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PHYSICAL METHODS FOR STORED PRODUCTS PEST MANAGEMENT

Dilşan BOYLU[1]*

[1]*Ordu University, Agricultural Faculty, Department of Plant Protection, 52200, Ordu, Turkey*

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Abstract

Adequate and balance nutrition of World human population is being a bigger problem day by day. Storage of obtained products has an importance for sustainability of human nutrition. 10% of storage products are loosed by stored products pests. In this study, physical stored products pest managements such as high and low temperate applications, low moisture grain application, using radioactive materials, ozone application, light traps and diatomaceous earth application were explained and introduced. Physical management methods can be preferred as it does not cause residues that may pose a threat to human health during product protection against harmful effects.

Keywords: Physical methods, Stored products, Managements, Pest

***Corresponding author:** Ordu University, Agricultural Faculty, Department of Plant Protection, 52200, Ordu, Turkey
E mail: dilsanboylu@gmail.com (D. BOYLU)
Dilşan BOYLU https://orcid.org/0000-0002-0558-7782
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1. Introduction

Providing adequate and balanced nutrition to the rapidly growing world population is one of the leading problems of today. Additionally, the available agricultural areas do not increase in parallel with the population growth. Therefore, increasing the amount of product obtained from the unit area is of primary importance; Proper protection of the product from production to consumption is also of great importance. Generally, the losses caused by the organisms of animal origin in stored products are accepted as 10% per year. This rate of damage can be increased by the level of contamination (Ferizli and Emekci, 2013; Shah and Khan, 2014).

Stored product pests have direct and indirect harmful effects; direct effects are real consumption, septicity, damage to package. Indirect effects are heating, bacteria, fungus, aflatoxinse, human parasites and control - management cost (Shah and Khan, 2014; Anonymous, 2017; Azizoğlu et al., 2010).

A wide range of imaging-detection methods, decision support systems, biological, chemical and physical pest control methods are available for entomologists working on stored product pests. In order to prevent economic losses, the method of struggle and the threshold level must be determined correctly (Hagstrum and Flinn, 2014).

Physical management methods aim to change the environment of pests to their disadvantage. In this method, it is aimed that the population of pest can be kept at acceptable levels by changing the physical factors. Physical management methods can be preferred because they do not cause residues that may pose a threat to human health (Bank and Fields, 1995).

2. Physical Management

Physical management is aimed that the population of pest can be kept at acceptable levels by changing the physical factors. However, many sources describe the physical methods in a broader context and deal with the methods of mechanical management in physical management methods. The reason for this is that the two main management methods are in close relation at many points (Tuncer, 2014). In this method, it is aimed to eliminate harmful insects or to keep the population at acceptable levels by changing physical factors (Bank and Fields, 1995).

In physical management; high and low temperature (hot water, hot steam, solarization, incineration, cooling, etc.), atmospheric gases, proportional humidity, water immersion, sound, mineral substances and radiation can be used. Changing the physical environment is not possible for many products. However, the use of some of these methods aimed at changing the environment of the pest is generally possible against insects in confined spaces such as warehouses and greenhouses. Although some of the mineral substances show physical effect, they can be handled as physical preparations because they are used as preparations (Tuncer, 2014). Physical management methods are the basic method used before the widespread use of synthetic chemicals. This method requires modification of modern systems to protect products stored in large quantities (Bank and Fields, 1995).

The advantages and disadvantages of the physical managements can be summarized as follows;

Advantages;

- As fast as chemical methods
- Insects are difficult to develop resistance.
- It does not affect product quality significantly.
- No permission for application and no residue.

Disadvantages;

- It may require high energy demand for the application.
- Investment cost is high (Mason and Strait, 1998).

2.1. Low and High Temperature Utilization

Stored product pests can only survive and reproduce in a narrow temperature range. At temperatures outside this range, the pest population either remains stationary or dies at fast or low rates. Low temperature application has two important effects on stored product pests; 1) development rate, nutrition and fertility reduction, 2) lower survivability. Temperatures between 15 and 25 °C cause fewer spawning, slow growth, less movement and a longer life span. Different methods can be used to reduce the temperature of the grain stack. They may be circulating (mixing, transferring) of the products, ventilation of the environment or chilled ventilation. However, the best way to apply low temperature is to apply cold air to the grain pile in a pressurized manner. A wide variety of storage options, such as fan type, fan power, silo height and width, loading and unloading method storage method, can be used in storage facilities (Bank and Fields, 1995; Fields, 2006). The average grain cooler has a cooling capacity of approximately 350 tonnes per day and is operated at a cost of approximately $ 12.8 per day (Bank and Fields, 1995; Fields, 2006). Temperatures below the development threshold will cause insects to die over time. The length of this time may vary depending on the temperature, insect species, life cycle, moisture content of the grain and cooling method. Generally, *Tribolium castaneum Herbst*, *Tribolium confusum Jacquelin* du Val and *Oryzaephilus mercator* (F.) are highly affected by low temperature application; *Trogoderma granarium* Everts, *S. granarius*, *Ephestia elutella* (Hübner), *E. kuehniella* and *Plodia* spp. (Hübner) can show high resistance to cold application. Resistance to cold may be 4 - 10 times higher in insects that can live in cold application after several generations. Cooling processes in warehouses are carried out by 4 methods; a) Air circulation (Turning), b) Ambient Aeration, c) Chilled Aeration and d) Freezing.

This method is not as effective as high temperature and is more difficult to implement. For example, cooling of some products at -12 °C or leaving them at this temperature for 1-2 days gives very positive results. If possible, some products can be stored in cold places or in cold storage, which can be of great benefit to the product due to the halting or minimization of pest activity (Fields, 2006). However, it is stated that the humidity level should be 13% especially for cold weather applications (Salha et al., 2009).

It has been known for thousands of years that stored product pests are affected by high temperature. The first written document for high temperature application was found in Chinese records 1500 years ago (Fields, 1992). The high temperature application is already applied on a large scale in warehouses and equipment. This application can be applied to grain as well as to warehouses (Fields, 2006). The effects of high temperature on insects can be summarized as follows; It causes water loss in insects (Dehydration), Cell membranes may melt, Harm to enzymes and Salt balance changes (Fields, 2006). Temperatures higher than the highest growth temperature for insects can cause insects to die rapidly. At temperatures above 45 °C, most of the storage pests die within 24 hours. It is very difficult to compare the results of these studies because the methods of heating the grains, the insects they are applied, the application times and the temperatures are very different (Fields, 2006). Low tolerance to high temperature of *Ephesita* spp, *Oryzaephilus* spp, *P. İnterpunctella* and *Sitophilus* spp and high tolerance to high temperature of *Lasioderma serricorne* (F.), *Rhyzopertha dominica* (F.) and *Trogoderma* spp. has been reported (Fields, 1992).

When exposed to high temperatures, the insects produce temperature shock proteins that alleviate temperature stress. However, habit of environment can delay at very low level of effect of high temperature. In high temperature application, besides the effect on pests, damage to the product should be taken into consideration. Generally, the high temperature applied in a narrow time period can be effective on insects without damaging the product. For this purpose, the storage structures are subjected to a temperature of 50 °C for 24 - 36 hours. Insects die quickly at this temperature. In order to achieve this, all parts of the structure must be heated evenly and fans can be used for this purpose. All warehouse pests die between 51.5-65.6 °C depending on the application period. However, this degree and duration must be adjusted so as to avoid damaging the product. For example; According to the type of product and the type of pest this time is 47 hours for 4 hours of application, 3 hours for 54.4 °C and for a few minutes for 55.5 °C. In these applications, most of the insects and eggs die (Hammond, 2015). Temperatures above 50 °C are completely fatal to *R. dominica*. For *T. castaneum* and *T. confusum*, application times of 2 and 0.5 hours are required, for *Cryptolestes turcicus* it is required to apply 49 - 51 °C (Adler, 2010). There are two important issues to be considered in temperature applications; energy loss prevention and good temperature distribution (Hammond, 2015). General stored product pests' response to temperatures was given in Table 1 (Bank and Fields, 1995; Fields, 2006; Das et al., 2013).

Table 1. Response of stored-product insect pests to temperature

Zone	Temperature (°C)	Effects
Lethal	Above 62	Death in <1 min
	50 to 62	death in <1 h
	45 to 50	death in <1 day
	35 to 42	Populations die out, mobile insects seek cooler environment Maximum temperature for reproduction
	35	
Suboptimum	32 to 35	Slow population increase
Optimum	25 to 32	Maximum rate of population increase
Suboptimum	13 to 25	Slow population increase
	13 to 20	Development stops
Lethal	5 to 13	Slowly lethal
	1 to 5	Movement ceases
	-10 to -5	Death in weeks, or months if acclimated
	-25 to -15	Death in <1 h

2.2. Use of Relative Moisture

The main source of water of stored product pests is food. The moisture content of foods affects the number of offspring, rate of growth, life expectancy and the rate of adulthood. Stored product pests cannot survive and reproduce at a relative humidity below 50%. Especially, this method can be applied in warehouses (Fields, 2006; Yildirim et al., 2001). The relationship between the relative humidity and mortality rate of Sitophilus granarius in 7 days is given in Figure1 (Bank and Fields, 1995).

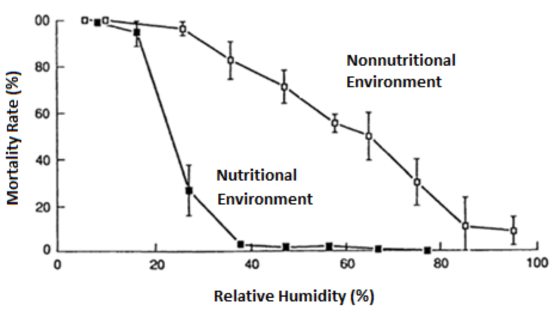

Figure 1. The relationship between the relative humidity and mortality rate of *Sitophilus granarius* in 7 days.

2.3. Use of Radioactive Substances

The In recent years, this method finds a wide range of applications, especially against the damage of the warehouse pests are managed by killing or sterilization. Cobalt (Co60) and Cesium (Ce137) are used as radiation sources. The lethal effect of radiation is only used against pests in stored products. Dose varies according to species. The dose of 12.5 kilorad (Krad) for the *Tribolium confusum* Duv. causes 100% death in two weeks. Lethal doses for *Trogoderma granarium* Everst and *Sitophilus granarius* (L.) were determined as 25 and 16 Krad. Very high doses, usually between 250 and 500 Krad, cause 100% death in insects within 24 hours. However, it is still debated whether this method is harmful for human health (Yildirim et al., 2001; Avan Aksoy et al., 2014).

2.4. Use of Ozone Gas

The Ozone gas (O3) has an important potential for pest control in stored cereals. Ozone can penetrate very large stack of grain, it is highly oxidative, non-stationary and dissolves with oxygen in the air, leaving no residue. Ozone supply and back flushing systems should be installed in the warehouses for ozone application (Maier et al., 2006). Studies have shown that the effective application of cereals in six days with doses of 35 ppm may be the best. However, for non-adult insects found in grains (the most difficult ones), it is recommended to use a dose of 135 ppm for eight days. Ozone is usually away from the environment in a short time. The ozone effect varies with temperature and ambient humidity (Hansen et al., 2013). A study on *Sitophilus granarius* and *Plodia interpunctella* showed that eight days were determined to be lethal. Insects living in each phase were found in six days (Hansen et al., 2013).

2.5. Diatom Application

Diatom soil is an effective powder of silica oxide and is derived from algae, algae fossil deposits. The effect on insects is that they absorb and erode the oils in the epicutic acid and cause insects to die from dehydration. Insects die when they lose 60% of water or lose 30% of their shells. Since the effect is not metabolic, insects do not develop genetic resistance to diatom. In recent years, many studies have been carried out, and 0.75 and 1.00 g/kg dose is recommended, especially for legumes (Lazzari and Ribeiro-Costa, 2006). It has been reported that an average of 97% lethality were observed for applying on a high-dose 1 kg / ton dose for *Sitophilus oryzae* and *Oryzaephilus surinamensis* (Moras et al., 2006).

2.6. Use of Atmosphere Gases

This method is intended to physically killing insect pests using carbon dioxide (CO2) oxygen (O2) and nitrogen (N) gases in different proportions in warehouses and it is only applied in closed volumes. For example, if the oxygen content in the tank is less than 1% and the carbon dioxide content is around 60%, the pests can be completely destroyed if these conditions persist for several weeks. The efficiency of this method varies according to the gas mixture ratios, humidity and temperature depending on insect species and physiological periods (Yildirim et al., 2001).

2.7. Use of Magnetic Field

By creating a high-voltage electric field, it is possible to kill pests in the product by passing the product which is contaminated with the harmful ones. Some tools have been developed for this purpose. However, this method does not have a wide range of applications (Yildirim et al., 2001).

2.8. Use of Mineral Salt

The purpose of this method is to cause the death of mites and soft-bodied insects using mineral salts or ashes to cause scratches on the body which cause the body water loss. It is especially applied in stored cereal and legume seeds. When the seeds, silicates, talc and other mineral substances or volcanic ash were mixed with the dust, physical death occurs due to the reduction of body water because of water loss (Yildirim et al., 2001).

3. Results and Discussion

Mechanical, biological and chemical control methods can be used for managing stored product pests. However, physical management methods such as low and high temperature applications, low moisture content storage, radioactive material utilization and algae sand plays an important role. The application costs in the physical management should be compared with the cost of the other methods of management and this should be done by considering the application. The damage caused by physical management methods such as high temperature application can be determined in the product and appropriate actions should be made by foreseeing the damage to the product while managing the insects.

Physical management methods are preferred because they do not cause residues that may pose a threat to human health during the protection of the product against pests. In the application of physical management methods, damage to the product should be taken into consideration and appropriate plans should be made in order to prevent economic losses.

Conflict of interest

The author declare that there is no conflict of interest.

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