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غاز الأوزون وأستخدامه كبديل مستدام عن المبيدات الكيمياوية في مكافحة آفات المواد المخزونة

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الجامعة المستنصرية – كلية التربية الأساسية – قسم العلوم(١&٢)
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الملخص :

تتعرض المنتجات الزراعية المخزونة من الحبوب والبذور والتقاوي والتمور والفواكه التي تخزن في المستودعات والمخازن لفترات طويلة الى الإصابة بالعديد من أنواع الآفات الحشرية والتى تعد من المشاكل المهمة والخطيرة على المستوى العالمي والمحلي نظراً لما تسببه هذه الآفات المخزنية من خسائر كبيرة وفادحة للمواد الغذائية المخزونة فضلاً عن الأضرار الذي تحدثه هذه الآفات في الغذاء يمكن ان تكون هذه الآفات ذات أضرار صحية على الأنسان مثل احداث الحساسية او تهيج أو تقرح في الجلد بالأضافة الى الأضرار التي تسببها للجهاز التنفسي وذلك من خلال المتبقيات التي تتركها تلك الآفات عند الإصابة.

ونتيجة لأهمية الآفات الحشرية المخزنية وللسيطرة عليها وحماية المحاصيل المخزونة يستخدم غاز الأوزون عوضاً عن المبيدات الكيميائية والتي تعتبر ضارة للبيئة والأنسان كبديلاً مستداماً للقضاء على هذه الآفات وكذلك يستخدم غازالأوزون لتطهير المواد الزراعية كما أن للأوزون فوائد كبيرة مثل تقليل النفايات وإتاحة فرصة الاستغناء عن المبيدات الكيميائية مما يؤدي إلى زراعة أكثر استدامة وخياراً صديقاً للبيئة .

الكلمات المفتاحية: غاز الاوزون، المبيدات الكيميائية، آفات المواد المخزنية ،مكافحة.

Ozone gas and its use as a sustainable alternative to chemical pesticides in controlling stored product pests

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Abstract:

Stored products such as grains, seeds, dates and fruits that are stored in warehouses for long periods of time are exposed to many insect pests, which is a serious issue at the global and local level due to the huge losses caused by these stored pests, in addition to the damage caused by these pests in food, these pests can be harmful to human health, such as causing allergies, irritation or ulceration of the skin in addition to damage to the respiratory system through the residues left by these pests when infected.

To control these stored pests and protect stored crops, ozone gas is used as a sustainable alternative to chemical pesticides to eliminate pests as well as ozone gas is used to disinfect agricultural materials and ozone has great benefits such as reducing waste and allowing the opportunity to dispense with chemical pesticides, which leads to more sustainable agriculture and an environmentally friendly option.

Keywords: ozone gas, chemical pesticides, stored product pests, pest control

Introduction:

Ozone gas is a chemical compound consisting of a mixture of 3 oxygen atoms and its chemical formula O3 that results from the reaction of the oxygen free radical with oxygen molecules, bluish in colour, has a pungent odour, is highly variable and unstable (Al-Saqr et al., 2022).

Ozone is found in the atmosphere when an oxygen molecule consisting of two atoms of oxygen (O2) is exposed to high voltage, it will separate and combine with an oxygen molecule to form ozone gas (O3), which consists of 3 atoms. Ozone is found in nature in the stratosphere and its existence is due to a series of reactions between molecular and atomic oxygen, and the formed ozone remains for a short time after which it is broken down by sunlight into an oxygen molecule and then formed and in the end we get a form that always maintains a layer of ozone in the stratosphere in balance and this balance depends on the speed of its formation and the speed of ozone disintegration.

The main reason for the presence of ozone gas in the atmosphere is that it protects the earth from the ultraviolet rays that reach us from the sun, which absorbs more than 99% of them, thus protecting the known life forms on the surface of the earth and this is what makes life on our planet possible unlike some other planets in our solar system (Al-Saqr et al., 2022).

Because ozone gas dissolves at room temperature, it will turn into oxygen, so it cannot be stored and must be produced at the place and time it is intended to be used, because ozone gas is an unstable molecule and therefore its ability to oxidise is very high. Ozone gas can be obtained in different ways, including

electrostatic discharge, ultraviolet radiation, thermochemical and electrical methods (Al-Mousawi et al., 2019).

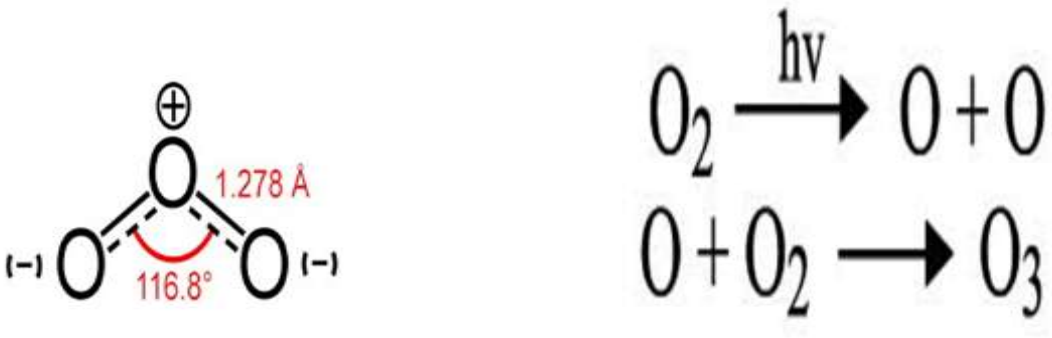

Figure (1) Chemical formula of ozone gas

Store pests:

In recent years, many types of store pests have appeared, which are known to have different structural and behavioural characteristics, even for strains that belong to a same species, which is called sub species, and it is not surprising to find such pests that have spread globally and on a large scale to differ in their habits and ways of living, which led to the emergence of complex morphological and behavioural changes and developments even within members of the same species (Al-Azzawi and Mehdi,1989). Some of the most important insect pests that affect stored products are listed in Table 1.

Table 1: shows Major pests adapted to live in grains and stored materials

العائلة	الاسم العلمي	الاسم العامي الانكليزي	الاسم العربي
Bostrichidae	*Rhyzopertha dominica*	Lesser grain borrer	١ ـ ثاقبة الحبوب الصغرى
Cucujidae	*Oryzaephilus surinamensis*	Sawtoothed grain beetle	٢ ـ خنفساء الحبوب المنشارية
Cucujidae	*Oryzaephilus mercator*	Merchant grain beetle	٣ ـ خنفساء الحبوب التجارية
Cucujidae	*Cryptolestes pusillus*	Flat grain beetle	٤ ـ خنفساء الحبوب المسطحة
Cucjidae	*Cryptolestes ferrugineus*	Rusty grain weevil	٥ ـ خنفساء الحبوب الصدئية
Curculionidae	*Sitophilus oryzae*	Rice weevil	٦ ـ سوسة الرز
Curculionidae	*Sitophilus zeamaize*	Maize weevil	٧ ـ سوسة الذرة
Curculionidae	*Sitophilus granarius*	Granary weevil	٨ ـ سوسة الحبوب
Dermestidae	*Trogderma spp.*	Khapra beetle	٩ ـ خنفساء الخابرا
Gelechiidae	*Sitotroga cerealella*	Angoumois grain moth	١٠ ـ عثة الحبوب
Ostomidae	*Tenebroides mauritanicus*	Cadlle	١١ ـ خنفساء الكادل
pyralidae	*Plodia interpuctella*	Indian meal moth	١٢ ـ عثة الطحين الهندية
Pyralidae	*Anagasta kuehniella*	Mediterranean flour	١٣ ـ عثة حوض البحر المتوسط
Tenebrionidae	*Tribolium confusum*	Confused flour beetle	١٤ ـ خنفساء الطحين المتشابهة
Tenebrionidae	*Tribolium castaneum*	Red flour beetle	١٥ ـ خنفساء الطحين الحمراء
Tyroglyphidae		grain and flour mites	١٦ ـ مجموعة حلم الطحين والحبوب

p 113 Hashmeia

3- The importance of agricultural pest control :

Insect pests are one of the most important reasons that cause damage to stored products of seeds and grains in all warehouses, where the loss in the weight of wheat and barley grains resulting from insect infestation reaches 35-55%, and in the Corn seeds 25 % and sorghum 45 %, while In the case of legume seeds, the weight loss is 16% (Bulletin, 2017),

Agricultural products are food for the whole world and their importance has been reflected in the lives of people, and grain crops as well as stored products are exposed to many factors of loss, damage and loss from the beginning of their cultivation until their consumption, so preserving them from insect pests is an important matter that contributes positively to food security, and if the percentage of loss or losses caused by these insect pests causes an increased risk On the issue of food in the world, warehouse pest control is an important issue to preserve stored products. (Mahjoub, 2018).

4- Harmful effects of chemical pesticides:

Chemical pesticides are used to control many agricultural and warehouse pests, and despite the positive and rapid results of chemical pesticides obtained when using them, there are many negative effects due to its random use including:

1- Chemical pesticides are toxic compounds and cause harm. If they are not carefully selected and not used correctly, they may lead to the emergence of pest strains that are resistant to pesticides.
2- The irrational use of chemical pesticides leads to damage to the environment and disrupts the ecological balance .
3- Randome use of chemical pesticides leads to the elimination of many natural enemies of insect pests such as predators and parasites.
4- its led to the emergence of pests that used to be secondary pests and became harmful primary pests.
5- Pesticides may affect humans causing cancerous diseases.
6- During the process of spraying pesticides, pesticides may fall on the soil, which leads to soil pollution and migrate with soil granules and may migrate to water sources and polluteing them (Aktar *et al*, 2009).
7- Pesticides in agriculture contribute to meeting the needs of the growing population. These pesticides are highly toxic by nature, posing serious risks to human health and the environment, and have negatively impacted agricultural workers. Agricultural workers are primarily exposed to these chemicals, both directly and indirectly. The general public is also exposed to these chemicals through skin contact, through pesticide leakage and drift during mixing. They also pose serious threats to human health, such as diabetes, reproductive disorders, neurological dysfunction, cancer, and respiratory disorders (Rani *et al*., 2020).

The importance of using ozone as an alternative to chemical pesticides: -5

Ozone gas can be easily generated at the treatment site using electricity and air, It has many safety advantages over chemical pesticides, including firstly, it does not need warehouses as toxic chemicals, and there are no risks around its disposal compared to residual pesticides or containers, and secondly, because of the short lifetime of ozone, it returns to the oxygen that occurs naturally without leaving residues in the product, research has focused on using ozone O3 as a fumigant to control insects and pests that infect materials. Research has focused on the use of O3 as a fumigant to control insects and pests that infect stored materials and microorganisms as well as reduce mycotoxins on stored grains due to the development of resistance in insects to chemical pesticides and the urgent need to develop alternatives to methyl bromide that are suitable for post-harvest treatment of agricultural commodities (Law, 1991).

Ozone gas helps to extend the life of products, and it is easy to obtain, as it does not require transportation or storage, and the process of preserving these

products is affected by multiple methods, including the use of ozone gas, which is one of the effective methods in reducing the damage of storage pests, as it is one of the oldest control methods used that was discovered and used by the German scientist Christian Schoenbein in 1840 (Fielding *et. al*., 2005;Fielding *et. al*., 2005).

Ozone gas has many advantages, including but not limited to the fact that it contributes to the elimination of 100% of the damage of pests and all stages of their growth (Al-Obaidi, 2015), its short residence time on the surfaces of products (Ledakowicz *et al*., 2017), as well as its low consumption. (Ramona *et al*., 2020), it is used in all types of warehouses and is one of the most powerful common oxidising agents (Ghernaout1 & Elboughdiri, 2020), and does not leave any toxic effects on those products (Al-Saadi & Hermes, 2022).

6- Mechanism of action of ozone gas in pest control:

Ozone gas is a highly reactive and powerful oxidising agent classified in 1982 by the United States Environmental Protection Agency (USEPA). It is a safe gas (Generally Recognised As Safe) The US Food and Drug Administration (FDA) has approved ozone gas to be used as an antimicrobial agent against many types of microbes in addition to the processing and storage of gaseous and aquatic foods, and ozone gas has been approved by the United States Department of Agriculture (USDA) in Organic food processing has been known in the food industry for a long time and ozone gas is used for food processing such as sterilisation, odour, taste and colour removal (USEPA, 1999).

The use of ozone gas to preserve stored grains and food would address the growing concern over the use of harmful chemical pesticides to kill storage pests, minimise the increase in insect resistance and increase consumer demand for chemical-free grains, leading many farmers and grain and seed producers to look for alternatives to storage pest control (USEPA, 1999). Commonly used chemical insecticides (fumigants) in seed, date and grain stores include aluminium phosphide, methyl bromide and phosphine, of which the use of methyl bromide is almost completely phased out as agreed in the Montreal Protocol. The continued use of these pesticides has been found to interfere with biocontrol (natural agents) leading to the spread of insect pests and the development of widespread resistance by affecting the genetics of the treated pests as well as undesirable effects on non-target organisms, the environment and human health. Increasing concern about the harmful effects of pesticides has highlighted the need to develop selective

alternatives in pest control (Colins *et al*., 2005; Islam, *et al*., 2005; Pimental *et al*., 2009).

Fumigation is the use of toxic gases to kill pests of stored products. Fumigants are chemicals that exist in gaseous form and concentrations that are lethal to any insect or animal pests. The fumigation process is one of the most effective methods for protecting stored food products from infestation by all types of stored pests that affect them during storage. These gases have the tremendous ability to penetrate and spread, which cannot happen with other chemical methods. Fumigation depends on the type of pest, its stage of development, and its degree of development. Fumigation gases enter the insect through the respiratory openings, which leads to a severe shortage of oxygen that the insect needs, which leads to its death (Marsh, 2001).

Structural fumigation is a method of controlling storage pests that involves filling the airspace inside a structure with toxic gas. The structure is covered with a tarp or tent to keep the gas inside, which penetrates the pores in the wood or penetrates between the grains of the treated wood to eliminate storage pests, as well as wood-destroying organisms and bed bugs. The tarp also provides flexibility for fumigating a range of infested museum items to museum artwork.

Fumigation or sterilisation of dates is one of the methods used in modern date processing units in order to eliminate date insects and their eggs. As well as to ensure that these insects are not transferred from infected fruits to healthy fruits in the packing houses (storage) (Mohammed, 2003; Younis, 2021).

7-The effect of fumigation using ozone gas:

7-1- The effect of fumigation using ozone gas on stored pests:

Due to the importance of storage insects and the great losses caused by these pests to,In recent years, studies have expanded on the control of stored pests, the development of methods and means to limit their activity, and the desire to find alternatives to the use of chemical pesticides.(methyl bromide and phostoxin) have expanded in recent years. In the treatment of stored materials and the use of less harmful substances in control, researchers have found the possibility of using many control methods for stored insects to reduce the severity of their infestation on different types of foodstuffs, as insect control is the first step in reducing their numbers, whether in the field or in the store.

The use of ozone gas was confirmed to know its effect in killing pest, it was found that ozone gas has a great and effective role in reducing and limiting the

damage of pests of stored products, and that ozone gas has proven its suitability in controlling store pests because it does not leave any toxic effect and can be used in all warehouses, and its residence time is short and can be generated quickly. It was found that ozone treatment alone gave high kill rates of *Ephestia kuehniella* adults and larvae, which are harmful stages that infect stored materials, are sensitive to ozone gas (Isikber et al., 2007).

Ozone gas was also used to reduce all stages of the Indian flour moth *Plodia interpunctella* and the grain sawfly *Oryaephillus surinamensis*, which are the main insects that infect stored products when infected dates were exposed to concentrations of (600, 1200, 2000 and 4000) ppm for 1 and 2 h. It was found that the concentration of 2000 ppm gave the highest kill rate in the larval and adult stages of the insect (Niakousari et al., 2010).

Research has recently focused on the use of ozone gas as an alternative to chemical pesticides due to the development of resistance in insects to chemical pesticides in addition to the gradual elimination of methyl bromide as a fumigant to control stored grain pests and microorganisms as well as to reduce mycotoxins. Ozone gas kills insects at 50 ppm in a 4-day exposure period and eliminates the infection in treated insects (Jian et al., 2013), Ozone gas is effective in killing insects at 50 ppm in a 4-day exposure period and eliminating the infestation in treated insects (Jian et al., 2013).), increasing ozone concentration and exposure time increased the killing rate of all stages of the Indian flour moth Plodia interpunctella (Keivanloo et al., 2014).

Ozone was used against all life stages of the cowpea beetle *Callosobruchus maculatus* (Fabricius) (egg, larva, pupa and adult). Longer exposure to ozone caused a greater reduction in adult emergence from eggs, larvae and pupae and 5 h ozone treatment caused 72.3% egg mortality and mortality (Gad et al., 2021). Ozone gas can effectively kill a large proportion of insects and ozone concentrations ranging from 1.4 to 5 mg/m³ with an exposure time of 5 hours were found to be sufficient to completely eliminate the grain weevil (Baskako et al., 2025.(

٧-2- Types of pests that ozone gas can help remove:

While ozone generators may have the ability to eliminate certain types of pests, their effectiveness can vary depending on factors such as the type of pest, the severity of the infestation, and the size and layout of the area being treated.

Here are some of the pests and other issues that ozone generators may help remove.

- **Insects**: Ozone gas is effective in eliminating many insect pests such as cockroaches, bed bugs, ants, fleas, and mosquitoes. By disrupting their habitats and interfering with their respiratory systems, ozone gas can help reduce insect populations and prevent infestations.

- **Odour causing pests**: Ozone gas is useful in neutralising and eliminating odours caused by pest infestations, including those caused by rodent droppings, urine and decaying pests. By removing odour, ozone gas can eliminate unpleasant odours and improve indoor air quality.

-**Mould and mildew**: Ozone gas can help eliminate the growth of mould and mildew that often attracts pests such as insects and rodents. By disinfecting surfaces and preventing the proliferation of mould spores, ozone gas can prevent mould-related issues and pests and promote a healthier indoor environment (Adeyeye, 2020).

- **Air purification**: Ozone gas improves indoor air quality by removing pollutants, allergens and airborne bacteria by oxidising and neutralising harmful substances. Ozone gas can help reduce allergy symptoms, respiratory issues and odours, creating a healthier and more comfortable living environment.

- **Surface disinfection**: Ozone gas has strong antiseptic properties and can be used to disinfect surfaces in the home including work surfaces, furnishings and carpets by killing bacteria, viruses and other pathogens. Ozone gas can also help prevent the spread of infectious diseases and maintain a healthy living environment (Holly et al., 2020; Cristiano, 2020).

-**Eliminate odours**: Ozone gas is effective in neutralising a wide range of odours including smoke, pet odours, cooking odours and musty smells by breaking down odour molecules at the molecular level and ozone gas can remove odours at their source leaving behind a fresh and clean smelling environment.

7.3-Areas of application of ozone gas

Ozone has wide application as a powerful disinfectant in water treatment, food processing, food preservation and various other environmental applications. Ozone as an oxidising agent has many potential applications in the food industry due to its advantages over traditional food preservation techniques. Ozone is often used in gaseous or liquid form in the processing of fruits and vegetables to inactivate pathogens and spoilage microorganisms. In addition to eliminating a

wide spectrum of microbial material (Sarron *et al*., 2021), ozone gas has the ability to kill storage pests and degrade mycotoxins. One of the potential advantages of ozone is that excess ozone spontaneously decomposes quickly to produce oxygen and therefore leaves no residue in food (Xues *et al*., 2023). Ozone gas has been found to be effective against a wide range of microorganisms including bacteria, fungi, viruses, protozoa and bacterial fungal spores. Such advantages make ozone attractive to the food industry, and has therefore been confirmed as generally recognised as safe for use in food manufacturing.

8-Future trends in the use of ozone gas as an alternative to chemical pesticides in warehouse pest control:

Future trends in ozone gas research and warehouse pest control indicate a growing interest in ozone gas as a sustainable, residue-free fumigant for stored grains and other commodities. This is due to the need for effective control of agricultural pests without any harmful chemical residues as well as the increasing development of ozone generation and application technologies (Pandiselvam *et al*., 2020).

The most important future trends in the use of ozone gas are:

8.1-Ozone gas as an evaporator:

The use of ozone gas as an alternative to traditional chemical fumigants, especially in light of growing concerns about pesticide resistance and residues in food products (Dong *et al*., 2022)

8.2-Efficiency and safety:

Improvements in ozone gas application techniques to increase its effectiveness against stored pests including pests and microorganisms while minimising any negative effects on treated products (Dong *et al*., 2022).

٨.3-Preserving the environment:

Ozone gas has the ability to decompose into oxygen and is an environmentally friendly option because it leaves no persistent chemical residues on the treated materials (Boopathy *et al*., 2021).

٨.4 - New applications:

Research is expanding to explore the use of ozone gas in various stages of grain handling and storage, including pre-harvest, post-harvest, and storage.

9- Technological developments:

9.1-Improving ozone gas generation:

Efforts are being made to develop more efficient and cost-effective methods of ozone gas generation, including advances in vacuum and degassing technologies.

9.2- **Controlled delivery of** ozone gas:

Emphasis should be placed on optimising ozone gas delivery systems to ensure uniform distribution and effective pest control in different storage environments including silos, warehouses and shipping containers.

9-3-Monitoring and control:

Advances in sensor technology allow for more accurate monitoring of ozone concentrations in food storage areas, enabling better control of the fumigation process and ensuring optimal conditions for pest control while minimising potential risks **(Isikber & Athanassiou, 2014).**

10- Challenges and Future Directions:

10-1- Expansion:

One of the major challenges is scaling up ozone fumigation technologies to large-scale storage areas while maintaining efficiency and safety (Boopathy et al., 2022).

10-2-Impact on Food Quality:

Further research is needed to fully understand the effects of ozone on the quality, nutritional value, and sensory properties of various food commodities.

10-3-Regulatory Means:

Establishing clear regulatory guidelines for the use of ozone gas to protect stored products is critical to ensure the safe and responsible application of this technology (Boopathy et al., 2022).

10-4-Integration with Integrated Pest Management:

Ozone fumigation should be integrated into a broader integrated pest management strategy to provide a sustainable and comprehensive approach to protecting stored produce (Chatterjee & Chakraborty 2022).

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