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Role of Inert Gases In Management Of Stored Pests

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Introduction

Pests not only damage crops in the field but also continue to threaten grains and food products during storage. Global estimates suggest that insects in stored products can cause post-harvest losses of 5–10%, and even up to 40% in developing nations. Among various management techniques, fumigation is considered the most effective method to eliminate all developmental stages of pests in grain bins, warehouses, and large storage facilities.

However, excessive reliance on chemical fumigants often results in pesticide residues in food, posing risks to human health, the environment, and contributing to insect resistance. As a sustainable alternative, inert gases such as oxygen (O_2), carbon dioxide (CO_2), ozone (O_3), argon (Ar), and nitric oxide (NO) are employed in Modified or Controlled Atmospheres (MAs or CAs). These techniques adjust gas composition-either by lowering oxygen or increasing CO_2 levels—to suppress insect activity, offering an environmentally friendly and cost-effective method for grain protection.

Although MA technology has been in use for over three decades, its role in pest management continues to expand. Understanding how insects respond and adapt to hypoxia (low oxygen) and hypercapnia (high CO_2) is crucial for improving its efficacy.

Modified Atmosphere:

A **Modified Atmosphere** involves altering the gas composition surrounding stored commodities, typically using packaging materials such as plastic films. The composition is not tightly regulated and can change over time due to the respiration of stored produce and the permeability of the storage material.

Essential Factors for MA:

Four factors are essential to the use of modified atmospheres for control of insects in stored commodities;

1. The atmosphere must be easily obtained in sufficient volume to displace existing atmosphere in large bulk storage;
2. The atmosphere must be lethal to storage pests within a reasonable time
3. The atmosphere must have no harmful effect on the quality of the treated commodity
4. The storage structure must have an adequate gas holding capability.

Controlled Atmosphere:

Controlled Atmosphere: System maintains specific gas concentrations typically low O_2 and elevated CO_2 levels through continuous monitoring and regulation throughout the storage period. These systems are more precise and stable than MAs.

Equipments involved in Controlled Atmosphere:

Equipment for Post-Harvest Controlled Atmosphere Storage are:

- ✓ Nitrogen Generators
- ✓ CO_2 Adsorbers
- ✓ Platinum Ethylene Scrubbers
- ✓ Combined CO_2 / Ethylene Scrubbers
- ✓ Humidity Sensors
- ✓ Temperature Sensors
- ✓ Pressure Sensors
- ✓ O_2/CO_2 Gas Analyzers
- ✓ Ethylene Analyzers
- ✓ Computerized Management Systems
- ✓ Insulated Panels
- ✓ Expansions Bags
- ✓ Hydraulic Traps, etc.

Scrubber:

Scrubbers are used in controlled atmosphere storage to absorb the extra amount **gases** present inside the packaging material.

Composition of Air:

The air in Earth's atmosphere is made up of approximately

- ➢ Nitrogen - 78 percent
- ➢ Oxygen – 21 percent
- ➢ Argon - 0.93 percent
- ➢ CO_2 - 0.04 percent

Inert gases:

The Inert gases involved in Management of stored grain pests are Oxygen, Carbon dioxide, Nitrogen, Argon, Ozone, Nitric Oxide, etc.,

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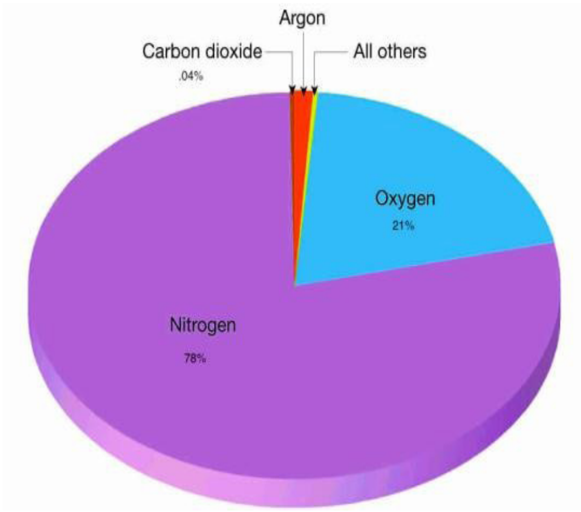
Mode of Action:

- In *Euphestiacautella*, high CO_2 level reduced ATP levels.
- High CO_2 and N_2 cause Anoxia, Spiracular control and weight loss and dessication. In *Sitophilusoryzae.*
- Majority of the weight loss is assumed to be water, and death is partially caused by desiccation in high N_2 atmospheres.
- Insects were immobilized soon (generally in less than 60 seconds) after exposure to the atmosphere and did not become active throughout the period of exposure.
- Some immobilized insects exposed for sub lethal subsequently had only a delay in development time approximately equal to the period of exposure. Others similarly exposed developed partial paralysis, particularly in the posterior segments, and appeared incapable of defecation.



- Larvae, so sticken, were often observed with dried fecal material protruding from the abdomen; none survived to the pupal stage.
- Reduced from their normal size and rudimentary wing development on cowpea weevil and red flour beetle.
- Exposing the adults of maize weevil and larvae of khapra beetle to nitrogen for periods below that required to kill them, only caused temporary paralysis and some of the insects recovered after they were restored to fresh air.
- Controlled atmospheres may be potential control agents for stored product mites.

Nitrogen in pest Management:

Nitrogen, being inert, is used primarily to displace oxygen and create low-O_2 environments. It does not have bacteriostatic properties and is less likely to penetrate stored products. Both CO_2 and N_2 have been employed in CA storage for decades, though CO_2 is generally more effective due to lower structural gas-tightness requirements.

Liquid N_2 can be used to maintain desired atmospheres but may be costlier than gaseous sources. In maize weevils, eggs and adults are more susceptible to nitrogen treatment than larvae or pupae.

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Example:

At 99.9% N_2 concentration, adult and egg stages of *Sitophiluszeamais* were eliminated more rapidly than immature stages in experimental mini-silos.

The egg and the adult stages of maize weevil were more susceptible in nitrogen atmosphere than the larval and pupal stages

Carbon dioxide in pest Management:

Atmospheres containing about 60% carbon dioxide rapidly kill stored- product insects. At 26°C, about four days of exposure would be sufficient to kill all stages (including eggs) of most stored-product insects.

Laboratory tests on the major stored-product insects have shown that adults can be killed with pure CO_2 within 10-48 hrs; exposure times of more than 14 days are required to kill them when the atmosphere contains less than 40% CO_2 even at temperature levels above 20°C.

The initial symptoms of carbon dioxide poisoning in insects include a narcotic effect, leading to knock-down, i.e., immobilization of the insects under carbon-dioxide-enriched atmospheres. Moreover, unlike other chemical control methods, CO_2 leaves no stable residues; it is neutral with respect to treated commodities.

Diapausing *Trogoderma granarium* (Khapra beetle) larvae are the most tolerant to high-CO_2 atmospheres of any species. They are tolerant of CO_2 concentrations of 60% or less in air at 25°C, and less than 95% mortality has been obtained after 25days, the longest exposures of tested. It appears that diapausing *Trogoderma variabile* (the warehouse beetle) larvae may have a similar response. Other *Trogoderma* spp. is also very tolerant.

	Tolerant to CO_2	Susceptible to CO_2
Insect species	*Trogoderma sp.* *Tribolium Castaneum*	*Sitophilus oryzae*

Oxygen in pest Management:

O_2 is critical for the survival of aerobic life. However, oxidative injury can be induced by a tool too high (hyperoxia) O_2 level in organisms, which will induce mortality. In addition to nitrogen, which is commonly used to pro-duce a low-oxygen atmosphere, rare gases like helium and argon have also used which effect similar to nitrogen. Generally, the lower the oxygen level, the higher the mortality. For effective control, the O2 level should be <3% and preferably <1% if a rapid kill is required.

Pupae and mature larvae of internally developing species such as the weevils (*Sitophilus spp.*) and lesser grain borer (*Rhyzoperthadominica*) were generally the most tolerant stages and early-star larvae and" adults of externally developing species such as the flour beetles (*Tribolium spp.*), the Indian meal moth (*Plodiainterpunctella*), and almond moth (*Ephestiacautella*) were the **most susceptible**.

	Tolerant to O_2	Susceptible to O_2
Insect species	*Sitophilus spp.* *Rhyzopertha dominica*	*Tribolium spp.* *Plodia interpunctella*

Nitric Oxide:

NO is a potent fumigant that shows excellent control effect on all insects, regardless of their life stage.

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However, the application of NO MAs should follow a logical order.

For example, when NO is used with nitrogen (N_2) in an airtight fumigation chamber to protect fresh fruit and vegetables against pests infection, N_2 should be flushed into the chamber first, to create an ultralow oxygen (ULO) environment, followed by injection of NO because nitrogen dioxide (NO_2) will be produced when NO reacts with O_2, NO fumigation must be applied under ULO conditions and under low temperature.

ECO_2 FUME:

ECO_2 FUME fumigant gas is a non-flammable premixed cylinderized mixture of phosphine and carbon dioxide, which provides highly effective fumigation in both sealed and unsealed facilities. This break through fumigation management system is available to professional applicators who seek an environmentally friendly alternative that is easy to use with improved worker safety.

ECO_2 FUME fumigant gas is a gaseous mixture of 2% phosphine in carbon dioxide. Carbon dioxide is excellent carrier for phosphine and diluting phosphineto this concentration ensures ECO_2 FUME is non-flammable in all proportions with air. The fumigant gas can be used in a wide variety of application to attain insect free condition.

Advantages:

- ✓ Highly Effective in pest management.
- ✓ No chemicals used hence Environment friendly.
- ✓ Increase the shelf life of products (eg: Oil seeds).
- ✓ No residues left in produce.
- ✓ Cost effective.
- ✓ Nonspecific target.
- ✓ Large area in short period.

Disadvantages:

- ✓ Not suitable in all produce.
- ✓ Different gas composition in each produce.
- ✓ Initial machinery cost is high.
- ✓ In Perishable good sit develops uneven ripening.
- ✓ Special operators are required.
- ✓ If leakage is done then entire system is lost.

Conclusion:

The first example is the storage of grains in ancient Egypt, where the cribs were sealed tightly to prevent

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the propagation and growth of insects through the use of lowered oxygen environment. Historically, controlled atmosphere treatments were designed to preserve commodity **quality** during long-term storage. Franklin Kidd and Cyril West of Cambridge University did the basic research into fruit respiration and ripening leading to the first commercial facility in 1929.

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