

POST-HARVEST INSECT CONTROL WITH INERT DUSTS

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INTRODUCTION

Inert dusts such as; clay, sand, rock phosphate, ashes, diatomaceous earth, and synthetic silica, have been used as insecticides for thousands of years by aboriginal peoples in North America and Africa and are also used in modern grain storage facilities (1). Modern day research on inert dusts as a stored-grain protectant began in the 1920's (1, 2, 3, 4). Some inert dusts work by damaging the insect cuticle, causing death by desiccation. Other dusts such as clay, sand and ashes are used at higher doses (above 10%, w/w), and they work by providing a physical barrier against insects (3). The main advantage of inert dusts is their low-mammalian toxicity. In Canada and the USA, diatomaceous earth is registered as an animal feed additive and silicon dioxide is registered as a human food additive (1). Also inert dusts are effective for long durations and they do not affect end use quality (2). Their main disadvantages are that they are dusty to apply, do not work at high relative humidities and impede the flow of grain (5, 6).

TYPES OF INERT DUSTS

Mineral Dusts

Rock phosphate, ground sulphur, lime (calcium hydroxide), limestone (calcium carbonate) and salt (sodium chloride), have shown some activity against stored-product insects (3).

Earths and Ashes

Powdered clay, sand and earth have been traditionally used as a control measure by applying a thick layer of dust on the top surface of a grain bulk. These are less effective than diatomaceous earth and synthetic silica and like the mineral dusts need to be used at much higher doses.

Diatomaceous Earth

Diatomaceous earth is made up of the fossilized skeletal remains of diatoms (Fig. 1), single celled algae that are found in fresh and salt water. Diatoms are microscopic and have a fine skeleton made up of amorphous silica ($\text{SiO}_2 + n\text{H}_2\text{O}$). The accumulation of diatom skeletons over thousands of years produces the soft sedimentary rock, diatomaceous earth. The diatomaceous earth deposits currently mined are millions of years old, and certain deposits are hundreds of metres thick. The major constituent of diatomaceous earth is amorphous silicon dioxide (SiO_2) with minor amounts of other minerals (aluminum, iron oxide, calcium hydroxide, magnesium and sodium). The insecticidal activity can vary by 20 times depending upon the geological origin of the diatomaceous earth (3, 4). Effective diatomaceous earths have: SiO_2 content above 80%, a pH below 8.5, a tapped density of below 300 g.L^{-1} (5).

Synthetic Silica

Synthetic silica are manufactured by various methods, and all have the common formula SiO_2 . The different types of silica have different specific surface area, particle size, drying loss, ignition loss and structure, which may affect their insecticidal activity. They are very light powders, are the most effective of all inert dusts and have an acute rat LD50 of 3160 mg.kg^{-1} (1)

FACTORS EFFECTING EFFICACY

For the most part, inert dusts are effective because they damage insect cuticle, and insects die from desiccation. As insects move through the grain or across a treated surface, they pick up dust particles on their cuticle. The

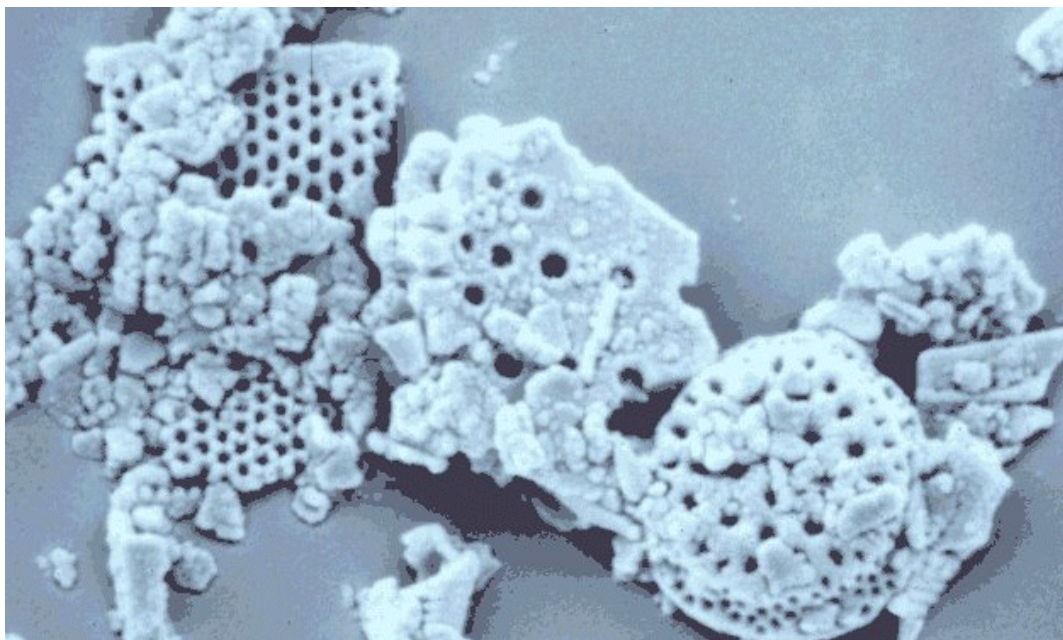


Fig. 1 Scanning electron micrograph of a saltwater diatomaceous earth.

silicon-dioxide-based inert dusts are thought to absorb the cuticular waxes. Abrasion of the cuticle is thought to be less important as a mode of action for the silica-based inert dusts, but may be the main mode of action for the other inert dusts. Insects die when they have lost approximately 60% of their water or about 30% of their body weight (1). Hence the lower the relative humidity, the higher the efficacy of the inert dusts. For example *Tribolium castaneum* has 35 to 85% mortality at

300 ppm at 10% moisture content wheat, but there is no mortality at 16% moisture content (7, Fig 2).

Not all insects have the same sensitivity to inert dusts (Table 1). The type of grain also affects efficacy; in

Table 1. The lethal dose for 50 and 90 % of the population (LD₅₀ and LD₉₀) of various stored-product insects in wheat at 10% moisture content treated with Protect-I® diatomaceous earth after 7 days

Insect	LD ₅₀ (ppm) (90% CI)	LD ₉₀ (ppm) (90% CI)
<i>Cryptolestes ferrugineus</i>	52 (45-61)	96 (89-112)
<i>Oryzaephilus surinamensis</i>	50 (24- 72)	158 (136-185)
<i>Sitophilus granarius</i>	204 (188-221)	373 (347-406)
<i>Sitophilus oryzae</i>	260 (242-281)	436 (393-496)
<i>Tribolium castaneum</i>	325 (303-347)	421 (397-449)
<i>Rhyzopertha dominica</i>	340 (313-367)	596 (560-637)

(From Korunic and Fields, unpublished data.)

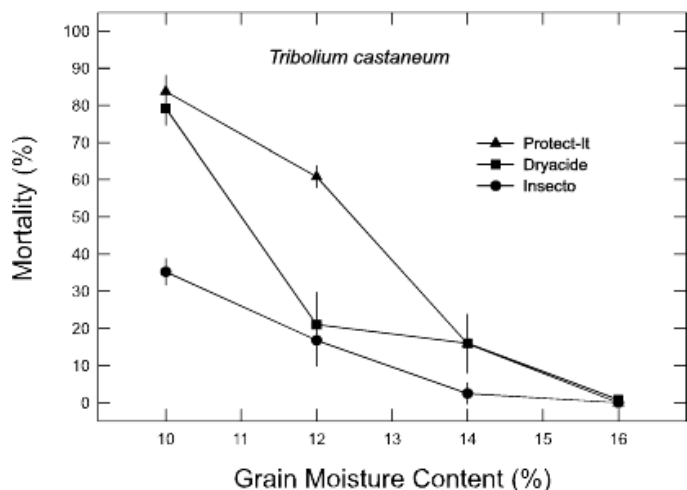


Fig. 2 The mortality of *Tribolium castaneum* held on wheat for 14 days at 30EC treated with three diatomaceous earths at 300 ppm (Modified from Ref. 7)

decreasing order for the amount of diatomaceous earth needed to obtain control: milled rice < sunflower < maize < paddy rice < oats < barley < wheat < durum (2).

METHODS OF APPLICATION

Diatomaceous earth is registered (as of spring 2000) as a grain protectant or for treating grain storage structures in Australia, Canada, China, Croatia, Denmark, Germany, Indonesia, Japan, Saudi Arabia and the USA. In Australia, diatomaceous earth is used principally as a treatment for empty silos, and the entire grain mass can not be treated for grain destined for the bulk handling companies, because of the adverse effects on the handling properties of the grain treated with diatomaceous earth. In most other countries, there are no restrictions on the destinations of diatomaceous-earth-treated grain. In India, during the 1960's, 70% of the grain was treated with activated kaolin clay. Egypt used rock phosphate and sulphur (1) and in the Philippines and Honduras lime is still used (3).

For grain treatment, the diatomaceous earth is applied as a dust as the grain is augered into the granary. In the USA, often only the grain surface or the top 10-20% of the grain is treated. This reduces the amount of diatomaceous earth needed to protect the grain mass, hence limiting the negative effects of diatomaceous earth treatment. One solution to the airborne dust problem is to apply the diatomaceous earth in a water suspension. This method of application is widely used in Australia to treat empty structures, but slurry application slightly reduces efficacy. On the farm, it is possible to treat empty granaries by blowing the diatomaceous earth in through the aeration ducts.

Another way to reduce the problems associated with diatomaceous earth is to lower the concentration needed to achieve control. A mixture of diatomaceous earth (90%) and silica gel (10%) doubles the efficacy compared to diatomaceous earth used alone (2).

Diatomaceous earth can be combined with other treatments to increase efficacy. In Australia, diatomaceous earth is used as a top dressing in conjunction with long duration, low dose phosphine fumigation (SiroFlo®). The major limitation of SiroFlo® used alone is that phosphine concentrations are too low to obtain control at the surface of the grain bulk. Diatomaceous earth serves a dual function in providing a physical barrier to retain the phosphine and controlling insects directly. In a similar role, diatomaceous earth is used as a top dressing in conjunction with cooling the grain mass by ambient air or refrigerated aeration.

Postharvest Insect Control with Inert Dusts

Diatomaceous earth can also be used in conjunction with heat to provide a more complete control of stored-product insects in food-processing facilities (2).

LIMITATIONS

Despite the numerous advantages of inert dusts, their use to control stored-product insects remains limited. The main problem with the use of diatomaceous earth is that it reduces grain bulk density and grain fluidity (2, 6). Adding diatomaceous earth at 50 ppm reduces grain bulk density by approximately 2 kg.hL⁻¹ for wheat (5). As bulk density is a grading factor, the addition of diatomaceous earth can reduce the grain grade. Another limitation is that grain must be dry for the diatomaceous earth to cause enough desiccation to control insect populations. Application of inert dusts can be undesirable because of the dust generated. Diatomaceous earth can be used as a mild abrasive, and there is concern over increased wear on grain handling machinery. However, tests need to be conducted to determine if diatomaceous earth does increase the wear on grain handling and milling equipment.

Depending upon the source and processing, diatomaceous earth can contain from 0.1 to 60% crystalline silica. The diatomaceous earths registered as insecticides generally have less than 7% crystalline silica. Crystalline silica has been shown to be carcinogenic if inhaled (8). However, the use of proper dust masks and diatomaceous earths with low crystalline silica can effectively protect against this health risk.

FUTURE OF INERT DUSTS

In the last decade there has been an increase in the use of diatomaceous earth because its low mammalian toxicity responds to the concerns of worker safety, food residues and resistant insect populations associated with the use of chemical insecticides. If the newer formulations can respond to the limitations of diatomaceous earth, there will be an even wider adoption of diatomaceous earth to control stored-product insect pests. We expect that to address the respiratory health concerns associated with crystalline silica, these new formulations will have less than 1% crystalline silica and only a minor fraction of their particles in the respirable range. The diatomaceous earths will come from deposits that have been rigorously tested to insure high efficacy and may be combined with additives to enhance activity.

Resistance to residual insecticides has been one of

the reasons to search for alternatives to chemical insecticides. Laboratory experiments have shown that several stored-product pests can have up to a 2-fold reduction in susceptibility when exposed to diatomaceous earth for 5-7 generations (4). Although there are no reported cases of insects developing resistance to diatomaceous earth in commercial stores, these results suggest that it will be necessary to use resistance management strategies to prevent widespread resistance to diatomaceous earth products.

REFERENCES

1. Ebeling, W. Sorptive dusts for pest control. **1971**, *Ann. Rev. Entomol.* *16*, 123-158.
2. Fields, P.G. Korunic, Z, and Fleurat-Lessard, F. Control of insects in postharvest: Inert dusts and mechanical means. in *Physical control methods in plant protection*, Vincent, C, Panneton, B., Fleurat-Lessard, F., Eds.; Springer-Verlag: Berlin, in press.
3. Golob, P. 1997. Current status and future perspectives for inert dusts for control of stored product insects. **1997**, *J. Stored Prod. Res.* *33*,69-79.
4. Korunic, Z. Diatomaceous earths, a group of natural insecticides. **1998**, *J. Stored Prod. Res.* *34*,87-97.
5. Korunic, Z. Rapid assessment of the insecticidal value of diatomaceous earths without conducting bioassays. **1997**, *J. Stored Prod. Res.* *33*, 219-229.
6. Fields, P.G. Diatomaceous earth: Advantages and limitations. In *Proceedings 7th Int. Working Conf. Stored Products Protection*, Jin Z., Liang Q., Liang Y., Tan X., Guan L., Eds.; Sichuan Publishing House of Science & Technology: Chengdu, 1999; Volume 1, 781-784
7. Fields, P.G.; Korunic, Z. The effect of grain moisture content and temperature on the efficacy of diatomaceous earths from different geographical locations against stored-product beetles. **2000** *J. Stored. Prod. Res.* *36*, 1-13.
8. International Agency for Research on Cancer (IARC) 1997. Silica, some silicates, coal dust and para-aramid fibrils. Volume 68, IARC Working Group on the Evaluation of Carcinogenic Risks to Humans, Lyon, 506