phosphine for fumigation

Notable studies have been conducted on the use of phosphine as a fumigant for the storage of agricultural produce to prevent the infestation of stored product pest. Some of the successful use of phosphine fumigations that have been conducted include the use of polyethene bags containing ground nuts (Proctor and Ashman, 1972), disinfestation of kiwifruits (Jamieson et al., 2012), wheat in silo bins (Boland, 2012), and wheat in silo bags (Ridley et al., 2011). Jamieson et al. (2012) observed that the phosphine gas was effective in the control of oleander scale, long-tailed mealybug and greedy scale insects.

Alternatives to the use of phosphine fumigation in Ghana

The use of phosphine gas as fumigant can be alternated with the use of hermetic storage (triple-layer hermetic storage bags), diatomaceous earth, controlled atmosphere storage, high concentration of CO_2, heat treatment, steam, electromagnetic waves such as microwave, gamma rays, infrared, ultraviolet, and ionized gas like ozone.

Hermetic storage

Hermetic storage is reported to be an effective method for the protection of agricultural produces in the absence of the use of fumigants for the control of insects and the preservation of the quality of the agricultural produce (Obeng-Ofori et al., 2015). The hermetic storage is a sustainable alternative to other methods of storage that protects commodities from different range of pests such as the stored product insects and moulds. Hermetic storage consisting of a sealed storage system containing a modified atmosphere has been adopted recently. This means that, as a result of respiration effects, there is generally depletion of oxygen (O_2) and production of high carbon dioxide (CO_2) atmosphere which can lead to a drastic reduction in pest population (Jonfia-Essien *et al.,* 2008).

The Triple-layer hermetic bags have been used in the control of different kinds of stored product beetles such as cowpea bruchids, *Callosobruchus maculatus* (F.) (Murdock et al., 2003), *Dinoderus spp* and *Prostephanus truncates* (Horn) on cassava chips (Hell et al., 2010) with very promising results. In Ghana, Ansah et al. (2015) assessed the storability of two maize cultivars in hermetic triple-layer biodegradable bags. In their study, it was observed that the biodegradable hermetic triple-layer bag reduced insect reproduction and maize sprouting, and could effectively maintain grain quality. Also, Anankware et al. (2013) distinguished that the triple-layer hermetic bag protected maize against *P. truncatus* and *Sitophilus zeamais* Motschulsky. The effectiveness of hermetic storage in insect control and quality preservation of cocoa beans in Ghana was studied by Jonfia-Essien et al. (2008). Through the study, it was observed that there was 100% mortality of the insects under study using the Cocoon^{TM} storage and it seemed to be the most promising method for storing cocoa beans. This shows that the triple hermetic layer bag has a promising use as a replacement of phosphine in Ghana. The hermetic layer bag is effective in the control of storage pests and it does not cause any harm to the food products, the environment, and the consumers. The use has resulted in pesticide-free commodities, and safe products for consumption. Hermetic storage improves grain quality and seed viability because it maintains the original grain moisture content and reduces pest damage.

Diatomaceous earth (DE)

The diatomaceous earth is a formulation made from natural substances of the earth. Diatomaceous earth is formed from the fossils of diatoms and is mainly composed of amorphous hydrated silica (Ebeling, 1971). There are many widely available DE formulations that have been tested effectively as grain protectants against a wide variety of storage pests (Arthur, 2000; Fields and Korunic, 2000; Subramanyam and Roesli, 2000; Athanassiou et al., 2008; Stathers et al., 2008; Kavallieratos et al., 2010; Arthur and Fontenot, 2013). Several notable studies have been conducted on the use of different types of diatomaceous earth on the control of stored product insects as an alternative to the use of phosphine gas in Ghana (Badii et al., 2013; Adarkwah et al., 2017). Badii et al. (2013) studied the efficacy of diatomaceous earth formulations against *C.*

maculatus in Kersting's groundnut (*Macrotyloma geocarpum* Harms) and characterized the influence of dosage and relative humidity. It was observed that the DEs were effective in suppressing the growth of the stored product insects. Also, the authors recommended that the DEs could serve as a potential alternative method to protect the Kersting's groundnut against the destructive *C. maculatus*, for smallholder farmers in tropical Africa. In the study conducted by Adarkwah et al. (2017), they assessed the insecticidal efficacy of botanical food by-products against selected stored-grain beetles by the combined action with modified diatomaceous earth. The combination of powders of the botanical food by-products and diatomaceous earth controlled the beetles faster compared to the plant products only. The DE blocks the insect spiracles and insects die from asphyxiation and the lodging of dusts between cuticular segments increases water loss through abrasion of the cuticle. The use of diatomaceous earth in the control of storage pests is promising in Ghana. It is worth to know that the use of diatomaceous earth formulation in the control of storage pests and the protection of grains have been on the increase. It is of low toxicity, is eco-friendly, and the effect on human health is minimal as compared to other protectants. The use of diatomaceous earth as a natural inert dust to control insect pests in stored grains as an alternative to insecticides should be encouraged to limit pest infestation (Arthur, 2003). Various diatomaceous earth formulations can be registered as a cocoa protectant in Ghana. This can help to reduce the level of stored pest infestations.

Natural enemies

Commercial application of natural enemies against stored product beetles can be adopted to prevent beetle infestation. The main application in grain storage is still for small-scale organic farms (Hansen, 2005). Females of the pteromalid wasps *Lariophagus distinguendus*, *Anisopteromalus calandrae* and *Theocolax elegans* lay their eggs on host larvae or pupae inside grains or cocoons. For this purpose, the ovipositor is inserted and the host larva is paralyzed prior to oviposition. After emergence from the egg, the parasitoid larva feeds on the host larva from the outside, thereby killing it. The bethylid wasp *Cephalonomia tarsalis* parasitises larvae of *Oryzaephilus* spp., the eggs are laid externally on host of the larva after paralyzation (Hansen, 2005).

Modified Atmospheres

Beside fumigants, use of modified atmospheres (MAs) seems to be the best bet for pesticide free organic storage. However, the technology of MAs can be well adapted where cheap sources of nitrogen or carbon dioxide are available and the storage structure is well sealed. Biogas, produced from the cow dung at farm level in many households has shown promising results to control the insect-pests in stored grains in some countries like India without affecting pulses' germination and quality. Also, Jayas (2012) noted that the latest approaches to controlling dry cocoa insect infestation in Ghana were the use of modified atmospheres (MAs) in conjunction with other IPM strategies.

Conclusions

Ghana faces a lot of challenges with the issue of stored product pests which has been a burden on the country in achieving the sustainable development goal of zero hunger. The government of Ghana, through the Planting for Food and Job policy, is putting measures in place for the country to be one of the hubs for food in Africa. The use of alternative methods aside the use of chemicals

in preventing the infestation of insect pests is a great area of concern. Many farmers lack understanding about use of chemical fumigants and their detrimental effects. However, several means of disinfesting grains from insect pests have been observed in our review which includes the use of triple-layer hermetic storage bags, diatomaceous earth, natural enemies, and modified atmospheres. Farmers need to be educated on the use of these technologies to enhance their productivity in a positive manner.

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