SORPTIVE COATINGS AS PROTECTANTS AGAINST STORED-PRODUCT PESTS[1]

J. G. Rodriguez, M. F. Potts, and C. G. Patterson
University of Kentucky, Lexington, KY U.S.A.

The behavior of stored product insects crawling among grain kernels and in the food substrate generally makes these insects quite susceptible to the effects of dust coatings on the kernels. It has been shown that abrasive powders (nonsorptive) provide some measure of protection, but the most efficient have been the nonabrasive powders because it is these sorptive dusts that have proven to be the most desiccating to the insect. Diatomaceous earth, for example, is both abrasive and sorptive, but it is inferior to nonabrasive silica gels for protection of beans, corn, and wheat against various species of grain-infesting beetles (Parkin and Bills, 1955; Quinlan and Berndt, 1966; Redlinger and Womack, 1966; and LaHue, 1970).

The protection of grain has understandably received the most attention, but there are other areas in stored product research that also constitute an important segment of the food industry, namely, those processed foods that are contained in boxes or are shipped in cardboard boxes. The insect, in order to infest these foods, is prone to crawl along the cardboard surface, thus "sponging up" dust particles which stick to the protective film of the cuticle.

The food industry has developed certain technologies which if extended further possibly would have application in pest management of certain stored product insects. Such is the case of silica-gel technology where a number of synthetic silicas are availabe for a wide range of applications. The Syloid® silicas, for example, are used as anticaking agents, as carriers for flavors/oils, as thickening agents, as protectants against moisture and as dispersants for powders. They are micron-sized forms of synthetic amorphous silica - odorless, tasteless, non-toxic and chemically inert. Silica gel is made by mixing pre-determined concentrations of an acid and a soluble silicate. The resulting hydrogel is allowed to set, and is washed, dried, milled and sized using special techniques to develop controlled particle size.

Some other agents used in the food and paper industry are starch based. Some are used to provide finishes for paper and cardboard, others to provide friction so as to facilitate stacking, palletizing, etc.

Our objectives were to examine selected newer formulations of silica gels, and starch and compare these with other inert materials for use as coatings on cardboard and evaluate their efficacy as desiccants on a number of common stored product insects. A concomitant objective was to gain an insight into the amount of water loss elicited by the most sorptive material found.

---

[1]The investigation reported in this paper (No. 83-7-201) is in connection with a project of the Kentucky Agricultural Experiment Station and is published with approval of the Director.

Materials and Methods

Six materials with possible sorptive qualities were tested as dust coatings on commcercial corrugated cardboard. The specified particle size and source of the materials were as follows:

Syloid® 244, 3μ,	W.R. Grace & Co.
Syloid® 63, 9μ,	W.R. Grace & Co.
Tricalcium phosphate, 200μ (tribasic calcium phosphate)	Fisher Scientific Co.
Talc (T-4), 40μ	Fisher Scientific Co.
Bentonite (B-235), 44μ	Fisher Scientific Co.
Oxy-Dry C®, 20μ,	Oxy-Dry Corp.

Applications were made by weighing the materials to give a calculated low rate of 0.01 mg/cm² when spread evenly on cardboard and a high rate of 0.08 mg/cm². The powders were spread evenly with the aid of fine plastic mesh disk to the surfaces of cardboard circles cut to fit tightly in 100-mm petri dishes, the sides of which had been coated with Teflon® (DuPont Co.) to restrict the insects inside the dish. The cardboard was single wall construction with a bursting strength of 200 lb/in.², (Champion International Corp., Container Division, Keokuk, IA). The insects tested were the red flour beetle, Tribolium castaneum (Herbst); confused flour beetle, T. confusum Jacquelin duVal; sawtoothed grain beetle, Oryzaephilus surinamensis (L.); cigarette beetle, Lasioderma serricorne (Fabricus); Indian meal moth, Plodia interpunctella (Hübner); and coffee bean weevil, Araecerus fasiculatus (DeGeer). Only larvae of Indian meal moth and adults of confused flour beetle and coffee bean weevil were tested. Tests were conducted under standardized conditions of 26°C, 60% R.H., and 16 hr light, with observations made at 16, 24, and 48 hr. Each treatment consisted of 4 replicates of 25 unsexed individuals each and the experiment was repeated.

In a related experiment, coffee bean weevil adults, and full grown larvae of the red flour beetle and Indian meal moth were exposed to Syloid 244 coatings at the high rate (0.08 mg/cm²) for a period of 24 hours. Weights were taken of 5 groups of the insects, 10 individuals per group, before and after 24 hours elapsed time. Scanning electron micrographs were taken of insects exposed to the various materials.

Results and Discussion

The difference among the sorptive coatings was dramatic. Outstanding in relative efficacy was Syloid 244. The high surface area and controlled pore volume characteristics of this micronized silica were the apparent factors in establishing that material as superior to the others tested. Since it is highly water and oil absorbent, the evidence points to severe disiccation as the cause of mortality of the insects exposed to those coatings. The insect epicuticular lipid complex consists of hydrocarbons, wax acids, esters, alcohols, diols and possibly other constituents such as aldehydes and phospholipids, all of which vary greatly, qualitatively and quantitatively, among species of insects (Ebeling, 1971). The complex feature of the cuticle lipid became evident as viewed from the wide range of effects obtained from the dust exposures to the various species.

The red flour beetle adult was relatively resistant to desiccation by all coatings, as shown in Table 1. The larvae were susceptible only to Syloid 244. The confused flour beetle was even more resistant (Table 2). The sawtoothed grain beetle, on the other hand, was comparatively susceptible to Syloid 244, with 99% of adults and 100% of larvae killed within 16 hours when exposed to coatings at 0.08 mg/cm². The effects were almost equally efficient at the lower rate, 0.01 mg/cm². Larvae were not so easilty killed at the low rate. The results also showed that tricalcium phosphate and talc were moderately effective but with a 48 hour exposure (Table 3). Cigarette beetle adults and larvae were easily killed by Syloid 244 exposure for 24 hours at 0.08 mg/cm², but only moderately effective at the lower level. None of the other materials demonstrated any effectiveness (Table 4).

Indian meal moth larvae (full grown) also were quite susceptible to 0.08 mb/cm² coatings of Syloid 244, and were moderately susceptible to the lower levels (Table 5).

The most susceptible adult tested was the coffee bean weevil. Exposure of adults to Syloid 244 coatings at both low and high levels for 16 hours caused 98 and 100% mortality. Syloid 63 was moderately effective and tricalcium phosphate was effective only at 0.08 mg/cm² (Table 6).

The small size of the insect, and long slender appendages, provide a great surface area as compared to the unit volume. The large evaporative area makes the insect/arthropod very susceptible to water loss and lethal desiccation. These arthropods are protected from a lethal rate of water loss only by the lipid film on the cuticle, which is only about 0.25 in thickness (Beament, 1945). The manufacturer of Syloid 244 specifies that it has a particle size of 3μ, and is capable of absorbing 2.8 pounds of oil/water per pound of material compared to approximately 0.6 pounds absorbed by Syloid 63, which has an average particle size of 9 microns. These physical characteristics apparently played an important role in the comparative effectiveness of Syloid 244 as a lethal desiccant when the insect was exposed to such coatings. The water loss of selected insects to Syloid 244 exposure is given in Table 7. Average water losses of 54.9 and 43.8 percent of original body weight were incurred by coffee bean weevil and red flour beetle adults while Indian meal moth larvae lost an average of 70.3 percent. Mortality in the treated insects was comparable to the previous tests described at the end of 24 hours. No mortality occurred in the untreated controls.

Scanning electron micrographs (SEM's) of larvae exposed to Syloid 244 coating at 0.08 mg/cm² showed variable densities of dust on the cuticle (Figs. 1-4), apparently reflecting differences in cuticular topography and chemistry of the lipid film. (Oxy-Dry C, a microencapsulated starch, has a particle that is about 7x as large as the Syloid 244 particle. SEM's show a considerable difference in adherence characteristics (Figs. 5 and 6). Oxy-Dry C exposure generally did not demonstrate lethality to the insects.

References

Beament, J. W. L. 1945. The cuticular lipids of insects. J. Exp. Biol. 21: 115-38.

Ebeling, Walter. 1971. Sorptive dusts for pest control. Ann. Rev. Entomol. 16: 123-58.

LaHue, D. W. 1970. Evaluation of malathion, diazinon, a silica aerogel, and a diatomaceous earth as protectants on wheat against lesser grain borer attack in small bins. U.S. Dept. Agr. ARS Market Res. Rep. No. 860, 11 pp.

Parkin, E. A., Bills, G. T. 1955. Insecticidal dusts for the protection of stored peas and beans against bruchid infestation. Bull. Entomol. Res. 46: 625-41.

Quinlan, J. K., Berndt, W. L. 1966. Evaluation in Illinois of four inert dusts on stored shelled corn for protection against insects - a progress report. U.S. Dept. Agr., Agr. Res. Serv. 51-56, 20 pp.

Redlinger, L. M., Womack, H. 1966. Evaluation of four inert dusts for the protection of shelled corn in Georgia from insect attack. U.S. Dept. Agr., Agr. Res. Serv. 51-57, 25 pp.

Table 1. Effect of sorptive dust coatings at 0.08 mg/cm^2 on cardboard on Tribolium castaneum: Percent mortality in 200 adults and larvae.

	Hours after treatment					
	Adults			Larvae		
Sorptive material	16	24	48	16	24	48
Syloid 244	4	13	70	75	88	100
Syloid 63	0	0	1	0	0	3
Tricalcium phosphate	0	0	0	0	0	5
Bentonite	0	0	0	0	0	3
Talc	0	0	0	7	8	10
Oxy-Dry C	0	0	0	0	3	7
Control	0	0	0	0	0	3

Table 2. Effect of sorptive dust coatings at 0.08 mg/cm^2 on cardboard on Tribolium confusum: Percent mortality in 200 adults.

	Hours after treatment		
Sorptive material	16	24	48
Syloid 244	4	5	7
Syloid 63	2	2	3
Tricalcium phosphate	1	2	3
Bentonite	0	0	0
Talc	0	0	0
Oxy-Dry C	0	0	0
Control	0	0	0

Table 3. Effect of sorptive dust coatings on cardboard on Oryzaephilus surinamensis: Percent mortality in 200 adults and larvae.

Sorptive material and rate (mg/cm^2)	Hrs after treatment					
	Adults			Larvae		
	16	24	48	16	24	48
Syloid 244						
0.08	99	100	---	100	--	--
0.01	70	99	100	24	34	87
Syloid 63						
0.08	3	7	33	1	12	23
0.01	4	7	22	---	--	--
Tricalcium phosphate						
0.08	2	20	72	0	11	20
0.01	0	1	8	---	--	--
Bentonite						
0.08	5	14	44	1	2	3
0.01	0	1	5	---	--	--
Talc						
0.08	2	20	72	0	1	6
0.01	0	0	3	---	--	--
Oxy-Dry C						
0.08	2	5	15	0	2	3
0.01	0	0	0	---	--	--
Contol	0	0	0	0	0	3

Table 4. Effect of sorptive dust coatings at 0.08 mg/cm^2 (and 0.01 mg/cm^2 where noted) on cardboard on Lasioderma serricorne: Percent mortality in 200 adults and larvae.

Sorptive material	Hrs after treatment					
	Adults			Larvae		
	16	24	48	16	24	48
Syloid 244	92	97	100	73	100	--
(0.01 mg/cm^2)	27	47	79	23	38	70
Syloid 63	1	2	8	3	11	33
(0.01 mg/cm^2)	--	--	---	5	6	10
Tricalcium phophate	12	19	48	3	4	28
Bentonite	1	2	7	0	0	3
Talc	1	1	7	1	4	7
Oxy-Dry C	7	7	15	0	0	7
Control	0	0	3	0	0	1

Table 5. Effect of sorptive dust coatings at 0.08 mg/cm² (except where noted) on *Plodia interpunctella*: Percent mortality in 200 larvae.

	Hours after treatment		
Sorptive material	16	24	48
Syloid 244	98	100	--
(0.01 mg/cm²)	55	69	89
Syloid 63	2	3	7
Tricalcium phosphate	0	0	0
Bentonite	3	5	7
Talc	3	4	7
Oxy-Dry C	0	1	2
Control	0	0	1

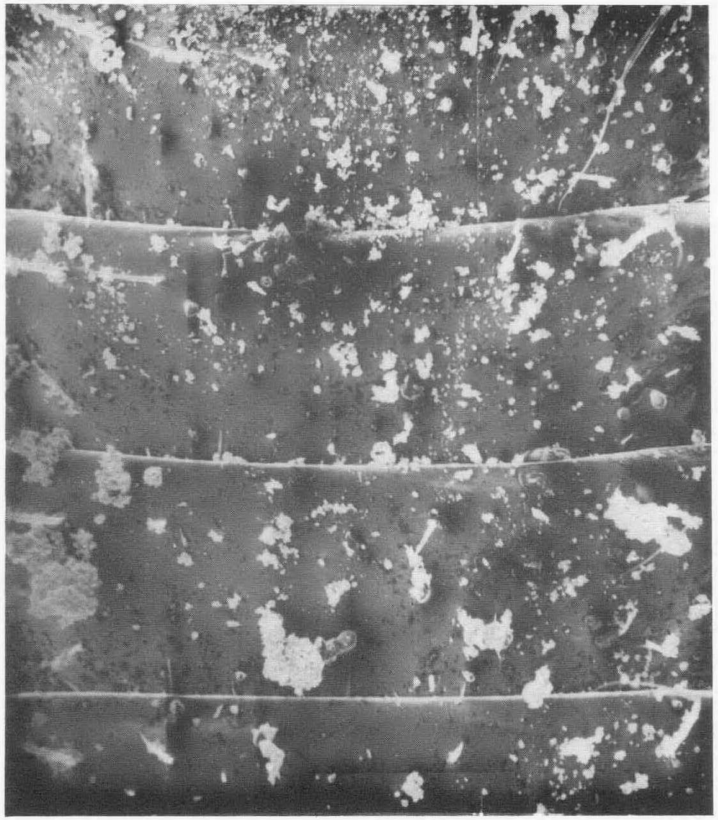
Table 6. Effect of sorptive dust coatings on cardboard on *Araecerus fasiculatus*: Percent mortality in 200 adults.

	Hours after treatment		
Sorptive material and rate (mg/cm²)	16	24	48
Syloid 244			
0.08	100	---	--
0.01	98	100	--
Syloid 63			
0.08	20	27	75
0.01	0	6	17
Tricalcium phosphate			
0.08	86	100	--
0.01	7	10	18
Bentonite			
0.08	2	6	13
0.01	---	---	--
Talc			
0.08	10	12	31
0.01	7	10	18
Oxy-Dry C			
0.08	5	12	26
0.01	0	0	0
Control	0	0	0

Table 7. Loss of body weight after 24 hour exposure to Syloid 244 coating (0.08) mg/cm²) on cardboard. Mean, 5 groups of 10 insects each.

Species	Initial fresh wt (mg)	Wt after 24 hr (mg)	Percent water loss
Araecerus fasiculatus adults			
Syloid	46.1	18.7	54.9
Control	45.2	42.8	4.9
Tribolium castaneum larvae			
Syloid	24.6	17.3	43.8
Control	31.1	28.9	7.0
Plodia interpunctella larvae			
Syloid	84.2	25.0	70.3
Control	80.4	54.8	34.0

1



2

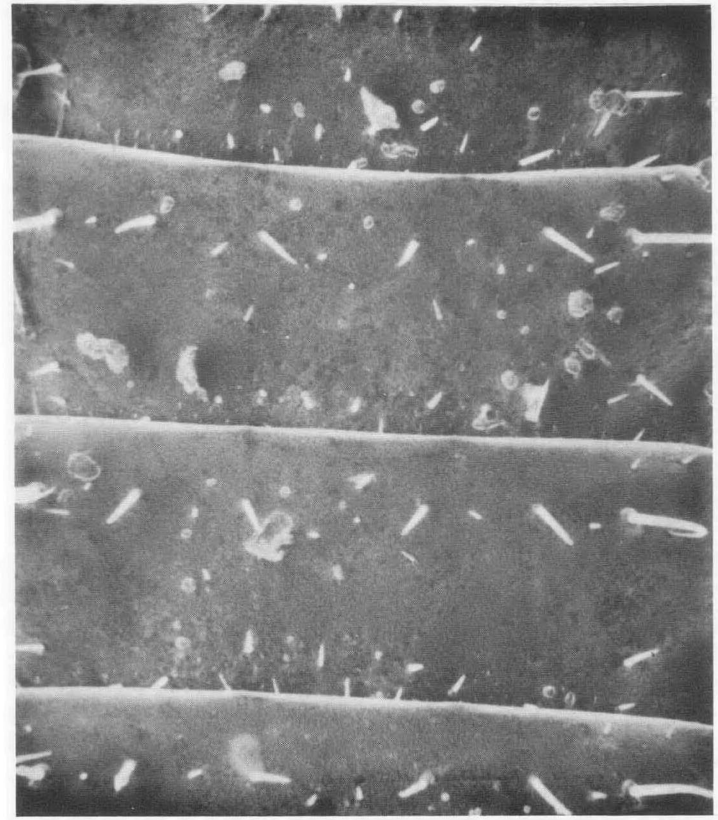


Fig. 1. SEM (220x, ventral view) of full grown larva of sawtoothed grain beetle exposed to Syloid 244 at 0.08 mg/cm^2 for 24 hr.

Fig. 2. SEM counterpart of Fig. 1, i.e., larya not exposed to Syloid 244 coating.

3

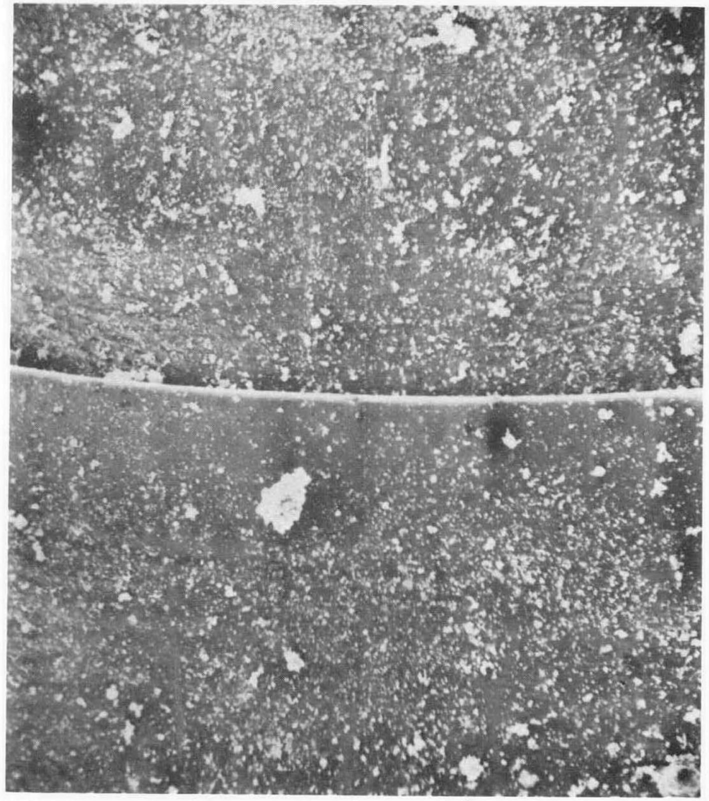


Fig. 3. SEM (220x, ventral view) of full grown larva of red flour beetle exposed to Syloid 244 at 0.08 mg/cm^2 for 24 hr.

4

Fig. 4. SEM counterpart of Fig. 3, i.e., larva not exposed to Syloid 244 coating.

5

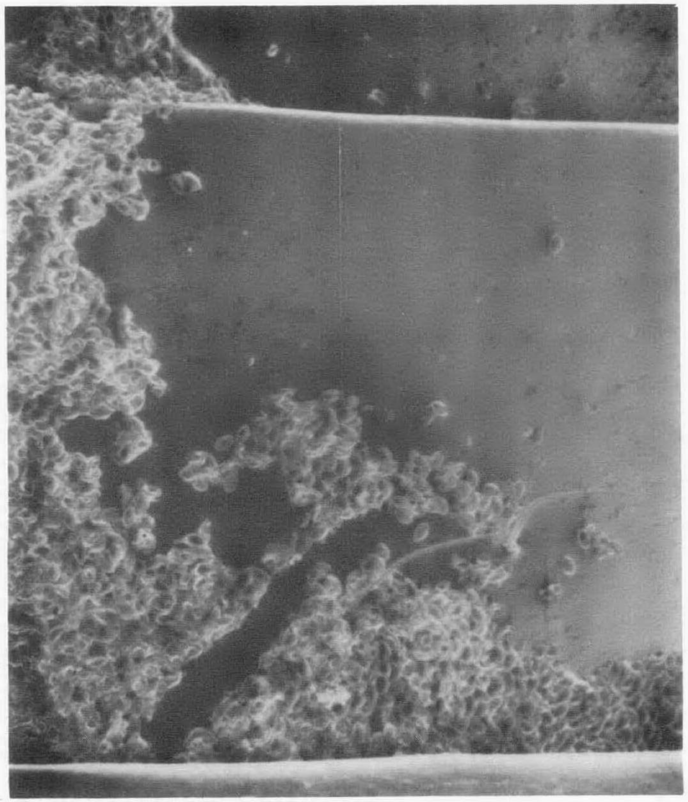


Fig. 5. SEM (220x, ventral view) of full grown larva of red flour beetle exposed to Oxy-Dry C at 0.08 mg/cm^2 for 24 hr.

6

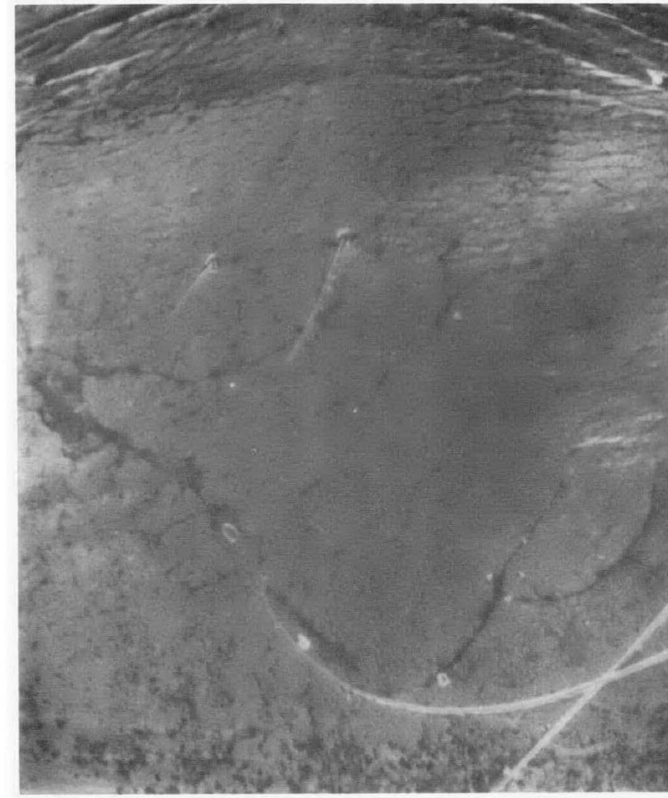


Fig. 6. SEM counterpart of Fig. 5, i.e., larva not exposed to Oxy-Dry C coating.