Surface Oil Application Effects on Chemical, Physical, and Dry-Milling Properties of Corn

A. J. PEPLINSKI,[1] R. A. ANDERSON,[2] and T. L. MOUNTS[1]

Cereal Chem. 67(3):232–236

ABSTRACT

Field-grown yellow dent corn from the Midwest was surface sprayed with 200 parts per million (ppm) mineral oil, 100 ppm soybean oil + 100 ppm lecithin, 200 ppm soybean oil, or 400 ppm soybean oil to suppress dust. We then examined chemical compositions (ash, fat, fiber, nitrogen, and starch), physical properties (kernel breakage susceptibility, test weight, flotation, flow rate, germination, hardness index, stress cracking, and 100-kernel weight), and dry-milling response (degermer throughput, yield and fat content of fractions, and recoverable oil yield). All tests were performed after corn was first surface coated with oil. Tests were repeated after eight months' storage at 25°C. Oil treatment reduced test weight by 41–60 kg/m^3 at the time of application, but there was little difference after eight months' storage. Floating kernels from oil-treated corn were decreased by 5 to 7 percentage points at time of application, and 2 to 8 percentage points after eight months. Kernel flow rate of oil-treated corn was decreased by 59–100 kg/hr at initial treatment time. Roller milling response was little affected by oil treatment or storage time. Compared with the control, degermer throughput of corn treated with 200 ppm soybean oil at zero time was increased 15%. Kernel chemical composition was not changed by oil treatment or storage time. Because of apparent decrease in kernel test weight of fresh oil-sprayed corn, care must be taken if test weight is used as a quality factor measurement.

Control and elimination of dust in the grain industry is necessary to maintain air quality, prevent explosions, and eliminate breeding grounds of pests. Dust is commonly removed from grain by air filtration, vacuum, or washing. Oil coatings sprayed on surfaces of barley, corn, soybeans, and wheat have been shown to suppress dust (Mounts et al 1988, Lai et al 1986, Goforth et al 1985). Since surface oil may become widely used to suppress dust, we examined the effect of oil coatings on chemical, physical, and dry-milling properties of surface oil-treated corn.

MATERIALS AND METHODS

Corn Treatment

Field-grown yellow dent corn harvested near Manhattan, KS, was dried with ambient air to 12.3% moisture. Four 160-kg lots were treated with surface oil coatings; another 160-kg lot was left untreated as a control. Treatments consisted of applying to the corn surface, based on corn weight, 200 ppm mineral oil, 200 ppm soybean oil, 100 ppm soybean oil + 100 ppm lecithin, or 400 ppm soybean oil. These treatments compare food-grade vegetable (soybean) oil, food-grade mineral oil, and a soybean

[1]U.S. Department of Agriculture, Agricultural Research Service, Northern Regional Research Center, 1815 North University Street, Peoria, IL 61604.

The mention of firm names or trade products does not imply that they are endorsed or recommended by the U.S. Department of Agriculture over other firms or similar products not mentioned.

[2]Retired from USDA-ARS, Northern Regional Research Center.

oil-lecithin mixture. Soybean oil is an edible food oil; the food-grade mineral oil does not exhibit rancidity over time (Wilbur 1985), and lecithin has antioxidant properties to help prevent oxidation and rancidity of the soy oil.

A Sonomist ultrasonic spray nozzle 700-1A was used at a pressure of 2.1 kg/cm^2 to apply the additives. The weighed additive was metered with an FMI Lab pump at approximately 5 ml/min. The spray nozzle was held near the grain surface to minimize spray drift while corn was tumbled in a small cement mixer. After spraying and blending, grain was placed in airtight drums and shipped to the USDA-ARS Northern Regional Research Center. Further details of the oil additions and technical specifications of lecithin, mineral oil, and soybean oil additives were given by Mounts et al (1988).

Degerming Corn

Lots (6 kg) of cleaned corn were tempered from a storage moisture of 12.3% to 16% moisture, held for 16 hr, additionally tempered to 21% moisture, and held for 1.75 hr. For loosening the hull (pericarp), final tempering brought the moisture content to 24% for 15 min before decortication in the horizontal rotor degermer (HRD). These tempering steps allow adequate moisture penetration into the endosperm with minimal stress crack development. Corn wetted to 24% moisture was fed to the HRD operating at 1,750 rpm while a constant net motor load of 0.26 kW was maintained. Details of the tempering steps, corn flow, and design and use of the HRD were published previously (Brekke et al 1972, Peplinski et al 1984b). The degermer throughput (broken pieces of endosperm, germ, and hull) was dried with 38°C air in a forced-air flow-through tray dryer to 17 ± 1% moisture and further processed by roller milling and grading to produce low-fat, food-grade products (prime products), feed products, and corn germ (Peplinski et al 1984b). All tempering and roller milling steps were performed at 25°C and 50% relative humidity.

Analytical Procedures and Calculations

Fat content of germ was determined by pentane-hexane extraction in the Butt procedure (AOAC 1960). Fat contents of other roller-milled fractions were assayed by gas chromatography (Black et al 1967) as modified by Nielsen et al (1979). Yield of recoverable oil was calculated from the amount of recovered germ fraction and its fat and moisture contents, with residual germ cake assumed to contain 5% oil, dry basis (db). Dry-milled product yields were calculated from samples air-dried at 50% relative humidity at 25°C to approximately 9 ± 1.0% moisture. Moisture levels were determined by heating 10-g ground samples at 130°C for 60 min in a forced-air Brabender moisture tester, a modification of AACC method 44-15A (1962).

Physical Analyses

All physical tests were performed on corn equilibrated to 10 ± 0.5% moisture. Test weight was determined according to USDA *Official Grain Standards* (1988). The percentage of floating kernels was determined on 150-g samples with the floaters test (Wichser 1961) modified by Peplinski et al (1984a). In this test, a sodium nitrate solution of 1.275 specific gravity is used for flotation. Kernel hardness index (Wichser 1961) is based on percentage of floating kernels and moisture content. Breakage susceptibility tests were run with the Stein breakage tester, model CK2, on 100-g portions of corn with 2-min impact. Breakage was determined as percentage of sample passing through a 0.48-cm (12/64-in.) round hole perforated sieve. Stress-crack counts were obtained on 50-g samples of whole unbroken corn by the method of Thompson and Foster (1963) under 3× magnification. Flow rate was measured by timing the gravity flow of a 1-kg sample of corn kernels at rest from an Ohaus bushel test-weight holding funnel. Germination was determined on 400 seeds by the method of the Association of Official Seed Analysts (AOSA 1970). All tests were replicated two or more times.

Statistical Analysis

A mean and standard error for the four treated values (tests B, C, D, and E) was calculated at zero time and at eight months for each measurement. The control measurement was then tested by two-tailed Z-test to estimate the probability that it could be in the distribution of measurements of the treated corn. A low probability (i.e. less than 0.05) would indicate that the treatments

TABLE I
Physical Characteristics of Whole Corn Kernels[a]

Test	Corn Treatment	Test Weight (kg/m^3)	100-Kernel Weight (g)	Floating Kernels (1.275 s.g., %)	Hardness Index	Stress Cracks (%)	Stein Breakage <12/64 in. (%)	Flow Rate (kg/hr)	Germination (%)
Time zero									
A	Control	770	31	86	Soft	6	2	544	91
B	200 ppm mineral oil	726	30	81	Soft	5	6	458	85
C	100 ppm soybean oil plus 100 ppm lecithin	729	31	79	Soft	3	5	485	84
D	200 ppm soybean oil	710	30	80	Soft	5	6	445	89
E	400 ppm soybean oil	717	30	79	Soft	4	5	444	90
Mean[b]		721	30.1	79.7	Soft	4.3	5.4	460	87
Standard error[b]		4.0	0.22	0.32	...	0.43	0.31	10	1.5
Probability[c]		<0.01	0.13	<0.01	...	0.08	<0.01	<0.01	0.16
Time eight months									
A	Control	749	30	83	Soft	4	4	544	91
B	200 ppm mineral oil	745	30	81	Soft	7	3	531	85
C	100 ppm soybean oil plus 100 ppm lecithin	741	33	77	Soft	3	4	517	85
D	200 ppm soybean oil	749	30	75	Soft	5	3	531	88
E	400 ppm soybean oil	739	29	76	Soft	5	4	522	91
Mean[b]		744	30.1	77.4	Soft	5.0	3.4	525	87
Standard error[b]		2.1	0.22	1.35	...	0.80	0.09	4.7	1.4
Probability[c]		0.14	0.98	0.03	...	0.52	<0.01	0.04	0.18
Average time effect[d]		23*	0.4	−2.4	...	0.7	−1.9*	65*	0.4

[a] 10 ± 0.5% moisture.
[b] Means and standard errors of means are based on the four treated values (tests B, C, D, and E).
[c] Probability that the control treatment value belongs with treated values (two-tailed Z).
[d] Average difference (eight months minus time zero) for the treated values, significance (* $P < 0.05$) determined by the paired t test.

had a significant effect on a particular measurement. Time effects were tested by paired *t* tests, where the pairs were the values after zero time and eight months for each of the treatments (controls were not included). A significant *t* test would indicate a change over time in a direction consistent across the four treatments.

RESULTS AND DISCUSSION

Physical Characteristics

Physical characteristics of the control and four oil-treated samples at zero time are listed in Table I. Test weight of the oil-treated samples was lower ($P < 0.01$) by 41–60 kg/m^3 compared with the control. Presumably this was caused by the adhesive character of surface oil on the kernel. Mounts et al (1988) also showed a decrease in corn and wheat test weight upon initial oil application. Lai et al (1981) showed no difference in test weight at zero time with corn treated with 200 ppm mineral oil or 400 ppm Durkex (vegetable oil). Kernel density as measured by the "floaters test" was increased by 5–7 percentage points for the oil-treated samples. The flowability of oil-treated corn averaged 460 kg/hr compared ($P < 0.01$) with 544 kg/hr for the untreated control. This flow-inhibiting effect of surface oil will increase energy use when such corn is handled with augers, pneumatic systems, or other methods. Kernel breakage susceptibility as measured by the Stein test showed slightly increased breakage for the oil-treated corn lots. Kernel hardness index, 100-kernel weight, stress crack count, and germination were only slightly affected by oil treatment at zero time. Germination measures corn viability and may indicate kernel damage by drying or handling (Peplinski et al 1975).

After eight months of storage at 25°C, test weight of the control was similar to treated test weights, ranging from 739 to 749 kg/m^3. Mounts et al (1988) also noted an increased test weight in oil-treated corn as storage time increased to 12 months. Hundred-kernel weight was increased only for the corn treated with 100 ppm soybean oil + lecithin. Kernel density measured by floating kernels remained increased by treatment after storage and ranged from 2 to 8 percentage points greater than the control at eight months. Kernel hardness index, stress crack count, kernel breakage susceptibility, and germination were still unaffected by oil treatment or affected only slightly after eight months. For the treated corn, test weight and flow rate increased while kernel breakage susceptibility decreased ($P < 0.05$) over time.

Roller Milling Yields and Fat Contents of Fractions from Degermed Corn

Table II lists roller milling product yields and HRD throughputs at zero time. First-break grit yield, an indicator of corn hardness, showed no trend with oil treatment and varied from 11 to 16%. Prime products, a mixture of low-fat grits, meal, and flour, ranged from 60 to 62% yield; these values are similar to those reported by Peplinski et al (1982, 1983). Germ, a source of corn oil, gave yields of 13–15%. The yields for hominy feed fractions showed little variation: degermer fines, 3%; bran meal, 4–5%; high-fat meal and flour, 9–11%; and hull, 7–8%. These fractions are usually high in fat content and generally go into animal feed products. Degermer throughput, the rate at which whole corn is ground through the HRD, was 1.73 kg/min with corn treated with 200 ppm of soybean oil, an increase of 15% compared with the control throughput.

After eight months of storage, roller milling response showed little variation in first-break grits (12–14%), prime products (58–61%), germ (14%), and hominy feed (23–26%) yields compared with zero-time milling. Degermer throughput was reduced after storage for all corns except for the lot treated with 100 ppm soybean oil + 100 ppm lecithin. Corn treated with 400 ppm soybean oil showed the lowest degermer throughput both at zero time (1.41 kg/min) and after storage (1.38 kg/min). None of the yield components had a consistent ($P < 0.05$) change over time.

Fat content of grits and prime products was significantly increased at zero time by oil treatment but not changed by eight months of storage (Table III). Results are similar to those reported previously (Peplinski et al 1983, 1984b). Control corn first-break oil content was slightly lower, 0.03–0.2 percentage points, than oil-treated corn at zero time and after eight months' storage. The addition of oil sprayed on the kernels does not account for the increased oil contents in the grits or prime products. The hominy

TABLE II
Degermer Throughput[a] and Yield[b] of Roller-Milled Fractions

Test	Corn Treatment	First-Break Grits (%)	2nd-, 3rd-Break Grits (%)	Low-Fat Meal and Flour (%)	Prime Products[c] (%)	Degerminator Fines (%)	High-Fat Meal and Flour (%)	Bran Meal (%)	Hull (%)	Germ (%)	Throughput (%)
Time zero											
A	Control	13	33	14	60	2.7	10	4.6	8.0	14	1.50
B	200 ppm mineral oil	13	34	16	62	2.6	9	4.2	6.6	15	1.55
C	100 ppm soybean oil plus 100 ppm lecithin	13	32	15	60	3.4	11	5.0	7.2	13	1.45
D	200 ppm soybean oil	11	34	16	61	2.3	11	4.7	7.5	14	1.73
E	400 ppm soybean oil	16	30	15	61	3.0	10	4.6	6.8	14	1.43
Mean[d]		13.0	32.6	15.4	61.2	2.8	10.5	4.6	7.0	14.0	1.54
Standard error[d]		1.09	0.92	0.17	0.46	0.23	0.28	0.18	0.19	0.44	0.07
Probability[e]		>0.50	>0.50	0.03	0.19	>0.50	>0.50	>0.50	0.01	>0.50	>0.50
Time eight months											
A	Control	13	31	15	59	3.1	11	4.9	8.1	14	1.48
B	200 ppm mineral oil	14	30	15	59	3.1	11	5.0	8.0	14	1.38
C	100 ppm soybean oil plus 100 ppm lecithin	13	33	16	61	3.1	11	3.9	6.6	14	1.48
D	200 ppm soybean oil	12	33	14	58	2.8	12	5.2	8.4	14	1.55
E	400 ppm soybean oil	13	32	15	61	3.2	10	4.0	7.5	14	1.38
Mean[d]		13.0	31.9	14.7	59.6	3.0	11.0	4.6	7.6	14	1.45
Standard error[d]		0.57	0.63	0.28	0.89	0.10	0.32	0.33	0.38	0.13	0.04
Probability[e]		0.50	>0.50	>0.50	>0.50	>0.50	0.40	>0.50	>0.50	0.32	>0.50
Average time effect[f]		−0.1	−0.8	−0.5	−1.5	0.2	0.40	−0.05	0.6	0.2	0.09

[a] 22% moisture.
[b] 9 ± 1.0% moisture.
[c] 1st, 2nd, 3rd-break grits, low-fat meal and flour.
[d] Means and standard errors of means are based on the four treated values (test B, C, D, and E).
[e] Probability that the control treatment value belongs with treated values (two-tailed *Z*).
[f] Average difference (eight months minus time zero) for the treated values, none were significant ($P < 0.05$) determined by the paired *t* test.

TABLE III
Fat Content[a] of Rolled Milled Fractions

Test	Corn Treatment	First-Break Grits (%)	2nd-, 3rd-Break Grits (%)	Low-Fat Meal and Flour (%)	Prime Products[b] (%)	Degerminator Fines (%)	High-Fat Meal and Flour (%)	Bran Meal (%)	Hull (%)	Germ (%)
Time zero										
A	Control	0.38	0.36	0.38	0.37	1.3	1.4	3.6	2.1	23.6
B	200 ppm mineral oil	0.48	0.52	0.57	0.53	1.3	1.6	3.7	1.9	23.0
C	100 ppm soybean oil plus 100 ppm lecithin	0.54	0.60	0.74	0.63	1.4	1.8	4.6	2.3	23.9
D	200 ppm soybean oil	0.58	0.55	0.63	0.58	1.1	1.7	4.1	2.1	22.9
E	400 ppm soybean oil	0.58	0.57	0.68	0.60	1.6	1.8	4.4	1.5	23.0
Mean[c]		0.55	0.56	0.65	0.58	1.3	1.7	4.2	1.7	23.2
Standard error[c]		0.022	0.018	0.05	0.027	0.11	0.08	0.19	0.30	0.24
Probability[d]		<0.01	<0.01	<0.01	<0.01	>0.50	0.03	0.15	>0.50	0.37
Time eight months										
A	Control	0.47	0.43	0.39	0.43	1.1	1.2	3.7	2.0	23.5
B	200 ppm mineral oil	0.50	0.45	0.47	0.47	1.3	1.4	3.5	1.7	23.6
C	100 ppm soybean oil plus 100 ppm lecithin	0.58	0.53	0.63	0.57	1.2	1.7	4.8	1.6	23.8
D	200 ppm soybean oil	0.66	0.60	0.70	0.63	1.4	1.6	4.4	2.7	23.4
E	400 ppm soybean oil	0.48	0.50	0.42	0.44	1.0	1.4	4.8	1.2	23.5
Mean[c]		0.55	0.52	0.55	0.53	1.2	1.5	4.4	2.0	23.5
Standard error[c]		0.04	0.033	0.08	0.059	0.08	0.11	0.32	0.24	0.08
Probability[d]		0.30	0.17	0.22	0.23	>0.50	>0.37	>0.50	>0.50	>0.50
Average time effect[e]		0.0	−0.04	−0.1	−0.04	−0.1	−0.2	−0.3	0.2	0.4

[a] Percent dry basis.
[b] 1st-, 2nd-, 3rd-break grits, low-fat meal and flour.
[c] Means and standard errors of means are based on the four treated values (test B, C, D, and E).
[d] Probability that the control value belongs with treated value (two-tailed Z).
[e] Average difference (eight months minus time zero) for the treated values, none were significant ($P < 0.05$) determined by the paired t test.

feed fraction oil contents were not affected by oil treatment or storage time. Calculated recoverable oil of the germ fractions ranged from 2.38 to 2.61 lb of oil per hundredweight of corn and was not statistically different at zero time or after storage.

Chemical compositions of the control and oil-treated whole kernel samples were unchanged at zero time and after eight months' storage and were similar to values previously reported (Peplinski et al 1982, 1989).

CONCLUSIONS

Oil treatment to reduce dustiness caused minor differences in corn physical characteristics and dry-milling response. There were no major differences whether 200 or 400 ppm soybean oil, 200 ppm mineral oil, or 100 ppm soybean oil + 100 ppm of lecithin was used as the treatment.

Some properties changed significantly upon storage after oil treatment. Corn bulk density as measured by test weight decreased an average of 50 kg/m^3 initially after oil treatment, but after eight months' storage the average test weight decrease was only 5 kg/m^3. Corn flowability was lowered an average of 84 kg/hr initially; after storage it was decreased only an average of 19 kg/hr. The initial test weight decrease most likely was caused by cohesion of oil-coated kernels, and was not a true decrease in kernel density. Zero time dry-milled control grit and prime product fat contents were significantly lower ($P < 0.01$) than those from the oil-treated corns.

Our results indicate that, when corn is sprayed with oil at levels used in this study, buyers and users will have to assume that freshly treated grain may have lowered test weight bulk density with no true density decrease. Dry millers may see a slightly higher fat content of less than 0.2 percentage points increase in the grit and prime products fractions.

ACKNOWLEDGMENTS

The authors gratefully acknowledge F. B. Alaksiewicz, J. D. Glover, R. L. Haig, and M. I. Schulte for their help in conducting the milling work and chemical and physical analyses, and T. Nelsen who performed the statistical evaluations.

LITERATURE CITED

AMERICAN ASSOCIATION OF CEREAL CHEMISTS. 1962. Cereal Laboratory Methods. Method 44-15A, approved October 1975. The Association: St. Paul, MN.

ASSOCIATION OF OFFICIAL AGRICULTURAL CHEMISTS. 1960. Official Methods of Analysis, 9th ed. The Association: Washington, DC.

ASSOCIATION OF OFFICIAL SEED ANALYSTS. 1970. Rules for Testing Seed. Vol. 60, no. 2. West Experiment Station, Univ. of Massachusetts: Amherst, MA.

BLACK, L. T., SPYRES, G. G., and BREKKE, O. L. 1967. Determination of oil contents of dry-milled corn fraction by gas-liquid chromatography. Cereal Chem. 44:152.

BREKKE, O. L., PEPLINSKI, A. J., GRIFFIN, G. L., JR., and ELLIS, J. J. 1972. Dry-milling of corn attacked by southern leaf blight. Cereal Chem. 49:466.

GOFORTH, K. J., PARNELL, C. B., JR., and JONES, D. D. 1985. Using oil additive for grain dust control. Agric. Eng. 66:8.

LAI, F. S., POMERANZ, Y., and ROBBINS, G. S. 1986. Effects on barley and malt of oil additives to reduce dust. Cereal Chem. 63:512.

LAI, F. S., MILLER, B. S., MARTIN, C. R., STOREY, C. L., BOLTE, L., SHOGREN, M., FINNEY, K. F., and QUINLAN, J. K. 1981. Reducing grain dust with oil additives. Trans. ASAE 24:1626.

MOUNTS, T. L., WARNER, K., LAI, F. S., MARTIN, C. R., POMERANZ, Y., BURKHOLDER, W. E., PEPLINSKI, A. J., CLASS, A. R., and DAVIS, C. W. 1988. Effect of laboratory scale oil applications on quality factors of corn, soybeans, and wheat. Cereal Chem. 65:175.

NIELSEN, H. C., WALL, J. S., and INGLETT, G. E. 1979. Flour containing protein and fiber made from wet-milled corn germ with potential food use. Cereal Chem. 56:144.

PEPLINSKI, A. J., BREKKE, O. L., GRIFFIN, E. L., JR., HALL, G. and HILL, L. D. 1975. Corn quality as influenced by harvest and drying conditions. Cereal Foods World 20:145.

PEPLINSKI, A. J., ANDERSON, R. A., and BREKKE, O. L. 1982. Corn dry milling as influenced by harvest and drying conditions. Trans. ASAE 25:1114.

PEPLINSKI, A. J., ECKHOFF, S. R., WARNER, K., and ANDERSON, R. A. 1983. Physical testing and dry milling of high-moisture corn preserved with ammonia while drying with ambient air. Cereal Chem. 60:442.

PEPLINSKI, A. J., ANDERSON, R. A., and ALAKSIEWICZ, F. B.

1984a. Corn dry-milling studies: Shortened mill flow and reduced temper time and moisture. Cereal Chem. 61:60.
PEPLINSKI, A. J., ANDERSON, R. A., and ECKHOFF, S. R. 1984b. A dry-milling evaluation of trickle sulfur dioxide-treated corn. Cereal Chem. 61:289.
PEPLINSKI, A. J., PAULSEN, M. R., ANDERSON, R. A., and KWOLEK, W. F. 1989. Physical, chemical, and dry-milling characteristics of corn hybrids from various genotypes. Cereal Chem. 66:117.
THOMPSON, R. A., and FOSTER, G. H. 1963. Stress cracks and breakage in artificially dried corn. U.S. Dep. Agric. Mkt. Res. Rep. 631. U.S. Government Printing Office: Washington, DC.
USDA. FEDERAL GRAIN INSPECTION SERVICE. 1988. Official United States Standards for Grain. U.S. Government Printing Office: Washington, DC.
WILBUR, D. A., JR. 1985. Patented process uses mineral, vegetable oils to suppress grain dust. Grain Storage Handling 7:24.
WICHSER, W. R. 1961. The world of corn processing. Am. Miller 89:29.

[Received June 30, 1989. Revision received October 7, 1989. Accepted October 23, 1989.]