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Reducing Grain Dust with Oil Additives

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ABSTRACT

WHEAT and corn were treated with 0.04 percent Durkex 500 oil and 0.02 and 0.06 percent mineral oil, each with and without added malathion, to reduce grain dust emission during handling and prevent insect attack during storage. A sample without additives served as control. After applying the additives, the grain was conveyed immediately in a small elevator leg and the amount of dust generated was measured. All samples were stored at ambient temperature (15 to 25 °C) and the dustiness measured after 1, 3, 6, 9, and 12 months of storage. Dust generation during handling of the grain was drastically reduced by as little as 0.02 percent added oil, however, the effect diminished after 1 month of storage for Durkex 500 oil and 6 months of storage for mineral oil. The application of malathion in combination with Durkex 500 oil or mineral oil did not affect the effectiveness or persistence of malathion on treated wheat or corn. Treatments of oil and malathion had functional (milling and breadmaking) properties of wheat samples after 1, 3, 6, 9, and 12 months of storage. Hydrolytic and oxidative rancidity did not appear to be a problem.

Control of the grain dust emitted during grain handling is badly needed to improve air quality and industrial safety. Unfortunately, cost-effective control measures for dust have yet to be established. Although separation of dust from dust-laden air by bag filters, electronic precipitators, and cyclone collectors (Brown and Reed, 1926; Martin and Stephens, 1977), can be effective, the costs of installation, operation, and maintenance for such equipment are expensive. This type of dust control allows explosible mixtures to occur. Moreover, the energy required by current methods of removing dust from dusty air may exceed the energy required to move the grain.

The problem of dust control can also be approached by prevention of dust emission. There are two broad categories of methods to prevent emission — (a) application of additives to grain and (b) use of mechanical devices. (This paper deals with the first category; the second category will be discussed in another paper.) Water, because of its ease in application and low cost, is the obvious additive for use in preventing dust generation. Lai et al. (1979) found that water applied under specified conditions did not appreciably increase the moisture content of grain and no spoilage was seen after storage for 1 year. However, water evaporates easily and must be added every time grain is handled.

Several kinds of additives merit consideration for use in reducing dust emission. Both animal and vegetable fats and oils are nutritious, but most are subject to oxidative and/or hydrolytic rancidity. In tests of pregelatinized cornstarch (Hubinger Co., Keokuk, IA) and heated cornstarch paste (Corn Products, North Kansas City, MO) at the U.S. Grain Marketing Research Laboratory (USGMRL), application was tedious, the resulting starch film did not remain attached to the grain, and a relative large quantity (5 percent) of starch was needed to coat the grain surface. Guar gum (Henkel, Minneapolis, MN) and molasses were not suitable because of their expense and the difficulty of application. Grain treated with molasses became sticky and lost its free flowing property. Cocke et al. (1978) found that dust levels in wheat were reduced more than 92 percent by treatment with a hydrocarbon-based oil at levels as low as 0.07 percent. They also found that the dust levels were reduced when the additive was applied to shelled corn and soybeans.

The objectives of this study were to (a) determine if edible oil can control dust emission, (b) determine the amount of oil needed to prevent dust formation, (c) measure the effectiveness of oil treatment after long periods of storage, (d) investigate the effect of oil and oil-malathion treatments on grain quality, (e) confirm the compatibility and biological effectiveness of oil-malathion mixtures and (f) determine the cost of an effective concentration of oil.

MATERIALS

Grain

Commercial wheat of unknown origin was obtained from the Commodity Credit Corporation; it had a moisture content of 9.9 percent and a test weight and a test weight of 62.8 lb/bu. It was graded No. 1 Hard Red Winter wheat. Number 1 yellow dent corn from the 1974 crop was dried with natural air to 12.5 percent moisture content; its test weight ws 58.3 lb/bu.

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Mention of firm names or trade product does not constitute endorsement by the U.S. Department of Agriculture over others of a similar nature not mentioned.

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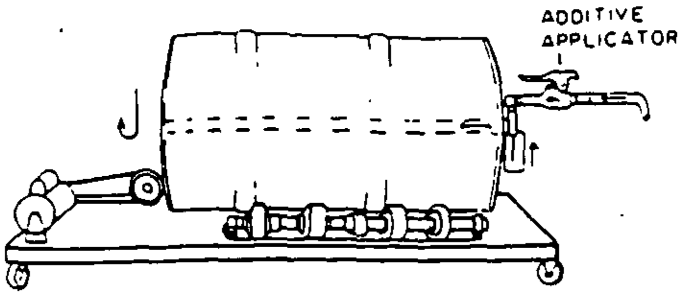

FIG. 1. Rotating drum mixer for applying additives.

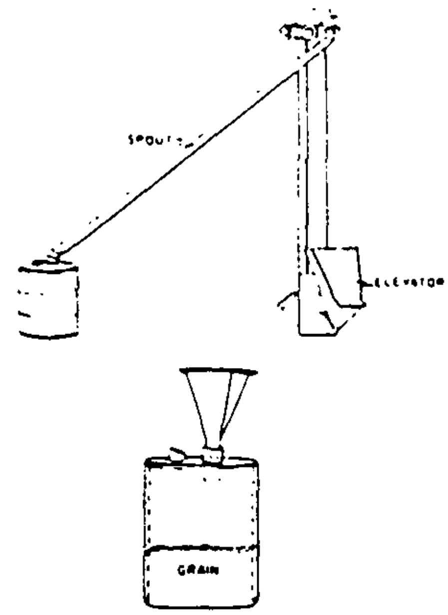

FIG. 2 Experimental grain handling system.

Additives

Durkex 500 oil was selected because it is one of the most stable fluid vegetable oils (AOM stability of 350 h). Durkex 500 oil was obtained from Durkee, Inc. (Joliet, IL). Carnation mineral oil, which is not subject to either hydrolytic or oxidative rancidity, was obtained from Witco Chemical Corp. (Petrolia, PA). Technical grade 95 percent malathion was obtained from the American Cyanamid Co. (Agricultural Division, Princeton, NJ).

METHODS

Two series of tests were conducted. Series I consisted of four replicated treatments of 120-pound lots of wheat and corn: malathion + water, malathion + 0.04 percent Durkex 500 oil, and a control with no additives. Series II consisted of six replicated treatments of 120-pound lots of wheat and corn: malathion + water, malathion + 0.02 percent mineral oil, malathion + 0.06 percent mineral oil, 0.02 percent mineral oil, 0.06 percent mineral oil, and a control with no additives.

Application of Malathion

Malathion sprays were prepared by mixing malathion with oil or water so that it could be applied at a dosage of 10 ppm malathion in 2 to 5 gal of fluid per 1,000 bu (depending on the volume of water or oil applied).

Application of Additives

All additives were applied with a siphon-type spray nozzle to deliver a fine spray through a hole in the center of a rotating drum (Fig. 1). All lots were rotated for 10 minutes, then transferred to a Universal mini grain elevator (Horst Co., Cedar Falls, IA) (Fig. 2). The grain was elevated 4.6 m (~15.5 ft) and returned via a spout 6 m (18 ft) long and 10 cm (4 in.) in diameter to 55-gal barrels. Grain flow rate was approximately 100 lb/min.

For each lot of grain, we tested: dustiness of the grain, milling and baking quality (wheat only), amount of rancidity (wheat only), bioassays, and malathion residue analyses.

Dust Measurement

Dust in the free space above the grain in the barrel (Fig. 2) was sampled immediately after treatment, and 1, 3, 6, 9, and 12 months after treatment for 2 min by a Hi-volume air sampler (UNICO 500, National Environmental Instruments, Inc., Fall River, MA), operated at a setting of 50. The airflow rate of 28 cu ft/min was checked with a 10-hole plate and a calibrated orifice. Dustiness was measured in grams of dust collected per gram of grain handled. After handling, the grain was stored in steel barrels at room temperature (15 to 25 °C).

Particle Size Analysis

The dust collected during the handling for each treatment was removed from the Hi-volume filters. We then measured the particle size distribution of each dust sample according to the sedimentation method developed by Whitby (1955), using equipment manufactured by Mine Safety Appliance Co. This method involves centrifuging a suspension of dust in a liquid at increasing speeds and noting the height of the resulting sediment column. Centrifuging was continued until all particles were settled. The dust was dispersed in naphtha and added on top of the sedimentation liquid, benzene. We assumed that dust samples had a density of 1.48 g/cc.

Milling and Baking Tests

Milling and baking tests were conducted on 5 pounds of wheat sampled from each wheat lot.

Samples of wheat were cleaned in the Carter dockage tester, mixed with a Gamet precision divider, and subsampled for chemical analysis and milling. Test weights were determined on the subsamples used for milling. The samples were tempered to 15 percent moisture 24 h before milling on the Allis experimental mill at the USGMRL. The process involved 4 breaks, 1 sizing, 2 tailings, and 9 middlings rolls. Weights of the coarse plus fine, bran, shorts, red dog, and combined flour streams were recorded. The flours were blended for 5 min, and a subsample was taken for chemical analysis prior to baking. Yields were determined by dividing weight of flour by weight of total products.

The baking procedure of Finney and Barmore (1943; 1945a; 1945b) and Finney (1945) for 100-g flour (14 percent moisture basis) was used except that *l*-ascorbic acid (50 ppm) was used as an oxidant.

Rancidity Measurements

Lipid was extracted from the whole grain with petroleum ether. First we placed 700 g of grain into a beaker and added petroleum ether to cover the grain. stirred the sample for about 1 min, then let it stand 5-10 min; then we filtered off the ether through No. 1 Whatman filter paper, evaporated the ether on a steam bath, and repeated the procedure until at least 20 g of fat

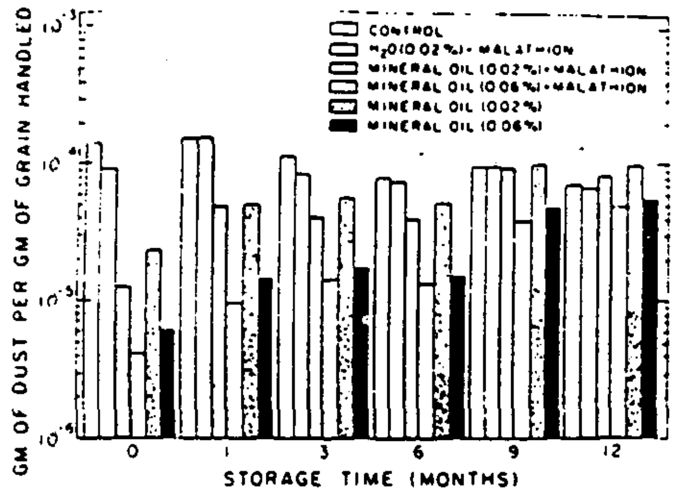

FIG. 5 The effects of storage on dust emission from corn treated with mineral oil.

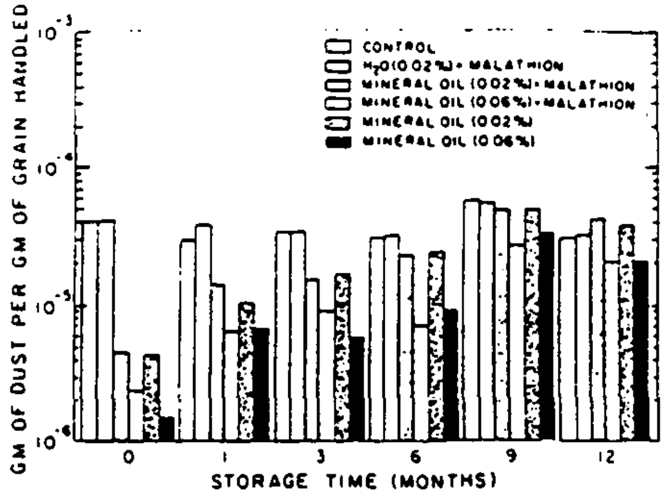

FIG. 6 The effects of storage on dust emission from wheat treated with mineral oil.

ferences among the four treatments.

The immediate effect of treatment of wheat with 0.04 percent Durkex 500 oil without malathion was a reduction in dustiness to 5.4 percent of that for the control (Fig. 4). The effect of Durkex 500 oil in preventing dust emission from wheat was lost after 1 mo of storage.

In the second series of tests, the effects of treatment with mineral oil on dustiness of corn were significant (Table 1 and Fig. 5). Dust emitted from corn immediately after treatment with 0.06 percent mineral oil was reduced to 4.4 percent of that for the control. The effect of water was less significant and was lost after 1 mo of storage. After 6 mo of storage, treatment with 0.06 percent mineral oil was still effective in reducing dust emission. Corn stored for 1 yr after treatment with 0.006 percent mineral oil exhibited dust emission at least half that of the control. The effects of treatment with mineral oil on dustiness of wheat were similar to those for corn (Fig. 6).

The application rate of oil had a significant effect on reduction of dust emission. Treatment with 0.06 percent mineral oil resulted in greater reduction of dust emission than did treatment with 0.02 percent mineral oil (Table 1). The upper limit of mineral oil is dictated by the cost and by the maximum allowable concentration of 0.15 percent of mineral oil in bakery products (Code of Federal Regulations, 1979). Mineral oil is used as a lubricant in a bakery when dividing the dough prior to baking into bread.

TABLE 2. AVERAGE PARTICLE SIZE OF DUST PARTICLES EMITTED BY GRAIN TREATED WITH OIL AND OIL WITH 10 PPM MALATHION

Treatment	Average particle size, µm				
	0	1 mo	3 mo	6 mo	12 mo
Corn					
Control	17	16	16	12	12
Water (0.04%) + malathion	15	15	14	12	11
Durkex 500 oil (0.04%) + malathion	30	19	18	13	12
Durkex 500 oil (0.04%)	32	19	19	14	12
Control	15	15	14	11	10
Water (0.04%) + malathion	16	14	12	11	10
Mineral oil (0.02%) + malathion	21	18	15	14	10
Mineral oil (0.02%)	22	17	15	11	9
Mineral oil (0.06%) + malathion	20	21	18	15	12
Mineral oil (0.06%)	24	23	18	14	11
Wheat					
Control	14	12	10	11	11
Water (0.04%) + malathion	16	13	11	12	12
Durkex 500 oil (0.04%) + malathion	22	19	15	11	11
Durkex 500 oil (0.04%)	22	17	15	11	11
Control	15	12	10	10	8
Water (0.04%) + malathion	13	11	10	9	10
Mineral oil (0.02%) + malathion	22	21	16	14	10
Mineral oil (0.02%)	21	16	18	13	10
Mineral oil (0.06%) + malathion	21	23	16	16	15
Mineral oil (0.06%)	23	27	19	17	14

No direct comparison of the effects of Durkex 500 and mineral oils can be made because of the different application rates. However, the amount of corn dust reduction was about the same for 0.04 percent Durkex 500 and 0.02 percent mineral oil, except that the reduction of dust emission immediately after treatment by 0.04 percent Durkex 500 was higher than that by 0.02 percent mineral oil (Table 1). For wheat dust a similar pattern was observed (Table 1). Therefore, we conclude that treatment with mineral oil is more effective than treatment with Durkex 500 oil. This effect may be due to the higher fluidity of mineral oil which may cause it to coat more thoroughly the surface of the grain.

Dust Particle Size Analysis

Small dust particles are more undesirable than large dust particles. The average size of dust particles emitted from oil-treated grain was larger than that from the controls (Table 2). Wheat treated with 0.06 percent oil and 0.06 percent oil plus malathion also showed an additional increase in average particle size after 1 mo of storage. After 3 mo of storage, the 0.02 mineral and 0.04 percent vegetable oil treatments showed no difference in average particle size of dust particles compared with those for the controls. Some effect of the 0.06 percent mineral oil treatment lasted at least 12 mo.

The percent of emitted dust particles smaller than 10 µm is given in Table 3. Fine particle concentration gradually increased with storage time, particularly after 3 mo.

Test Weight

Oil had no effect on the test weight of corn (Table 4). Oil served as a lubricant for wheat and increased its compactness, resulting in a statistically insignificant increase in test weight during 3 mo of storage. After 6 mo of storage, the test weight was the same as that of the control.

Moisture Content

Storage times and treatments with either Durkex 500

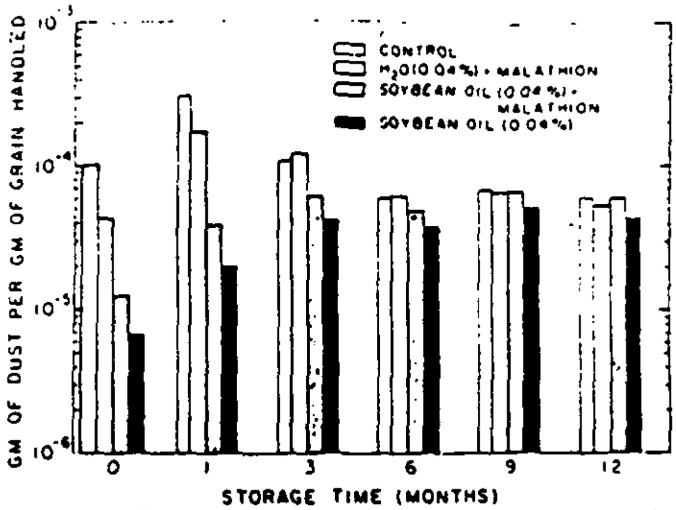

FIG. 3 The effects of storage on dust emission from corn treated with soybean oil.

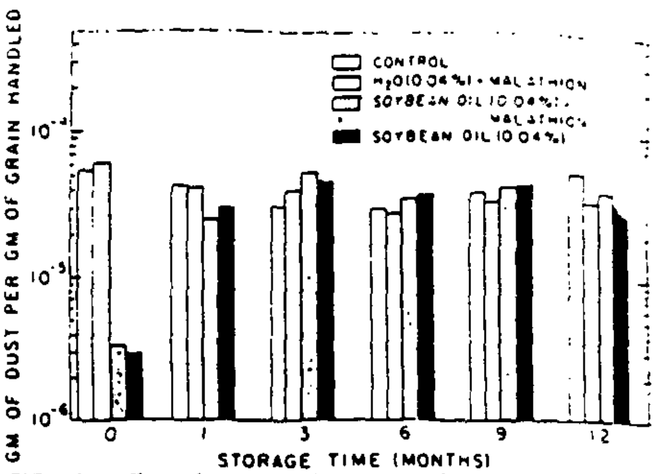

FIG. 4 The effects of storage on dust emission from wheat treated with soybean oil.

was obtained. Free fatty acids and peroxide values were measured by AOCS procedures Ca 5a-40 and Cd 8-53, respectively.

Bioassays and Residue Analysis

Fifty adult insects from laboratory cultures of the rice weevil, *Sitophilus oryzae* L., and the confused flour beetle, *Tribolium confusem* Jacquelin duVal, were each placed in 0.47-L (1 pt) jars containing 100 g of grain from each replicated treatment. Mortality was determined after the test insects had been exposed to the treated grain for 1 wk at 27 °C and 60 ±5 percent relative humidity. Bioassays with each insect were replicated three times.

Samples of wheat and corn were obtained for malathion analysis from each replicated treatment after 24 h and 1, 3, 6, 9, and 12 mo of storage. Residues of malathion were extracted from the grain and anlayzed in a Tracor[f] M.T. (Microtec) gas chromatograph using a procedure adapted from Storrherr et al. (1964) and reported by Quinlan et al. (1979). The lower detectable limit was 0.1 ppm.

RESULTS AND DISCUSSION

Dust Emission

We found that oil was effective in reducing dust emission from grain. In the first series of tests (Table 1), the immediate effect of treatment of corn with 0.04 percent Durkex 500 oil was a reduction in dustiness to 6.7 percent of that for the control (Fig. 3). Application of water and malathion also slightly reduced dust emission; however, after 1 mo of storage, the difference in dust emission between the control and lots of corn tre[illegible] with water and malathion became less significant. [illegible] 1 mo of storage, the effect of Durkex 500 oil began to diminish, probably because the oil was absorbed by the kernels. After 9 mo of storage there was no distinct dif-

TABLE 1. NEGATIVE LOGARITHM OF DUSTINESS FOR GRAINS TREATED WITH OIL AND OIL WITH 10 PPM MALATHION AFTER 0-12 MONTHS OF STORAGE*

Treatment	Negative logarithm of dustiness					
	0	1 mo	3 mo	6 mo	9 mo	12 mo
Corn			Series I			
Control	4.00^{a}	3.53^{a}	3.98^{b}	4.24^{a}	4.17^{a}	4.22^{a}
Water (0.04%) + malathion	4.38^{b}	3.79^{a}	3.83^{a}	4.22^{a}	4.18^{a}	4.27^{a}
Durkex 500 oil (0.04%) + malathion	4.91^{c}	4.43^{b}	4.22^{cb}	4.31^{b}	4.17^{a}	4.21^{a}
Durex 500 oil (0.04%)	5.17^{d}	4.71^{b}	4.37^{c}	4.42^{b}	4.28^{a}	4.35^{a}
			Series II			
Control	3.85^{a}	3.84^{a}	3.96^{a}	4.10^{a}	4.02^{a}	4.16^{bc}
Water (0.04%) + malathion	4.04^{a}	3.84^{a}	4.08^{b}	4.14^{a}	4.02^{a}	4.19^{bc}
Mineral oil (0.02%) + malathion	4.92^{c}	4.21^{b}	4.39^{c}	4.40^{b}	4.04^{a}	4.09^{b}
Mineral oil (0.02%)	4.64^{b}	4.21^{b}	4.26^{bc}	4.28^{b}	4.00^{a}	4.00^{a}
Mineral oil (0.06%) + malathion	5.37^{d}	5.02^{c}	4.84^{d}	4.88^{c}	4.42^{c}	4.32^{c}
Mineral oil (0.06%)	5.21^{d}	4.85^{c}	4.76^{d}	4.82^{c}	4.32^{b}	4.26^{bc}
Wheat			Series I			
Control	4.26^{a}	4.36^{a}	4.51^{a}	4.53^{b}	4.41^{b}	4.28^{a}
Water (0.04%) + malathion	4.21^{a}	4.38^{b}	4.40^{a}	4.54^{b}	4.48^{b}	4.48^{c}
Durkex 500 oil (0.04%) + malathion	5.47^{b}	4.59^{b}	4.27^{a}	4.44^{c}	4.37^{b}	4.38^{bc}
Durkex 500 oil (0.04%)	5.53^{b}	4.51^{b}	4.33^{a}	4.40^{a}	4.35^{a}	4.31^{b}
			Series II			
Control	4.40^{a}	4.55^{a}	4.48^{a}	4.53^{a}	4.25^{a}	4.51^{a}
Water (0.04%) + malathion	4.39^{a}	4.43^{a}	4.48^{a}	4.50^{a}	4.28^{a}	4.50^{a}
Mineral oil (0.02%) + malathion	5.35^{b}	4.87^{b}	4.83^{b}	4.64^{a}	4.32^{b}	4.37^{a}
Mineral oil (0.02%)	5.35^{b}	4.99^{cb}	4.77^{b}	4.61^{a}	4.31^{b}	4.42^{a}
Mineral oil (0.06%) + malathion	5.63^{c}	5.19^{c}	5.06^{c}	5.14^{b}	4.57^{d}	4.69^{b}
Mineral oil (0.06%)	5.82^{d}	5.18^{c}	5.23^{c}	5.03^{b}	4.48^{c}	4.69^{b}

*Dustiness was measured in grams of dust collected per gram of grain handled.

For each set of data, values in columns with no superscripts in common differ significantly at $P<0.05$ (Duncan's multiple range test).