IJFEAT
INTERNATIONAL JOURNAL FOR ENGINEERING APPLICATIONS AND TECHNOLOGY

ASPHYXIANT GASES FOR GRAIN STORAGE

Vaishali Sawant[1], Shyamkant Munje[2], Richa Chaudhry[3] and Saurabh Padmashali[4].

1. Ph.D. Scholar, Department of Entomology, College of Agriculture, Indira Gandhi Krishi Vishwavidyalaya, Raipur (C.G.). and Author for correspondence: Email: vaishalisawant254@gmail.com.
2. Assistant Professor, Regional Research Centre, Amaravati (M.S.).
3. Ph.D. Scholar, Department of Entomology, College of Agriculture, Indira Gandhi Krishi Vishwavidyalaya, Raipur (C.G.).
4. Ph.D. Scholar, Department of Entomology, College of Agriculture, Indira Gandhi Krishi Vishwavidyalaya, Raipur (C.G.).

Abstract :

Asphyxiant gases like nitrogen, carbon dioxide, argon are used in silos for effective control of stored insect pests. Use of these gases is the best alternative to the poisonous fumigants like phosphine, sulfuryl fluoride, etc. The poisonous fumigants are harmful, hence more precautions have to be taken. In comparison with poisonous gases, nitrogen and carbon dioxide are relatively safer. Use of asphyxiant gases to control stored insect pests is one of the organic way. The objective of this study is to review the use of gases like carbon dioxide, nitrogen and even oxygen to control insect pests in storage and to review published research works on control strategies of stored product pests using asphyxiant gases.

Introduction:

An asphyxiant gas is a nontoxic or less toxic gas or vapour which can cause unconsciousness or death of living organism due to reduction or displacement of normal oxygen concentration in the air causing suffocation or asphyxiation. Asphyxiants having no other harmful effects are referred as simple asphyxiants[1]. eg. nitrogen, argon, helium, methane, propane,butane, carbon dioxide. Though asphyxiant gases are present in the surrounding atmosphere in high concentration, it is difficult to know their presence because they are relatively inert and inodorous. The exception for this is carbon dioxide[2]. If higher concentration of carbon dioxide present in the air, due to inhalation of such air, carbon dioxide in the blood level get elevated causing Hypercapnia, or hypercarbia or CO_2 retention [3]. Carbon dioxide is hazardous even at lower concentrations than simple asphyxiants because it interferes with the breathing regulation of the body [1]. Attributable to this action, carbon dioxide is used as a pesticide for controlling insect pests in storage under modified atmospheres having approximately 60 per cent carbon dioxide. It is also used as rodenticide against mice and rats[4].

Chemical asphyxiants or toxic gases are those which interfere with the transportation or absorption of oxygen in the body. Eg. hydrogen cyanide and carbon monoxide[1]. If these toxic gases are inhaled by living organism, it may cause death by competing with oxygen on the cellular level (e.g. carbon monoxide) or directly damage the respiratory system (e.g. phosgene). These gases are very toxic

even in small quantities[2]. All these gases are present in the earth's atmosphere, even though the atmosphere is mostly harmless because of the presence of oxygen[2]. Some of these asphyxiant gases could be used in warehouses to control stored grain pests organically i.e. without using chemicals. In this article, we are reviewing safer asphyxiant gases and their role in storage to control insect pests.

Controlled atmosphere storage[5] :

Generally, the poisonous gases like phosphine, sulfuryl fluoride are used in warehouses to control insect pests in storage[6]. But in controlled atmosphere system, the natural gases *viz.* carbon dioxide, nitrogen of the atmosphere can be used to get control. Oxygen, nitrogen and carbon dioxide which are natural components of the atmosphere are used and executed to preserve food/grain/seed is referred to as "controlled" or "modified" atmosphere storage. Controlled atmosphere techniques are mostly used for storing perishable commodities such as fruit, vegetables, cut flowers, etc. to delay ripening and reduce spoilage from micro-organisms. Along with this, controlled atmospheres are also used for controlling insect pests on agricultural commodities in storage. To manage insect pests in storage, the atmospheres are modified or controlled by removing or depleting oxygen or by adding high levels of carbon dioxide or nitrogen. These new atmospheres should be maintained for sufficient time to kill all stages of insect pests. These modified atmosphere should not have any adverse effect on the stored commodities.

As in controlled atmosphere storage, the natural gases viz. carbon dioxide, nitrogen and oxygen are managed to control stored insect pests, it is also called as green or organic storage. This sound pest management should be promoted as this minimizes the use of toxic chemicals.

Though the asphyxiant gases are toxic to insect pests, they are also harmful to humans if necessary precautions are not taken. As stated earlier[3], if carbon dioxide is inhaled in high concentration, it is lethal and though nitrogen itself is non-toxic to humans, the absence of oxygen cause lethal to persons handling these gases.

1. **Low oxygen atmospheres[5]:**

Modified atmospheres lacking oxygen are produced by adding nitrogen in the storage to change the normal nitrogen-oxygen atmosphere. Liquid nitrogen from tanks may be used as a gas source. These generators burn propane or other hydrocarbon fuel to give an atmosphere of less than 1 per cent oxygen with about 10 per cent carbon dioxide and 89 per cent nitrogen. Oxygen can also be removed by the metabolic activity of micro-organisms and insects in hermetic storages, thus producing an atmosphere where insects cannot survive. For complete insect control the level of oxygen must be maintained below 1.2 per cent for one week, at temperatures above 35°C, or more than 24 weeks at 15°C.

2. **Application of carbon dioxide in warehouses[7] :**

Carbon dioxide is most commonly used gas for controlled or modified atmosphere. Carbon dioxide is used to control insect pests in storage and is one of the best alternatives to poisonous gases like phosphine. This process involves replacement of oxygen with carbon dioxide up to the level which is toxic to insects for longer period. Carbon dioxide is easy to manage in smaller, gas-tight silos having capacity less than 300 tonnes. The most critical factor of this process is

gas-tightness of the silo. Even small air leaks in the silo allow carbon dioxide gas to escape and oxygen to re-enter which cause failure to control of all insect pests in silo. Another important factor is time. The grain treatment should be undertaken for 15 days. Generally carbon dioxide is added to a gas-tight, sealed silo with pressurised cylinders of liquid, which changes to a gas when released from the bottle. Carbon dioxide is about one and a half times heavier than air and is non-flammable, colourless and odourless. Gas is introduced into the base of the silo and concentration levels are measured at the top with a gas line going to the headspace. The gas-tight, sealed silo need the standard pressure relief valve fitted to sealable silos to allow natural expansion and contraction of the air inside the silo when it's sealed. Once the target starting concentration level of 80-90 per cent carbon dioxide is reached at the top of the silo, the gas is turned off and the top lid is sealed shut.

The minimum required concentration for effective control of all insect species (except *Trogoderma* spp.) at all life stages is not less than 35 per cent carbon dioxide for 15 days where the temperature is at or above 20^0C. Carbon dioxide is less effective at grain temperatures below 20^0C so a longer exposure period is required.

Carbon dioxide is lethal to humans and concentrations between 7-10 per cent may cause suffocation. Concentrations even as low as two per cent can cause respiratory distress. Hence during and after treating silo with carbon dioxide, it should never be entered or until the silo is sufficiently ventilated. Use the silo aeration system to thoroughly vent all the carbon dioxide.

3. **Nitrogen application in warehouses**[8]:

Nitrogen, the asphyxiant gas is also used in warehouses to control stored insect pests. For the effective control of insect pests in storage, 99 per cent nitrogen gas is applied in the storage structure or silo. The main purpose of applying nitrogen gas is to bring down oxygen levels from 21 per cent to less than 1 per cent. In this process, nitrogen gas (99 per cent) is applied in the base of the silo. This helps in completing at least two air changes which deplete oxygen levels to less than 1per cent measured in the head-space at the top of the silo. When the concentration of oxygen is 1 per cent, then top lid of silo is sealed. Silo is kept sealed for 14 to 15 days with the inner temperature 25°C and above. The grain temperature should not be lower up to 20^0C because it will not give effective pest control. If the sealing is extended up to 3 weeks or more, it results in best pest control. When the silo is sealed, it is important to moniter oxygen concentration regularly. There should not be even small lakage in silo because very small leaks allow oxygen concentration to rise to 3 to 4 per cent. Oxygen concentration less than 3per cent for 28 days is sufficient to control all insect life stages. Along with this advantage of using nitrogen, it also helps to maintain grain quality. It maintain colour of stored pulses and oilseeds. Eg. Lupins, Chickpeas, Canola. It also affects oil content quality positively. Because of low oxygen level in storage, less oxidation of oils in oilseeds takes place. Hence the oil content in oil seeds do not reduce. Eg. canola, sunflower, linseed. Use of N in warehouses is safe and do not have harmful effects on human beings. No venting of grain is required. It is definitely much more safe as compared to using phosphine fumigation for pest control.

Banks *et. al*.[9] studied modified atmosphere techniques for grain storage in Australia. In 1972, full scale testing of nitrogen-based atmospheres started and

has led to development of a process, based on a tanker-delivered liquid nitrogen. Since, under dry Australian conditions, the quality of grains such as wheat is maintained in storage because of the use of nitrogen-based systems and effective on insects rather than quality control. According to them, the use of CO_2 is the preferred atmosphere for insect control as it is easy to apply and, unlike nitrogen atmospheres, does not require a continuous input of gas after the initial purge if the storage is well sealed. CO_2-based atmospheres are now in use in Australia for insect control in stored grain.

Valentin, N.[10] investigated non-toxic methods for insect control in museums, archives and herbaria in different climatic regions. He evaluated the efficacy of gases by using modified atmospheres including nitrogen, argon and carbon dioxide to eliminate insect families. He analysed eight different species, and all their development stages, in the families Cerambicidae, Anobiidae, Dermestidae and Lyctidae in the Coleoptera. The modified atmospheres were used in several treatment systems, i.e. plastic bags of low permeability, a fumigation vacuum chamber and a fumigation bubble, and the most appropriate conditions for disinfestation of ancient objects were assessed. He found that an argon atmosphere achieved the best results for insect elimination with a short exposure time. Different species of Coleoptera were found to be resistant to carbon dioxide.

Sadeghi, R. and Jamshidnia, A.[11] conducted the study to determine the effect of nitrogen mixed with carbon dioxide on controlling stored-grain insects in the storehouse. Adults of *Sitophilus oryzae* (L.), *Tribolium castaneum* (Herbst), *Rhyzopertha dominica* (F.), *Oryzaeohilus surinamensis* (L.) and 3th larvae of *Plodia interpunctella* (Hubner) were exposed to the mixture of nitrogen and carbon dioxide. They found that the mixture of nitrogen and carbon dioxide in the interaction between depth and diet (depth ×diet) are not significant for the *S. oryzae, T. castaneum, R. dominica* and *P. interpunctella* but for *O. surinamensis* is significant. The influence of nitrogen gas and carbon dioxide in the date is more than rice and wheat. Authors concluded that the mixture of nitrogen with carbon dioxide could be safer fumigant for decreasing phosphine fumigation.

Conclusion:

Though there are various techniques to manage insect pests in storage or warehouses, use of asphyxiant gases is safer and eco-friendly. Use of these gases in silo also maintain the quality of stored commodity. This also helps in reducing the problem of insecticide/ phosphine resistance in storage insect pests. Hence in my view, this is the best method to control stored grain pests.

References:

1. https://chemistry.nd.edu/assets/159790/asphyxiants.docx. 03/07/2018
2. https://en.wikipedia.org/wiki/Asphyxiant_gas. 30/06/2018.
3. https://en.wikipedia.org/wiki/Hypercapnia. 03/07/2018.
4. https://toxnet.nlm.nih.gov/cgi-bin/sis/search/a?dbs+hsdb:@term+@DOCNO+516.03/07/2018
5. http://www.fao.org/docrep/X5042E/x5042E0o.htm. 03/07/2018
6. http://pest.ca.uky.edu/PSEP/fumexamples.html. 03/07/2018
7. http://storedgrain.com.au/carbon-dioxide-co2 . 28/06/2018.
8. http://storedgrain.com.au/nitrogen-notes-use-stored-grain. 28/06/2018.

9. Banks, H.J., Annis, P.C., Henning, R.C. and Wilson, A.D. (1980). Experimental and Commercial Modified Atmosphere Treatments of Stored Grain in Australia. Developments in Agricultural Engineering. Vol. 1; 207-224.
10. Valentin, N. (1993). Comparative analysis of insect control by nitrogen, argon and carbon dioxide in museum, archive and herbarium collections. International Biodeterioration & Biodegradation. 32:(4);263-278.
11. Sadeghi, R. and Jamshidnia, A. (2014). Effects of nitrogen and carbon dioxide mixtures on the mortality of five stored-product insects. Romanian Journal of Plant Protection Vol. 7; 56-64.