Germ Weight, Germ Oil Content, and Estimated Oil Yield for Wet-Milled Yellow Dent Corn as Affected by Moisture Content at Harvest and Temperature of Drying Air

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ABSTRACT

A split-plot experimental design was used to determine the effect of moisture content at harvest and temperature of drying air on weight, oil content, and estimated oil yield of corn germs recovered from laboratory wet milling. The effects were determined for a high-yielding hybrid of yellow dent corn widely grown in the corn belt that was hand-picked and hand-shelled. Germ oil content decreased significantly as moisture content at harvest and temperature of drying air increased. Germ weight and estimated oil yield generally decreased as both moisture content at harvest and temperature of drying air increased from 17.2 to 29.6% and 22 to 93° C, respectively.

The advent of mechanical picking and shelling and artificial drying have made a tremendous impact on farming practices. The vast majority of corn in the United States is harvested with a combine and dried with some form of heated air. Both the harvesting and drying methods used affect the quality of corn used for wet milling (Watson 1987).

One aspect of the wet milling process, besides starch recovery, that is affected by harvesting and drying is oil recovery. Freeman (1973) noted that the introduction of field shelling initiated a decline in the oil content of corn received by wet milling plants. He explained that kernel impacts due to field shelling of corn containing 20–25% (wet basis) moisture caused structural damage and rupture of the germ. Rupture of the germ allows oil to flow into the endosperm. Oil that is lost from the germ is not recoverable after wet milling, because only the germ is processed for oil recovery. Approximately 84% of the kernel oil is stored in the germ (Watson 1984).

MacMasters et al (1959) were the first to hypothesize that drying corn with air at elevated temperatures contributed to low oil recovery from the germ. Vojnovich et al (1975) later reported that recovery of oil in wet-milling operations from corn with a high degree of combine damage was considerably lower than that from corn with a lower incidence of combine damage. Combine damage was obtained by regulating the cylinder speed and its clearance from the concave. However, the levels of damage were not quantified and the characteristics of damage were not clearly detailed.

Vojnovich et al (1975) also noted that increasing the drying temperature from 49 to 149° C (120 to 300° F) significantly reduced oil recovery from wet-milled corn that had low combine damage. Their tests indicated that oil recovery decreased from the control mean of 75.7% by 0.11 percentage points for each degree Celsius of drying air temperature above 49° C. However, harvest moistures ranging from 17 to 34% (wb) did not significantly affect oil recovery (Vojnovich et al 1975).

Previous studies did not compensate for mechanical damage in their determination of the effects of moisture content at harvest and temperature of drying air on oil recovery. The purpose of this study was to determine the effects of harvest moisture and drying temperature on the oil content of germ and oil yield without being confounded by differing levels of mechanical damage. The germ analyzed in this study was recovered from laboratory wet-milling experiments that used hand-picked and hand-shelled yellow dent corn.

MATERIALS AND METHODS

The raw material for this study was yellow dent corn, genotype B73 × LH38, grown during the crop year of 1985 on a Champaign County farm in Stanton Township, IL. The genotype was a high-yielding hybrid widely grown in the corn belt that was used as part of the studies conducted by Weller et al (1988). A 37-kg sample was hand-picked and hand-shelled at high, medium, and low mean moisture contents of 29.6, 21.9, and 17.2% (wb), respectively. The harvested samples were stored in sealed plastic bags and held at 4° C for up to 48 hr until the corn could be dried.

Drying

The corn samples were dried with the same laboratory dryers

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that Gunasekaran and Paulsen (1985) had previously used. Drying temperatures were controlled to within ±2°C at 22, 49, 71, and 93°C. Each laboratory dryer was equipped with a fan, heater, and temperature controller, and an airflow rate of 2.0 m^3/min per cubic meter of corn was maintained throughout drying. The drying was conducted in an environmentally controlled room at 22°C and 55% relative humidity.

A removable drying tray containing about 5 kg of corn leveled to a depth of approximately 2 cm was placed over the plenum chamber of each dryer. The grain bed was mixed intermittently during drying to obtain uniform drying. The drying tray with corn was periodically weighed for calculating moisture loss. When a grain sample reached 14% (wb) moisture based on a reading from an electronic moisture meter (GAC II, Dickey-john, Inc., Auburn, IL), it was transferred to a nylon mesh bag. The mesh bag was sealed inside a plastic bag and allowed to equilibrate at room temperature before storage.

After reaching room temperature, the samples were removed from the plastic bag and placed inside an environmental chamber (Aminco-Aire unit, PGC, Inc., Black Mountain, NC) at 20°C and 70% relative humidity. All the samples were allowed to equilibrate for at least four weeks before further testing.

Germ Recovery

Germs were liberated from each corn sample after steeping. The steeping process used was part of a laboratory-scale wet-milling process developed by Watson et al (1951, 1955) and modified by Weller et al (1988). Corn samples containing approximately 350 g of dry matter were steeped for a minimum of 40 hr in a 0.1% (w/w) sulfur dioxide solution at 53°C and pH 3.7. After steeping, the steeped corn was strained from the steepwater, and a 200.00 ± 0.005 g sample of steeped corn was retained for degermination. The remainder of the steeped corn was stored in a plastic bag at 4°C for later moisture determination.

Degermination was carried out in a commercial blender model 5011 (Waring, Dynamics Corp. of America, New Hartford, CT). The agitator blades in the 800-ml bowl had been reversed to increase the impacting action and decrease cutting. The blender motor was operated on the low setting through an autotransformer set at 40% of the 120 V line voltage. The bowl was charged with 250 ml of distilled water for each 200-g corn sample and blended for 2 min. Slurry from the degermination blending was poured into a 1,000-ml beaker and periodically swirled to keep slurry solids suspended with germs floating.

The germs were physically removed from the degermination slurry. After separation, the germs were twice rinsed with distilled water and dried at 40°C in a laboratory convection oven for 48 hr before weighing. Germ samples, consisting of 2.00 g of germ already dried at 40°C, were removed for determination of dry matter (moisture content).

Moisture Content

Moisture content was determined using a modification of the AACC air oven method 44-15A (AACC 1983). A whole germ sample of 2.00 ± 0.01 g was weighed into a tared metal dish. The dish was placed in an air oven at 103 ± 1°C for 72 hr, cooled in a desiccator, and reweighed to the nearest 0.01 g. Corn moisture contents were determined in a like manner except that 100.00 ± 0.01 g whole-kernel samples were used.

Oil Content

Oil content was determined by nuclear magnetic resonance (Varian PA-7, Varian Associates, Palo Alto, CA) following the procedure described by Alexander et al (1967). Predried germ samples of 4.00 ± 0.05 g and predried whole kernel samples of 20.00 ± 0.05 g were tested in duplicate.

Estimated Oil Yield

The estimated oil yield was calculated as the weight of germ dried at 40°C multiplied by the germ dry matter multiplied by the germ oil content.

Statistical Analyses

A split-plot experimental design was used to evaluate the effect of harvest moisture, drying air temperature, and their interaction on germ weight, germ oil content, and estimated oil yield for wet-milled yellow dent corn at a 5% probability level (Steel and Torrie 1960). Orthogonal comparisons of the main effects in the split-plot were made at a 5% probability level (R. D. Seif, University of Illinois-UC, Department of Agronomy, 1985, *personal communication*). Significant main effects and interactions in the split-plot were analyzed using Tukey's standardized range test at a 5% probability level (SAS 1985).

TABLE I
Means of Germ Weight, Germ Oil Content, and Estimated Oil Yield for Wet-Milled Yellow Dent Corn at Three Harvest Moistures[a]

Harvest Moisture (%, wb)	Germ Weight (g)	Germ Oil Content (%, db)	Estimated Oil Yield (g)
29.6	8.37 ± 0.36 a	43.3 ± 2.5 a	3.5 ± 0.3 ns[b]
21.9	8.24 ± 0.16 a	46.2 ± 1.7 b	3.7 ± 0.1 ns
17.2	7.81 ± 0.19 b	46.5 ± 1.0 b	3.5 ± 0.1 ns

[a] Means ± SD of eight samples. Means within columns with different letters differ significantly ($P < 0.05$) using Tukey's standardized range test after the effect of harvest moisture was found to be significant ($P < 0.05$) in the split-plot analysis.
[b] Not significant.

TABLE II
Means of Germ Weight, Germ Oil Content, and Estimated Oil Yield for Wet-Milled Yellow Dent Corn at Four Drying Air Temperatures[a]

Drying Air Temperature (°C)	Germ Weight (g)	Germ Oil Content (%, db)	Estimated Oil Yield (g)
22	8.23 ± 0.34 ns[b]	46.1 ± 1.9 a	3.7 ± 0.2 a
49	8.06 ± 0.43 ns	46.3 ± 1.7 a	3.6 ± 0.2 ab
71	8.18 ± 0.32 ns	45.5 ± 1.8 ab	3.6 ± 0.1 ab
93	8.10 ± 0.34 ns	43.4 ± 2.9 b	3.4 ± 0.3 b

[a] Means ± SD of six samples. Means within columns with different letters differ significantly ($P < 0.05$) using Tukey's standardized range test after the effect of drying air temperature was found to be significant ($P < 0.05$) in the split-plot analysis.
[b] Not significant.

RESULTS AND DISCUSSION

Germ Weight

A significant linear decrease in mean germ weights from 8.37 ± 0.36 to 7.81 ± 0.19 g was observed as moisture content at harvest decreased from 29.6 to 17.2% (Table I). Temperature of drying air did not have a significant effect on the mean germ weights shown in Table II. At the highest moisture of 29.6% and highest drying temperature of 93°C, the mean germ weight fell below the means of the remaining samples harvested at 29.6% moisture and of all the samples harvested at 21.9% moisture (Table III). Such an observation may result from the severe drying treatment the samples received, and may account for the significant harvest moisture and drying air temperature interaction.

Germ Oil Content

Analyses of variance with orthogonal comparison showed that increases in both moisture content at harvest (Table I) and drying air temperature (Table II) resulted in significant linear decreases in germ oil content means. The oil content means at the high, medium, and low harvest moistures were 43.3 ± 2.5, 46.2 ± 1.7, and 46.5 ± 1.0%, respectively. The oil content means decreased from 46.1 ± 1.9 to 43.4 ± 2.9% as drying air temperature increased from 22 to 93°C. The interaction of moisture content at harvest and temperature of drying air on oil content was found not to be significant.

Estimated Oil Yield

The calculation of "estimated oil yield" represented the total

TABLE III
Means of Germ Weight, Germ Oil Content, and Estimated Oil Yield for Wet-Milled Yellow Dent Corn at Each Harvest Moisture and Drying Air Temperature Combination[a]

Harvest Moisture (%, wb)	Drying Air Temperature (°C)	Germ Weight (g)	Germ Oil Content (%, db)	Estimated Oil Yield (g)
29.6	22	8.62 ± 0.01 a	45.5 ± 2.8 ns[b]	3.8 ± 0.2 a
29.6	49	8.44 ± 0.21 abc	44.3 ± 0.9 ns	3.6 ± 0.2 ab
29.6	71	8.54 ± 0.10 a	43.6 ± 0.6 ns	3.6 ± 0.1 ab
29.6	93	7.88 ± 0.40 cde	39.9 ± 0.8 ns	3.0 ± 0.2 b
21.9	22	8.17 ± 0.15 abcd	47.3 ± 2.3 ns	3.8 ± 0.2 a
21.9	49	8.18 ± 0.04 abcd	47.6 ± 0.6 ns	3.8 ± 0.0 a
21.9	71	8.17 ± 0.16 abcd	45.5 ± 0.8 ns	3.6 ± 0.1 ab
21.9	93	8.47 ± 0.05 ab	44.4 ± 0.9 ns	3.6 ± 0.1 ab
17.2	22	7.89 ± 0.13 bcde	45.7 ± 1.0 ns	3.5 ± 0.0 ab
17.2	49	7.55 ± 0.20 de	47.1 ± 0.4 ns	3.5 ± 0.1 ab
17.2	71	7.84 ± 0.08 de	47.4 ± 1.0 ns	3.6 ± 0.0 ab
17.2	93	7.96 ± 0.01 bcde	46.0 ± 0.5 ns	3.6 ± 0.0 ab

[a]Means ± SD of two samples. Means within columns with different letters differ significantly ($P < 0.05$) using Tukey's standardized range test after the effect of harvest moisture and drying air temperature interaction was found to be significant ($P < 0.05$) in the split-plot analysis.
[b]Not significant.

amount of oil theoretically recoverable from the germ obtained by wet milling. Increasing drying air temperature resulted in a significant linear decrease in the mean estimated oil yield from 3.7 ± 0.2 g at 22°C to 3.4 ± 0.3 g at 93°C (Table II). No significant change in the mean oil yield was observed as harvest moisture decreased from high to low levels as shown in Table I.

The significant harvest moisture and drying air temperature interaction was most likely due in part to the large drop in estimated oil yield observed between the medium and high harvest moisture levels at 93°C. However, in general, no clear pattern was observed relating change of oil yield with changes in moisture content at harvest and temperature of drying air. Only corn harvested at 29.6% moisture and dried with air at 93°C had an estimated oil recovery significantly different from similar corn dried at 22°C (Table III).

Comparison of the effects of moisture content at harvest and temperature of drying air on the oil recoveries of Vojnovich et al (1975) with the estimated oil yields of this study show similarities. Vojnovich et al (1975) determined oil recoveries for corn samples with either high or low mechanical damage. This study determined oil yield for corn samples with no mechanical damage. Each study observed no significant effect of moisture content at harvest on oil recovery or yield. However, both showed significant decreases due to increases in temperature of drying air. Therefore, a general observation can be made that mechanical damage is not a prerequisite for a reduction in recoverable oil to result from increased temperature of drying air. Further study is necessary to elucidate if indeed mechanical damage to corn samples does decrease oil recovery or yield beyond that of hand-picked and hand-shelled corn samples, given the same moisture content at harvest and the same drying air temperature.

CONCLUSIONS

Germ weight means decreased significantly as harvest moisture decreased from 29.6 to 17.2% for the three lowest drying temperature treatments. Germ oil content decreased significantly as the moisture content at harvest and the temperature of drying air increased from 17.2 to 29.6% and 22 to 93°C, respectively. Estimated oil yield decreased significantly as temperature of drying air increased from 22 to 93°C for the two highest harvest moistures.

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LITERATURE CITED

AMERICAN ASSOCIATION OF CEREAL CHEMISTS. 1983. Approved Methods of the AACC. Method 44-15A, revised October 1981. The Association: St. Paul, MN.

ALEXANDER, D. E., SILVELA S., L., COLLINS, F. I., and RODGERS, R. C. 1967. Analysis of oil content of maize by wide-line nmr. J. Am. Oil Chem. Soc. 44:555-558.

FREEMAN, J. E. 1973. Quality factors affecting value of corn for wet milling. Trans. ASAE 16:671-678,682.

GUNASEKARAN, S., and PAULSEN, M. R. 1985. Breakage resistance of corn as a function of drying rates. Trans. ASAE 28:2071-2076.

MacMASTERS, M. M., FINKNER, M. D., HOLZAPFEL, M. M., RAMSER, J. H., and DUNGAN, G. H. 1959. A study of the effect of drying conditions on the suitability for starch production of corn artificially dried after shelling. Cereal Chem. 36:247-260.

SAS INSTITUTE. 1985. The GLM procedure. Pages 433-506 in: SAS User's Guide: Statistics. The Institute: Cary, NC.

STEEL, R. G. D., and TORRIE, J. H. 1960. Principles and procedures of statistics. McGraw-Hill: New York.

VOJNOVICH, C., ANDERSON, R. A., and GRIFFIN, E. L., JR. 1975. Wet-milling properties of corn after field shelling and artificial drying. Cereal Foods World 20:333-335.

WATSON, S. A. 1984. Corn and sorghum starches: Production. Pages 417-418 in: Starch: Chemistry and Technology. R. L. Whistler, J. N. BeMiller, and E. F. Paschall, eds. Academic Press: Orlando, FL.

WATSON, S. A. 1987. Measurement and maintenance of quality. Pages 125-183 in: Corn: Chemistry and Technology. S. A. Watson and P. E. Ramstad, eds. American Association of Cereal Chemists: St. Paul, MN.

WATSON, S. A., WILLIAMS, C. B., and WAKELY, R. D. 1951. Laboratory steeping procedures used in a wet milling research program. Cereal Chem. 28:105-118.

WATSON, S. A., SANDERS, E. H., WAKELY, R. D., and WILLIAMS, C. B. 1955. Peripheral cells of endosperms of grain sorghum and corn and their influence on starch purification. Cereal Chem. 32:165-182.

WELLER, C. L., PAULSEN, M. R., and STEINBERG, M. P. 1988. Correlation of starch recovery with assorted quality factors of four corn hybrids. Cereal Chem. 65:392-397.

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