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Evaluation of basalt powder against stored product insects

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Abstract

The insecticidal effect of natural basalt powder on *Tribolium castaneum* was evaluated. Two tests were used to study the insecticidal action of the basalt powder on the stored durum wheat. The coating test followed by the Bioassay test. The coating test of *Tribolium castaneum* adults in 10g of natural basalt powder, for 17 samples at rate of 25 adults per sample and an uncoated control, showed an insecticidal effect of the said powder with mortality rate of 100% for 70 hours of exposure against 5% for the control sample with a homogeneity of the mortality rate for the 17 samples. The bioassay test was carried out on durum wheat, the natural basalt powder was applied as dust at six different doses. The results showed an insecticidal efficacy closely related to the dose and the time of exposure. The 500ppm dose showed insecticidal potential after 12 days of exposure against *Tribolium castaneum* (100% mortality). However, the 300ppm

2 Evaluation of basalt powder against stored product insects

dose showed significant efficacy (100% mortality) against *Tribolium castaneum* after 14 days of exposure. In addition, the doses over than or equal to 75ppm resulted in a significant reduction in the insect population (mortality more than 74% for 14 days of exposure) compared to the control, providing new approach of integrated pest management strategy.

Keywords: basalt powder, *Tribolium castaneum*, Stored grain insects

1 Introduction

In the last 80 years, the story of insect control has been written predominantly by chemists and toxicologists. The stunning successes of the organochlorines, organophosphates, and fumigants in controlling insects in the 1950s led to a dramatic increase in the number and quantity of insecticides used in agriculture. From then 1962, the public, scientists, and the agricultural community began to examine the hidden costs of chemical pesticide control [1]. drastically because of the restrictions imposed by the domestic users, the government, and the importing countries [2, 3]. Some of the constraints to their use are environmental concerns, such as the presence of pesticide residues in food or the adverse effects on non-target organisms but especially the worrying development of insect resistance to the long used protectants, which in addition, cause toxicity problems to the food workers [4]. However, for centuries the grain has been protected from insect infestations by adding some form of powder or dust directly to the grain. These powders have a physical mode of action since they kill insects by desiccation. The theory of the mechanism of action of natural insecticides was developed as early as 1931 when Zacher and Kunike described the “Zacher effect” [5]. They discovered that the action mode of certain powder is primarily through dehydration or desiccation. The body of an insect is covered with a wax layer made up of curricular lipids. These lipids are found on the outermost layer of an insect’s exoskeleton, called its epicuticle, and perform the essential function of limiting water loss from the body and preventing desiccation. The particles powder stick (adsorb) to lipids on the insect’s epicuticle and prevent the lipids from limiting water loss [6, 7]. As a result, the insect loses its body moisture through the damaged spots of its epicuticle and, after some time, dies of desiccation. We distinguish sand, kaolin, paddy husk ash, wood ash, and clays. This group of materials is used commonly by small scale farmers in the developing world as grain protectants. However, a large quantity, above 5% by weight, are required for application to exert an effect [8]. we also talk about diatomaceous earth (or diatomite) which are the fossilized remains of diatoms, composed mainly of amorphous hydrated silica, but also other minerals including aluminum, iron oxide, magnesium, sodium, and lime. These deposits dated mostly from 30 to 80 million years ago [9, 10], are distributed all over the planet and can accumulate in several hundred meters

deep [11]. Diatomaceous earth, therefore, corresponds to a geographical origin, that is to say, a deposit, which contains a set of fossilized species. The properties of diatomaceous earth will depend on the species predominantly present in the original deposit. Various studies on the efficacy of inert dust have been reported. Diatomaceous earth have been used as viable alternatives to conventional pesticides for the control of stored product pests and have been extensively studied against a wide range of insects species [12–19]. Despite the advantages of diatomaceous earth such as low toxicity to mammals [20, 21] and remarkable insecticidal activity [22–25]. Their main limitations are the reduction in the flowability and reduction of the bulk density of grain, ineffective in some situations, discomfort due to air borne dust, health concerns due to crystalline silica [26–29] and reluctance of milling industry to accept grain treated with diatomaceous earth because of its abrasive nature and possible wear to milling machinery [30].

The basalt is a tuff originates from volcanic projections [31]. The basalt is a tuff originates from volcanic projections. These small fragments, that are sometimes observed as blocks or even ashes with black, red, or even dark green color. Basalt is a basic volcanic effusive rock that contains many natural chemical components such as SiO₂ (37.76 to 59.64%), Al₂O₃ (11.77 to 14.32%), CaO (5.57 to 14.75%), MgO (5.37 to 9.15%), Fe₂O₃ (10.1 to 20.93%), K₂O (1.7 to 6.69%), Na₂O (1.4 to 3.34%) and TiO₂ (1.81 to 3.73%) [32]. Its average particle diameter is less than 30 mp. Basalt powder has been used for resistance building against pests and diseases [33, 34]. However, the effectiveness and potential of basalt powder as an insecticide for stored grains are not yet evaluated. Therefore, the purpose of our research is to test the activity of natural basalt powder against *Tribolium castaneum* adults and evaluate the performance of this new product compared to the natural diatomaceous earth and natural zeolite.

2 Materials and Methods

2.1 Description of basalt powder

Basalt is a basic volcanic effusive rock containing natural mineral elements, such as silicium, alumina, potassium, and calcium. Basalt powder was obtained by mechanical grinding of basalt rock. The physical properties and chemical composition of the basalt powder used in this work are summarized in Table 1.

2.2 Test insects

2.2.1 Coating test

This process was carried out using pheromone traps. The adults of the insects were kept for 8 hours to account for the natural mortality of the insects injured during the collection process. When selecting the insects for the coating test healthy and active individuals were kept and lethargic or abnormal individuals were discarded. Eighteen cylindrical vials with a diameter of 10 cm and a height

4 *Evaluation of basalt powder against stored product insects***Table 1** Physical properties and chemical composition of basalt powder

Component	Physical properties and chemical composition
Mean particle diameter $d_p(\mu)$	28.7
Bulk density (kgm^{-3})	1077
Slope angle ($^\circ$)	35.20
(SiO ₂)	49(%)
(Al ₂ O ₃)	20,5(%)
(K ₂ O)	8(%)
(Fe ₂ O ₃)	7,5(%)
(CaO)	7,2(%)
(MgO)	2,8(%)
(Na ₂ O)	2,5(%)

of 15 cm were used to test the effect of the basalt powder on weevil adults. For each vial, 10 g of the basalt powder were distributed over the bottoms of the 17 vials homogeneously, the 18th vial was used as a control. The healthy and active insects was distributed over the 18 bottles at a rate of 20 insects per bottle. In this coating test, the criteria used to classify insects as moribund, or death are the absence of coordinated movement. These observations may include the inability to straighten up if placed on its dorsal surface, lack of coordinated movement when gently pushed with a blunt instrument. If the individual can straighten up but tilt, there is no coordinated movement, the insect should be considered dead. The death rate is calculated by the following equation:

$$MC = \frac{(S_{VT} - S_{VC})}{S_{VT}} 100 \quad (1)$$

With MC is the corrected mortality (%), S_{VT} is the percentage of insects living in the control vial and S_{VC} is the percentage of insects living in the treated vials.

2.2.2 Bioassay test

The Karim variety of untreated Tunisian durum wheat, clean, low in impurities, and without infestation, with an initial moisture content of 13.5% conditioned for 7 days at 28 ± 1 °C and $65 \pm 5\%$ RH was used in the experience. Crude basalt powder was applied to wheat grains in different doses at 50, 75, 100, 200, 300, 400 and 500 ppm (mg/kg). Glass jars were filled with 100 g of clean wheat kernels with the addition of 1% (by weight) of cracked wheat. The dosages already mentioned have been added to the jars. The jars were sealed with the lids and carefully shaken by hand for 30 s in order to have an even distribution of the added basalt and cracked wheat throughout the kernels. Jars with untreated grains served as a control. After the dust had settled, 25 unsexed adults were added to each glass jar. All treatments were repeated four times for each dose of basalt. The same procedure was followed for the untreated wheat which served as a control. The environmental conditions during the bioassay were set at 28 ± 1 °C and $60 \pm 5\%$ RH.

2.2.3 Data analysis

Mortality data for exposed and control adult insects were processed by IBM SPSS Statistics for coating and bioassay testing. A one-way analysis of variance of the tested variables was examined. Tukey's HSD test ($P = 0.05$) was used to detect differences between the means of the examined traits. For the bioassay tests, the data obtained were subjected to probit analysis and the doses LD_{50} and LD_{90} values and their 95% confidence intervals were estimated using IBM SPSS Statistics 22.

3 Results

3.1 Efficacy of coating tested against *Tribolium castaneum* adults

The one-way analysis of variance showed a homogeneous effect of basalt powder on the tested adults of *Tribolium castaneum* (Figure 1). Indeed, the effect of natural basalt powder coating on the tested of *Tribolium castaneum* adults manifests itself after 18 hours of the test with complete control (100% corrected mortality) after 72 hours of coating treatment for the 17 repetitions (Figure 2). However, the mortality rate of the control remains unchanged during the coating period (5% corrected mortality). The coating with the natural basalt

Fig. 1 Mortality mean values of *Tribolium castaneum* adults following the coating test with basalt powder for 17 repetitions (anova1, $p = 0.0024$, $F = 2.29$)

powder showed an important mortality power and highlights the insecticidal nature of the natural basalt powder. The coating test indeed showed a conclusive result as an insecticide however, Bioassay tests are widely used tools for the evaluation of insecticides

6 *Evaluation of basalt powder against stored product insects*

Fig. 2 Mortality mean values of *Tribolium castaneum* adults following the coating test with basalt powder for 17 repetitions (anova1, $p = 0.0024$, $F = 2.29$)

3.2 Efficacy of bioassay tested against *Tribolium castaneum* adults

The basalt powder tested showed an insecticidal effect on the tested *Tribolium castaneum* adults. Indeed, the 400ppm dose presents complete control (100% mortality) observed and applied after 12 days of exposure and the 300ppm dose presents a complete control for 14 days of exposure. In general, adult mortality is proportional to the exposure duration and treatment dose. Indeed, the mortality rate increases gradually as a function of the dose and the number of exposure days (Table 3). Nevertheless, 10 days after treatment, adult mortality was notably high for the 300, 400, and 500ppm doses (was still above 74%). According to Vayias and Athanassiou (2004) [35] For *Tribolium castaneum* adults one week of permanent contact at 32 °C with the grain treated only results in about 85% mortality, and extending this period to two weeks does not allow average mortality to exceed 95%, even at the highest dose of 1.5 g/Kg. However, the estimated lethal dose (LD_{90}) for natural basalt powder is 124.3ppm (0.12g/kg) against *Tribolium castaneum* adults for two weeks of treatment (Table 2).

Table 2 Lethal doses LD_{50} and LD_{90} of tested basalt, diatomaceous and Zeolite earth toward *Tribolium castaneum* adults. ($P = 0.05$)

Powdres	Estimate LD_{50}/LD_{90}	Lower Bound (LD_{50}/LD_{90})	Upper Bound (LD_{50}/LD_{90})
Basalt	34.12/124.3	54.74/298.42	14.4/87.26
Diatomaceous	75.4/105.6	-69.4/98.3	80.9/116.2 [36]
Nano zeolite	74.78/-[37]	-	-

4 Discussion

Inert dust are a promising alternative to conventional chemical insecticides and have been widely studied and used in practice due to their low toxicity to mammals and little or no effect on quality products treated with commercially applicable concentrations [17, 38]. Since there is no report or published work on natural basalt powder, in this work the evaluation and performance discussion of this powder as an insecticide was based on comparison with natural diatomaceous earth dust and Zeolite powder against *Tribolium castaneum* adult.

Insects die when they have lost approximately 60% of their water or about 30% of their weight [6]. It is therefore vital for them to maintain their water balance, which they do mainly thanks to the outermost part of their exoskeleton, the cuticle, made up of fatty substances (hydrophobic). Basalt powder works through the silicon dioxide it contains. This chemically inert compound is caused by abrasion of the cuticle and digestive tract [39, 40], by obstruction of the spiracles (respiratory openings) [40] and by adsorption of fatty substances. During their movement, insects come into contact with the product, making their cuticle permeable to water exchange [17]. The insects, therefore, die by desiccation. Previous studies with powders similar to basalt powder

Table 3 Mean mortality ($\pm$ SD %) of *Tribolium castaneum* adults after 2, 4, 6, 8, 10, 12 and 14 days of exposure to treated wheat grains with tested basalt powder ($P = 0.05$)

Dose (ppm)	2d	4d	6d	8d	10d	12d	14d
0	1.3 $\pm$ 1.3	6.6 $\pm$ 1.3	12.0 $\pm$ 4.0	6.0 $\pm$ 4.0	18.6 $\pm$ 5.8	24.0 $\pm$ 6.1	26.6 $\pm$ 0.5
50	0.0 $\pm$ 0.0	5.3 $\pm$ 1.3	13.3 $\pm$ 1.3	20.0 $\pm$ 2.3	24.0 $\pm$ 6.1	29.3 $\pm$ 4.8	33.3 $\pm$ 1.3
75	0.0 $\pm$ 0.0	17.3 $\pm$ 7.4	33.3 $\pm$ 8.1	41.3 $\pm$ 7.4	49.3 $\pm$ 7.4	64.0 $\pm$ 12.8	74.6 $\pm$ 6.6
100	0.0 $\pm$ 0.0	10.6 $\pm$ 5.3	29.3 $\pm$ 0.9	41.3 $\pm$ 5.3	61.3 $\pm$ 10.4	81.3 $\pm$ 1.3	88.0 $\pm$ 2.3
200	0.0 $\pm$ 0.0	18.6 $\pm$ 5.8	38.6 $\pm$ 17.3	52.0 $\pm$ 10.5	69.3 $\pm$ 9.3	77.3 $\pm$ 7.4	80.0 $\pm$ 6.1
300	0.0 $\pm$ 0.0	22.6 $\pm$ 2.6	38.6 $\pm$ 2.6	57.3 $\pm$ 9.6	70.6 $\pm$ 8.0	74.6 $\pm$ 13.5	100 $\pm$ 3.5
400	0.0 $\pm$ 0.0	22.6 $\pm$ 2.6	38.6 $\pm$ 2.6	57.3 $\pm$ 9.6	70.6 $\pm$ 8.0	74.6 $\pm$ 13.5	100 $\pm$ 3.5
500	1.3 $\pm$ 1.3	30.6 $\pm$ 8.7	56.0 $\pm$ 12.0	69.3 $\pm$ 11.6	84.0 $\pm$ 8.3	100 $\pm$ 3.5	100 $\pm$ 1.3
F	0.85	3.80	3.52	7.74	12.28	15.01	62.82
P	0.041	0.013	0.017	0.00	0.00	0.00	0.00

and with several formulations have indicated that adults of *Tribolium castaneum* are among the most tolerant species. The adults of *Tribolium castaneum* are among the most tolerant of diatomaceous earth [41–45]. Rumbos and all (2006) [46] have also shown that adults of *Tribolium castaneum* are among the most tolerant species for zeolite powder formulations.

Adult mortality of *Tribolium castaneum* was significantly affected by the exposure interval and natural basalt powder. In fact, for wheat treated at 500ppm, mortality attains 100% for 12 days of exposure, while the 300ppm dose is typical for an exposure period exceeding 12 days (Table 3). These results indicate the importance an effectiveness of the new insecticide product (natural basalt

powder) against *Tribolium castaneum* the most resistant space for powders similar to basalt (diatomaceous earth and zeolite). Our results also indicate the importance of the new insecticide product in terms of efficacy compared to all zeolite formulations on wheat. Indeed, the experiments with all the zeolite formulations have shown a mortality rate which rate that does not exceed 25%, even after 21 days of exposure with doses of 500ppm and 1000ppm [46]. The results found with the use of basalt powder as an insecticide against *Tribolium castaneum* adults show very good performance in terms of dose and exposure time compared to the use of diatomaceous earth. Indeed, Vayias and Athanassiou (2004) [35] studied the effectiveness of SilicoSec® (diatomaceous earth formulation) against larvae and adults of Brown Tribolium at several temperatures, water contents (11% and 13%), and doses during treatment on soft wheat. It has been shown for adults a week of permanent contact at 32 °C with the treated grain only results in about 85% mortality and extending this period to two weeks does not allow average mortality to exceed 95%, even at the highest dose of 1.5g/Kg. Generally, it has been shown that diatomaceous earth applied at rates 0.75g/kg and Natural zeolite applied at a rate of 1 g/kg showed high insecticidal potential against [38]. The results presented in this study confirm the insecticidal power of basalt powder for the most resistant insect space (*Tribolium castaneum*) and indicate that the dose of 0.3g/kg is typical for the total control of *Tribolium castaneum* for 14 days of exposure, that is to say, a difference of 0.45g/kg compared to natural diatomaceous earth and a difference of 0.7g/kg compared to natural zeolites.

5 Conclusion

The results presented in this work show that basalt powder has a significant insecticidal power. The 300 ppm dose is typical for the control of *Tribolium castaneum* for an exposure period of 14 days. Despite the use of various commercial inert dust products in current stored-product pest management programs, detection of new deposits of natural inert dust and evaluation of their insecticidal activity is beneficial for the ecosystem storage . However, before introducing a new product regarding placing on the market, regulatory approval by Regulation (EC) No 1107/2009 should be obtained. Testing is required to determine if the new product effect on non-target organisms, human health and operator exposure as well as environmental safety and efficacy on the target organisms.

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Declarations

There is no conflict of interest for each contributing author.

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