Effect of Laboratory-Scale Oil Applications on Quality Factors of Corn, Soybeans, and Wheat

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ABSTRACT

Cereal Chem. 65(3):175–181

Previous research has demonstrated that application of 200 ppm soybean oil is 90% effective in controlling dust generated during handling of grain in elevator operations. Soybeans, hard red winter wheat, soft red winter wheat, and corn were treated with 200–800 ppm of soybean oil, two mixtures of soybean oil and lecithin, or mineral oil, stored at ambient temperature for periods up to one year, and then evaluated for grade evaluation, odor detection threshold, germination, flammability, and handling properties. Single treatments up to 800 ppm of soybean oil had no significant effect on odor or grade of soybeans or soft red winter wheat. Consistently objectionable odors were reported for soybeans treated with single applications of mineral oil and stored for six months or more. Single treatments up to 800 ppm of soybean oil and lecithin mixtures had no significant effect on odor and grade of any of the grains studied. Multiple treatment with soybean oil to levels of 1,200 ppm and above adversely affected the odor of soybeans, and combined with storage for six months or more, adversely affected the odor of soft red winter wheat. Multiple oil treatments up to 4,800 ppm did not affect the odor of hard red winter wheat stored six months. Corn samples treated with up to 6,400 ppm oil and stored up to 12 months underwent very little odor change but did decrease in test weight. There was no adverse affect by treatment on dry or wet milling properties of corn. Soybeans treated with up to 2,400 ppm soybean oil did not increase in flammability. Similarly treated hard red winter wheat had no significant repellency against the granary weevil. No changes in germination and stress crack percentages of corn were observed with oil treatment.

The concept of using edible oils to reduce dustiness of grain during handling dates back to 1951, when Moen and Dalquist (1952) patented the use of an oil emulsion for this purpose. They found that applying 300–800 ppm of mineral oil to grain effectively reduced dust emissions in subsequent handlings. The same technique, with lecithin, has been used for many years to suppress dust in feeds. Research has shown that additives with an oily consistency can significantly reduce dust levels generated during processing of cotton (Miller and Pomeranz 1979; Cocke et al 1975, 1977, 1978).

Laboratory tests by Lai et al (1981) showed that application of either mineral oil or Durkex 500, a hydrogenated and fractionated soybean oil, at 600 ppm effectively reduces the dustiness of corn and wheat. As little as 200 ppm was effective in reducing dust for one to three months. At a 600 ppm application, dust control was maintained for about six months. The applied oils had no effect on test weight, moisture content, rancidity, or milling and baking properties. They also had no effect on insecticidal activity or persistence of malathion applied to wheat or corn.

The objectives of the present collaborative study were 1) to determine odor detection threshold levels of treatment with soybean oil, combinations of soybean oil and lecithin, or mineral oil on wheat, corn, and soybeans by sensory panel techniques; 2) to determine the effect of these same treatments on Federal Grain Inspection Service (FGIS) grade evaluation, germination, and physical characteristics of the treated grain; 3) to determine the flammability of treated soybeans; 4) to determine the effects of treatment on dry and wet milling parameters of corn; and 5) to evaluate insect repellency of the treatments.

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

MATERIALS AND METHODS

Grain

Four types of grain were studied: hard red winter (HRW) wheat, soft red winter (SRW) wheat, yellow dent corn, and soybeans. Commercial HRW wheat harvested in 1983 and obtained from the COOP grain elevator, Manhattan, KS, had a moisture content of 13.0%, a test weight of 62.5 lb/bu, and graded no. 1. SRW wheat harvested in 1983 at Purdue University, Romney, IN, had a moisture content of 12.8%, a test weight of 61.0 lb/bu, and graded no. 1. Yellow dent corn from the 1983 crop harvested in Manhattan, KS, and dried with natural air to 12.3% moisture content had a test weight of 58.0 lb/bu and graded no. 1. Soybeans harvested in 1983 at Kansas State University, Manhattan, KS, had a moisture content of 11.8%, a test weight of 54.0 lb/bu, and graded no. 2.

Additives

Soybean oil and lecithin were obtained from A. E. Staley (Decatur, IL). Carnation white mineral oil was obtained from ARCO (Philadelphia, PA).

Application of Additives

All test samples were prepared at the U.S. Grain Marketing Research Laboratory (USGMRL). A Sonimist ultrasonic spray nozzle model 700-1A (Heat Systems Ultrasonic, New York, NY) was used at 30 psi to apply the additives. The required amount of additive was weighed in a syringe and metered to the nozzle with an FMI Lab piston pump at a rate of approximately 5 ml/min. To minimize fine spray drift, the nozzle was held close to the grain surface. Replicate samples of a grain were tumbled and sprayed in each of two cement mixers, one a 0.19-m^3 drum rotating at 15 rpm, the other a 0.12-m^3 drum rotating at 20 rpm. Both lots were individually transferred to a barrel, and the barrel was rotated end to end for 10 revolutions.

Four series of samples (designated as I, II, III, and IV) were prepared. In series I, 17 treatments each were made on 25-kg lots of corn, HRW and SRW wheat, and soybeans. Treatments consisted of applying 100% soybean oil, 75/25 soybean oil/lecithin, 50/50 soybean oil/lecithin, or mineral oil at levels of 200, 400, 600, or 800 ppm, as well as an untreated control. Each of the 136 test lots (17 treatments × 4 grains × 2 replicates) of 25 kg was further evenly divided into five sublots (5 kg each) after treatment. Four sublots were marked for evaluation after zero, three, six, and 12 months of storage at ambient temperature (60–95° F). The fifth sublot was stored at ambient temperature for possible further reference. After zero, three, six, and 12 months of storage, each sublot was further evenly divided into three identical portions of approximately 1.5 kg; one for grade evaluation, one for sensory panel evaluation, and one for insect repellency study.

In series II, five treatments were made on 25-kg lots of the four grains. Treatments consisted of applying soybean oil monthly at 200, 400, 600, and 800 ppm, and a control. Each of the 40 samples (5 treatments × 4 grains × 2 replicates) was stored in a covered 25-gallon galvanized container inside the USGMRL grain elevator at ambient temperature (60–95° F). After each monthly treatment, two samples of 1.5 kg each were drawn from the container: one for grade evaluation and the other for sensory panel evaluation. Flammability tests were conducted after three months' treatment on soybeans that received 400 and 800 ppm additive levels. Accumulated application levels of those two treatments were 1,200 (3 × 400) and 2,400 (3 × 800) ppm, respectively.

In series III, 90-kg lots of corn, HRW wheat, and soybeans were treated in triplicate with soybean oil, 50/50 soybean oil/lecithin, and mineral oil at 200 and 600 ppm, plus controls. Each of the 21 90-kg test lots (7 treatments × 3 triplicates) was stored in a covered 55-gallon drum at ambient temperatures inside a grain elevator. After zero, three, six, and 12 months of storage, two samples of 1.5 kg and two samples of 200 g were drawn from each of the mixed 21 test lots. The two 1.5-kg samples were for grade evaluation, a 200-g sample was for sensory panel evaluation, and a 200-g sample was for germination tests. Test weight, angle of repose, and flow rate were measured on samples taken from each of the 21 test lots. These latter samples were returned to the main lot after each test.

In series IV, four lots of corn, 160 kg each, were treated with 200 ppm of mineral oil, soybean oil, a 50/50 blend of soybean oil/lecithin, and 400 ppm of soybean oil for evaluation of milling characteristics (Anderson 1963, Brekke et al 1972). A fifth lot served as a control. Samples were shipped after treatment and milled with minimal storage time.

Evaluation Procedures: Grade and Odor of Grain

Grade evaluation was performed by the FGIS on samples from series I, II, and III. The procedures are described in the FGIS Grain Handbook (FGIS 1980). Grade evaluation for wheat included heating, odor, moisture, dockage, test weight, other grains, damaged kernels, foreign material, shrunken and broken kernels, defects, weevily wheat, and stones; for corn it included odors, weevily corn, stones, moisture, test weight, broken corn and foreign material (BCFM), and damaged kernels; for soybeans it included odors, garlicky soybeans, weevily soybeans, moisture, test weight, foreign material, stones, splits, and damaged kernels.

Samples were evaluated at the Northern Regional Research Center (NRRC) for rancid and other "off" odors by 15 panelists experienced in evaluating the odors and flavors of vegetable oils and/or grain products and trained to recognize the natural odor of each grain and to identify rancid odors and other off-odors (Warner et al 1982). Evaluation procedures were the same for all samples at zero, three, six, and 12 months of storage. The untreated grains were spiked with up to 1% aged soybean oil to serve as standards for weak, moderate, and strong intensity levels of rancid odor. Panelists recorded overall intensity of off-odors and identified all off-odors, including rancid. Overall intensity of off-odors was indicated, rather than just rancid odor, because additional odors such as grassy, beany, painty, etc., could be present. Grains were evaluated in an 8 × 4 × 10 ft room, held at a constant temperature of 25°C, and ventilated with air filtered through activated charcoal. Intake-exhaust ventilation rate was 2,500 cfm. Samples of 50 g of grain were placed in 4-oz, wide-mouth clear glass jars (2/3 full) with screw-top closure. Aluminum foil sleeves covered the glass to prevent panel bias by the grain's appearance. Each grain was evaluated by the panel in separate tests. Prior to evaluating each set of 16 treated samples and one untreated control, panelists were asked to evaluate three identified grains (an untreated control, a weak rancid standard, and a moderate rancid standard). Panelists were instructed to shake each jar, then remove the lid, smell the headspace, and allow at least 25 sec between sample evaluations. During each test, panelists evaluated 20 samples; four treatment levels (200, 400, 600, and 800 ppm) of each of the four additives, two untreated controls, one replicate of one of the 16 treated samples, and one spiked sample with a weak to moderate level of rancid odor. Each jar was coded, and the order of presentation was randomized for each tester in permutations of 1–20. Duplicate samples of each treatment for each grain were evaluated in separate panel tests. The percentage of panelists noting a positive response for each sample was calculated, and results from the duplicate tests were averaged. Odor detection thresholds were statistically set at the level at which 50% of the panel gave a positive response for off-odor (ASTM 1968).

Evaluation Procedures: Physical Tests

Test weight of the series III samples was determined at USGMRL by the official USDA method (FGIS 1980). The angle of repose, a measure of the packing characteristics of a grain, was determined by measuring the angle at which grain began to move in an apparatus that was slowly tilted from the horizontal. Flow rate was determined by monitoring the weight of grain flowing through a 5-in. diameter orifice with respect to time. The output signal from an electronic platform scale was recorded on a digital oscilloscope, and the flow rate was determined from the slope of the weight versus time signal.

Evaluation Procedures: Flammability

Samples of soybeans from the series II treatments of 400 and 800 ppm of soybean oil were tested for flammability at USGMRL in two forms after three months of storage: 1) at 600°C as material ground to pass a 0.040-in. round-hole screen in a modified Weber mill, and 2) at 500 and 750°C as whole kernels. A 3-g sample of each form was weighed and placed in a 25-ml crucible. The crucibles containing the samples were then placed at opposite corners of the front row of a furnace rack inside a heat-treating furnace (model CPT 3042, Thermolyne, Dubuque, IA). The furnace was preheated to the appropriate temperature. The furnace door was open to allow a 1-in. gap for observing the flame. The time interval from initial placement of the sample inside the furnace to when it burst into flame was recorded. After each test, the rack was removed from the oven and allowed to cool. Two racks and three pairs of crucibles were alternately used to allow for cooling between replicates; the door was closed to reheat the oven to the appropriate temperature.

Evaluation Procedures: Insect Repellency

After three and six months of storage, 21 samples of HRW wheat from the series I treatments were tested for insect repellency at the Stored Products Insects Laboratory. Glass test chambers, similar to those utilized by Qi and Burkholder (1981) for evaluating repellency of oils to weevils, were modified to include perforated plastic tube traps 2.5-cm in diameter with 2.7-mm holes, instead of metal traps (Burkholder 1984). Each chamber held 500 g of wheat. One hundred granary weevil adults, 1–7 days old, were added to the top of each chamber. The number of trapped weevils for each sample was recorded after 16, 24, 48, and 120 hr. Estimates of the time (RT_{50}) required for 50% of the weevils to be repelled from the grain were computed using the procedures of Finney (1971) and Kramer et al (1985).

RESULTS AND DISCUSSION

Grade and Odor

Results of evaluations of grade and odor for the four treated grains are presented in Tables I–IV. FGIS grade and odor data represent a single inspector's evaluation of replicate samples. NRRC odor threshold data report the statistical results of a 15-member panel. A general trend toward lower FGIS grade evaluations of series I samples was observed as the storage time of all four grains increased, including the controls and those treated with mineral oil (Tables I–IV). This trend was probably due to storage in sealed containers with no ventilation and a fairly high environmental temperature for the first six months of storage.

In Table I (soybeans), there are 34 designations of sample grade (SG) for 26 samples but only eight duplicate samples were evaluated as SG. Of those eight, seven were treated with mineral oil. The strong off-odors noted by the panelists for the mineral oil treated soybeans aged six and 12 months were identified as musty and plastic. The eighth soybean sample (treated with the lowest level of soybean oil at 200 ppm after six months of storage) was found to have commercially objectionable foreign odor (COFO). In panel evaluations of this same sample, 42% reported off-odors, which is just below the 50% threshold level. No consistent or significant effect of vegetable oil treatment on odor or grade of soybeans was established.

In Table II (SRW wheat), there were four designations of off-odor by the panel; all were detected immediately after treatment and disappeared after storage. Ten sets of duplicate samples were graded SG by FGIS on the basis of odor; in two of those samples the panel detected an off-odor above the threshold level. Some of the objectionable denotations given by graders were in the samples that received low-level, rather than high-level, oil treatments. Therefore, no consistent or significant effect of oil treatment on odor and on grade of SRW wheat was established. In Tables III (HRW wheat) and IV (corn) any off-odors were below the threshold level of the panel. None were consistently (in duplicate samples) objectionable by FGIS.

After storage of corn for six months or more, there was a deterioration in FGIS grade in the samples treated with mineral oil or soybean oil/lecithin. That deterioration was due to the increase in BCFM rather than a change in test weight or objectionable odor; the cause for this increase is unknown. A similar deterioration in grade was recorded for samples of corn subjected to repeated monthly treatments (Table V).

Results of grade and odor evaluation of grains from series II

TABLE I
Grade and Odor Evalution of Treated Soybean Samples (Series I)

		Months of Storage											
		0			3			6			12		
	Level	FGIS[a]		NRRC[b]	FGIS		NRRC	FGIS		NRRC	FGIS		NRRC
Additive	(ppm)	Grade	Odor	Odor	Grade	Odor	Odor	Grade	Odor	Odor	Grade	Odor	Odor
None	...	2/SG	*/S	0	2	*/NA	0	2/2	*	0	2/SG	*/M	0
Soybean oil	200	3	*	56	3	*/S	41	SG	C	46	2/SG	*/M	38
	400	3	*	82	3	*	41	3/SG	*/C	30	3/SG	*/M	27
	600	3	*	82	3	*	54	3	*	42	3/SG	*/C	26
	800	3/SG	*/C	70	3	*	29	2/SG	*/C	38	3/SG	*/M	41
Mineral oil	200	SG/NA	M/NA	0	2	*	25	SG	C	78	SG	M	87
	400	2	*	13	2	*	38	SG	C	96	SG	M	93
	600	2	*	8	2	*	33	SG	C	71	SG	*/M	93
	800	2	*	4	2	*	46	2/SG	*/C	92	SG	M	93
Soybean oil/ lecithin (75/25)	200	2/3	*	38	2	*/NA	38	2	*	21	2/3	*	34
	400	2/3	*	0	2	*	33	2	C	21	2/3	*	21
	600	2	*	18	3	*	50	3	*	33	3/SG	*/M	27
	800	2	*	4	3	*	58	2/SG	*/C	13	3	*	28
Soybean oil/ lecithin (50/50)	200	2	*	4	2	*	25	2	*	33	2/3	*	7
	400	2	*	0	3	*	42	2	*	36	2	*	33
	600	2/SG	*/M	4	3/SG	*/C	50	2/SG	*/C	29	3/NA	*	13
	800	2/SG	*/M	6	3	*	46	2/3	*	21	3/SG	*/M	14

[a] FGIS = Federal Grain Inspection Service. Single designation indicates same grade or odor for both samples; M = Musty; NA = not available; S = sour; SG = sample grade; * = no odor detected; C = commercially objectionable foreign odor.
[b] NRRC = Northern Regional Research Center. Percent of panel reporting off-odor(s); 50% level = odor detection threshold.

TABLE II
Grade and Odor Evaluation of Treated Soft Red Winter Wheat Samples (Series I)

		Months of Storage											
		0			3			6			12		
	Level	FGIS[a]		NRRC[b]	FGIS		NRRC	FGIS		NRRC	FGIS		NRRC
Additive	(ppm)	Grade	Odor	Odor	Grade	Odor	Odor	Grade	Odor	Odor	Grade	Odor	Odor
None	...	1	*	0	1	*/NA	0	1/SG	*/C	0	1	*	0
Soybean oil	200	2	*	4	1/2	*	12	1/SG	*/C	18	1/SG	*/C	6
	400	2	*	39	1/NA	*	17	1/SG	*/C	13	SG	C	30
	600	2	*	69	2	*	33	SG	C	26	2/SG	*/C	25
	800	2/SG	*	85	2	*	38	1/2	*	30	SG	C	41
Mineral oil	200	1/2	*	0	1	*	30	1	*	5	1	*	18
	400	1	*	7	1	*	12	1	*	18	1	*	11
	600	1	*	4	1	*	33	1/SG	*	9	1	*	7
	800	1	*	7	1	*	21	1/SG	*/C	9	1	*	0
Soybean oil/ lecithin (75/25)	200	2	*	14	1	*	17	SG	C	9	1/2	*	0
	400	2	*	42	2	*	29	1/SG	*/C	26	2/SG	*/C	29
	600	2	*	43	1/2	*	46	SG	C	22	SG	C	42
	800	2/SG	*	58	2/NA	*	33	2/SG	*/C	30	SG	C	47
Soybean oil/ lecithin (50/50)	200	2	*	12	1	*	12	1/SG	*	14	1	*	11
	400	2	*	23	2	*	25	1/2	*	18	SG	C	42
	600	2	*	46	1/2	*	38	SG	C	13	SG	C	18
	800	2	*	40	2	*	50	2/SG	*/C	39	2/SG	*/C	27

[a] FGIS = Federal Grain Inspection Service. Single designation indicates same grade or odor for both samples; NA = not available; SG = sample grade; * = no odor detected; C = commercially objectionable foreign odor.
[b] NRRC = Northern Regional Research Center. Percent of panel reporting off-odor(s); 50% level = odor detection threshold.

treatments are presented in Table V. Evaluations of soybeans by FGIS graders and the NRRC panel noted off-odors at soybean oil application levels of 1,200 ppm or higher. Some discrepancies and inconsistencies in odor evaluation for wheat were recorded by graders and the panel. Graders rated 15 samples of SRW wheat as COFO, whereas the panel detected off-odors in six samples receiving higher application levels. Generally, high cumulative oil levels (1,600 ppm and above) and long storage times were detrimental to SRW wheat samples. The evaluation of odor of HRW wheat by the panel detected off-odors in the samples stored 12 months with oil levels of 1,600 ppm. In HRW wheat stored for six months, graders recorded all COFO at cumulative application levels of 1,200 ppm and above. The odor evaluations of aged corn by both graders and the panel detected no effect of up to 6,400 ppm oil. There was inconsistent variation in grade of treated samples due to varying amounts of BCFM. A probable bias was confirmed by the fact that all corn samples, including the untreated ones, showed deterioration in grade numbers after storage. That deterioration was a result of increases in BCFM and was unrelated to oil treatment.

Physical Tests

Results of the USGMRL test weight measurements, shown in Table VI, are the averages of three replicates. Oil treatment had no consistent or significant effect on test weight of soybeans, with the possible exception of soybeans stored for six or 12 months after application of 600 ppm vegetable oil. There was an average decrease of 1.3 lb/bu in the test weight of corn immediately after oil application. The decrease in corn test weight was reversed as the length of storage time increased. The average test weight of samples stored for 12 months after oil application was slightly higher than that of the untreated, original corn. Test weight of

TABLE III
Grade and Odor Evaluation of Treated Hard Red Winter Wheat Samples (Series I)

		Months of Storage											
		0			3			6			12		
		FGIS[a]		NRRC[b]	FGIS		NRRC	FGIS		NRRC	FGIS		NRRC
Additive	Level (ppm)	Grade	Odor	Odor	Grade	Odor	Odor	Grade	Odor	Odor	Grade	Odor	Odor
None	···	1	*	0	1/NA	*/NA	0	1	*	0	1	*	0
Soybean oil	200	1	*	14	1/NA	*	14	1	*	5	1	*	7
	400	1	*	20	1	*	14	1/SG	*/C	17	1	1*	11
	600	1	*	30	1	*	14	1	*	31	1	*	44
	800	1	*	35	1	*	21	1/SG	*/C	31	1	*	49
Mineral oil	200	1	*	6	1	*	18	1	*	13	1	*	0
	400	1	*	10	1	*	29	1	*	32	1	*	36
	600	1	*	7	1/NA	*/NA	18	1	*	17	1	*	7
	800	1	*	10	1	*	14	1/SG	*/C	18	1	*	7
Soybean oil/ lecithin (75/25)	200	1	*	7	1	*	14	1/SG	*/C	16	1	*	7
	400	1	*	14	1/NA	*	18	1	*	17	1	*/NA	29
	600	1	*	20	NA	*	18	1	*	27	1	*	29
	800	1	*	23	1/SG	*	29	1/SG	*/C	39	1	*/NA	36
Soybean oil/ lecithin (50/50)	200	1	*	4	1	*	18	1	*	9	1	*	7
	400	1	*	14	1	*	22	1/SG	*/C	14	1	*	29
	600	1	*	7	1	*/C	25	1/SG	*/C	28	1	*	29
	800	1	*	18	1	*	29	1/SG	*	34	1/SG	*/C	44

[a] FGIS = Federal Grain Inspection Service. Single designation indicates same grade or odor for both samples; NA = not available; SG = sample grapde; * = no odor detected; C = commercially objectionable foreign odor.
[b] NRRC = Northern Regional Research Center. Percent of panel reporting off-odor(s); 50% level = odor detection threshold.

TABLE IV
Grade and Odor Evaluation of Treated Corn Samples (Series I)

		Months of Storage											
		0			3			6			12		
		FGIS[a]		NRRC[b]	FGIS		NRRC	FGIS		NRRC	FGIS		NRRC
Additive	Level (ppm)	Grade	Odor	Odor	Grade	Odor	Odor	Grade	Odor	Odor	Grade	Odor	Odor
None	···	1	*	0	1	*	0	2	*	0	1	*	0
Soybean oil	200	1	*	16	1	*	8	1	*	19	1/NA	*	20
	400	1/2	*	12	1	*	4	1	*	9	2/4	*	20
	600	1/2	*	20	1/NA	*	8	1	*	14	3/SG	*	20
	800	1	*	12	1	*	0	1/2	*	18	2/3	*	29
Mineral oil	200	1/3	*	8	1	*	4	2	*	14	5/NA	*	15
	400	1	*	8	1	*	8	2	*	4	4/5	*	15
	600	1	*	8	1/4	*	8	1	*	4	5/NA	*	25
	800	1/2	*	5	1/2	*	8	4	*	9	5/SG	*	2
Soybean oil/ lecithin (75/25)	200	1/2	*	11	1/2	*	4	2	*	9	5/SG	*	20
	400	1	*	12	2/NA	*	8	2/3	*	9	4/SG	*	12
	600	2/4	*	8	2/3	*	8	2/5	*	13	3/SG	*	37
	800	2	*	12	3/4	*	4	3	*	4	5	*	12
Soybean oil/ lecithin (50/50)	200	2/SG	*	12	2	*	4	2/3	*	18	5/SG	*	17
	400	1/4	*	18	2/5	*	0	4/5	*	9	SG	*	26
	600	1/2	*	12	2/1	*	17	1/3	*	14	5	*	20
	800	3/4	*	4	2	*	17	1/2	*	0	5/SG	*	22

[a] FGIS = Federal Grain Inspection Service. Single designation indicates same grade or odor for both samples; NA = not available; SG = sample grade; * = no odor detected.
[b] NRRC = Northern Regional Research Center. Percent of panel reporting off-odor(s); 50% level = odor detection threshold.

TABLE V

Grade and Odor Evaluation of Samples of Soybeans, Soft Red Winter (SRW) Wheat, Hard Red Winter (HRW) Wheat, and Corn After Repeated Monthly Treatments with Soybean Oil (Series II)

		Months of Storage											
		3				6				12			
	Applic. Level (ppm)	Cum. Level (ppm)	FGIS[a] Grade	FGIS[a] Odor	NRRC[b] Odor	Cum. Level (ppm)	FGIS Grade	FGIS Odor	NRRC Odor	Cum. Level (ppm)	FGIS Grade	FGIS Odor	NRRC Odor
Soybeans													
	0	0	2	*	0	0	2	*	0	0	2	*	0
	200	600	3	*	46	1,200	3/SG	*/C	58	1,600	SG	C	72
	400	1,200	SG	C	56	2,400	SG	C	54	3,200	SG/NA	C/NA	72
	600	1,800	SG	C	66	3,600	SG	C	71	4,800	SG	C	65
	800	2,400	SG	C	75	4,800	SG	C	71	6,400	SG	C	85
HRW Wheat													
	0	0	1	*	0	0	1	*	0	0	1	*	0
	200	600	SG/NA	C/*	14	1,200	SG	C	12	1,600	1/SG	*/C	58
	400	1,200	1/NA	*/C	43	2,400	SG	C	19	3,200	1	*	79
	600	1,800	1	*	36	3,600	SG	C	12	4,800	1	*	65
	800	2,400	1/NA	*/C	43	4,800	SG	C	34	6,400	1/SG	*/C	81
SRW Wheat													
	0	0	1	*	0	0	1	*	0	0	1	*	0
	200	600	2/NA	*	4	1,200	SG	C	47	1,600	SG	C	59
	400	1,200	SG/2	C/NA	29	2,400	SG	C	47	3,200	SG	C	59
	600	1,800	SG	C	42	3,600	SG	C	61	4,800	SG	C	42
	800	2,400	SG	C	55	4,800	SG	C	65	6,400	SG	C	59
Corn													
	0	0	1/5	*	0	0	2/5	*	0	0	3/5	*	0
	200	600	5/5	*	10	1,200	3/SG	*	21	1,600	5/SG	*	28
	400	1,200	5/SG	*	10	2,400	2/4	*/NA	0	1,600	5/SG	*	17
	600	1,800	3/5	*/NA	10	3,600	1/3	*	9	4,800	3/SG	*	28
	800	2,400	SG	*	14	4,800	2/SG	*	13	6,400	4/SG	*	28

[a] FGIS = Federal Grain Inspection Service. Single designation indicates same grade or odor for both samples; NA = not available; SG = sample grade; * = no odor detected; C = commercially objectionable foreign odor.

[b] NRRC = Northern Regional Research Center. Percent of panel reporting off-odor(s); 50% level = odor detection threshold.

TABLE VI

Grade, Test Weight, and Odor Evaluation of Samples of Soybeans, Hard Red Winter (HRW) Wheat, and Corn (Series II)

		Months of Storage											
		0			3			6			12		
Additive (lb/bu)	Level (ppm)	Grade[a]	Odor[a]	TW[b] (lb/bu)	Grade	Odor	TW (lb/bu)	Grade	Odor	TW (lb/bu)	Grade	Odor	TW (lb/bu)
Soybeans													
None	...	2	*	54.0	2	*	54.0	2	*	54.2	2	*	54.0
Soybean oil	200	2	*	54.4	2/3/2	*	53.8	2	*	54.1	SG	C	53.8
	600	2	*	54.0	3	*	53.1	3/2/3	*	53.3	3/WG/3	*/*/C	53.0
Mineral oil	200	2	*	53.5	2	*	54.2	SG	C	54.0	2/SG/2	*/M/*	54.0
	600	2	*	54.0	2	*/*/NA	53.8	SG	C	54.1	2/3/SG	*/*/M	53.9
Soybean oil/ lecithin	200	2	*	54.1	NA/2/2	*/*/NA	53.8	2	*	54.0	3/3/2	*	53.3
	600	2	*/*/NA	54.4	2	*	54.0	2/2/3	*	53/4	SG/3/NA	*/*/NA	53.6
HRW Wheat													
None	...	1	*/*/NA	62.2	1	*	62.3	1	*	62.3	1	*	62.4
Soybean oil	200	1	*/NA/LO	62.1	1	*	61.2	SG/1/1	C/*/*	61.4	1	*	61.5
	600	1	*	61.4	1	*	61.1	1/SG/SG	*/C/*	60.9	1	*	61.0
Mineral oil	200	1	*	62.1	1	*	62.0	SG/SG/1	C/C/*	62.1	1/NA/1	*/NA/*	52.1
	600	1	*	61.8	1	*	63.3	1/SG/1	*	62.4	1	*	62.1
Soybean oil/ lecithin	200	1	*	61.9	1	*	61.7	1/1/SG	*/*/C	61.8	1/1/SG	*	61.8
	600	1	*	61.9	1	*	61.6	SG/1/SG	*	61.5	1	*	61.1
Corn													
None	...	1/2/1	*/*/NA	58.4	3/2/3	*	58.4	4/2/2	*	58.5	5/3/3	*	58.9
Soybean oil	200	1/1/2	*/*/NA	57.0	2/3/1	*	57.6	2/3/2	*	57.5	4/5/3	*	58.1
	600	1/2/1	NA	56.4	1	*	57.0	2	*	57.5	4/5/3	*	58.1
Mineral oil	200	1/3/1	*	57.6	1	*	57.6	3/3/1	*	58.3	4/SG/4	*	58.7
	600	1	*/*/NA	56.8	3/1/1	*	57.2	3	*	58.4	5/4/3	*	58.9
Soybean oil/ lecithin	200	1	*	57.5	1/1/2	*	57.8	2/1/4	*	58.2	5/4/5	*	58.7
	600	1	*	57.5	2/2/NA	*/*/NA	57.5	3/4/3	*	58.4	4	*	58.2

[a] Single designation indicates same grade or odor for all three samples; LO = light oil; M = musty; NA = not available; SG = sample grade; * = no odor detected; C = commercially objectionable foreign odor.

[b] TW = test weight, average of three replicates.

TABLE VII
Repellency of Oil-Treated Wheat Against the Granary Weevil, Insects Repelled (Series III)

Additive	Level (ppm)	Number[a] of Insects Repelled			
		Hours After Introduction			
		16	24	48	120
		3 Months' storage			
None	0	8/5/6	9/8/7	11/10/9	18/17/19
Soybean oil	200	7/7/7	7/9/9	11/11/10	16/13/13
Mineral oil	200	13/5/6	14/6/7	22/17/15	30/30/29
Soybean oil/ lecithin (50/50)	200	8/9/9	10/9/11	10/12/13	18/20/15
		6 Months' storage			
None	0	3/2/5	5/4/8	12/12/13	32/30/33
Soybean oil	200	1/2/2	4/2/4	8/4/8	39/23/22
Mineral oil	200	1/5/1	2/17/27	8/23/8	28/44/31
Soybean oil/ lecithin (50/50)	200	2/1/0	11/3/3	13/3/9	27/24/27

[a] One hundred insects per sample; three samples per test.

TABLE VIII
Repellency of Oil-Treated Wheat Against the Granary Weevil, RT_{50}[a] (Series III)

Additive	Level (ppm)	RT_{50} After	
		3 months (hr)	6 months (hr)
None	0	397	187
Soybean oil	200	593	186
	600	311	253
Mineral oil	200	193	148
	600	150	177
Soybean oil/	200	448	208
lecithin (50/50)	600	204	164

[a] RT_{50} = Time in hours when half of the weevil population migrated from the grain into the trap.

HRW wheat decreased on the average 0.3 lb/bu immediately after treatment; the decrease averaged 0.6 lb/bu after 12 months of storage. The decrease was generally larger with the 600 than with the 200 ppm treatment. These variations in test weight may be an artifact of the test procedure influenced by the oil treatment.

Handling properties of treated grain were further tested at the USGMRL. As a result of oil treatment, the angle of repose of corn increased. Angle of repose was affected least in soybeans. Soybean oil produced the largest change in angle of repose.

Soybean oil treatments initially increased the flow rate of soybeans 2–4%. After three months of storage, however, the flow rate increase was less significant. Flow rates were affected most in soybean oil-treated samples, least in mineral oil-treated samples, and intermediate in samples treated with the 50/50 blend. Flow rates decreased 2–6% in the treated samples of corn; however, after storage for three months, flow rates returned to normal levels. At the 200 ppm level, all three additives decreased flow rate in corn. The greatest decrease in flow rate occurred at the 600 ppm level for the 50/50 blend. The flow rate of treated wheat samples changed only slightly.

Flammability

The flammability test of ground and unground soybeans showed that even at the 2,400 ppm level there was a negligible difference in flammability between the treated and untreated samples.

Insect Repellency

Results of the three- and six-month insect repellency studies are given in Table VII. Estimates of repellency (RT_{50}) were derived from the linear regression of number of insects repelled versus time after introduction, based on a 50% repellency level. The mineral oil exhibited a repellent action against the granary weevil on HRW wheat at both the 200 and 600 ppm levels (Table VIII). For the wheat stored three months, an estimated 397 hr was required for 50% of the population to be trapped in the untreated wheat control, 193 hr for the samples treated with mineral oil at 200 ppm, 448 hr with the 50/50 blend of soybean oil and lecithin, and 593 hr with soybean oil. No repellent effect was evident for soybean oil or soybean oil/lecithin (50/50) at 200 ppm. A repellent effect was recorded for all oils applied at the 600 ppm level. After storage for six months, the RT_{50} for the untreated wheat control was 187 hr, a 50% reduction in time compared to three months of storage. No significant repellency was recorded after six months of storage for any oil at any level of treatment, except mineral oil, which exhibited only minor repellency.

Properties and Processing of Corn

Oil additives had little effect on germination. The largest decrease in germination as a result of treating corn was after 12 months of storage, and was less than 10%.

Oil treatment lowered the average test weight, as determined by the NRRC, by 2–4 lb/bu, possibly because of decreased flowability of corn in the test apparatus as noted below. There was no consistent or significant effect of oil application on weight per 100 kernels or percentage of stress cracks. Flowability of corn as measured by the standard bushel test weight apparatus was reduced 10–18% by the application of mineral or vegetable oils; increasing soybean surface oil application from 200 to 400 ppm gave no further decrease in corn flowability.

It was observed in replicate dry milling tests that first break grit yield was significantly increased only from corn treated with 400 ppm soybean oil. We were unable to explain this observation. No significant yield differences were shown with second and third break grits, prime products, germ, or homing feed from all of the treated corn. Degermer throughput was raised 15% (vs. control corn) in corn treated with 200 ppm soybean oil; no other oil treatment exhibited increased degermer throughput.

Wet-milled corn products showed no consistent trends due to oil treatment. Starch yields ranged from 58 to 68%, germ yield varied from 7 to 8%, and fiber yield ranged from 11 to 14%. Gluten (protein) yields varied erratically, ranging from 12% in corn treated with soybean oil/lecithin to 22% in corn treated with mineral oil. Protein content of the gluten, germ, or fiber showed no definite trends with respect to treatment of corn with oil.

CONCLUSIONS

In single oil application treatment (up to 800 ppm), 1) no consistent or significant effect of vegetable oil treatment was established on odor and grade of soybeans or SRW wheat, 2) none of the samples of HRW wheat or corn denoted a consistently objectionable odor, and 3) an increase in BCFM and a related decrease in grade of corn during storage could not be correlated to oil treatment.

In successive oil application treatments (cumulative levels up to 6,400 ppm), 1) soybean oil levels of 1,200 ppm and above adversely affected the odor of soybeans, 2) high levels and long storage adversely affected the odor of SRW wheat, 3) odor of HRW wheat stored three months was not affected by up to 2,400 ppm oil (evaluation by FGIS and NRRC after six and 12 months yielded conflicting results), and 4) odor of corn stored for up to 12 months was affected little by up to 6,400 ppm oil.

Oil application had little effect on test weight of soybeans. An average decrease of 1.3 lb/bu in the test weight of corn was observed immediately after oil application and was less with increased storage time after application. Average test weight of HRW wheat decreased by 0.3 lb/bu immediately after treatment; however, the decrease was greater (0.6 lb/bu) after 12 months of storage.

Angle of repose increased in corn and was affected little in soybeans. Soybean oil produced the largest effect observed with corn.

Oil treatments generally decreased the flow rate of corn but increased the flow rate for soybeans. There was no significant effect on the flow rate of wheat.

Treatment of soybeans with 1,200 or 2,400 ppm soybean oil did not affect the flammability of soybeans.

Oil treatment had no consistent adverse effects on dry and wet milling parameters.

No insect-repellent effect was evident after three months for wheat treated with 200 ppm soybean oil or soybean oil/lecithin (50/50); a repellent effect was recorded at the 600 ppm level. No repellency was recorded after six months of storage, except for a minor repellency in wheat treated with mineral oil.

ACKNOWLEDGMENTS

This research was supported in part by a grant from American Soybean Association and National Grain and Feed Association. Donation of white mineral oil by ARCO, Philadelphia, PA is greatly appreciated. L. Parrott provided technical assistance in sensory panel evaluations.

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[Received July 6, 1987. Revision received November 19, 1987. Accepted November 24, 1987.]