The Influence of Moisture Content and Cooking on the Screw Pressing and Prepressing of Corn Oil from Corn Germ

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ABSTRACT: Samples of corn germ were obtained from a commercial corn wet mill (factory dried to about 3% moisture) and a commercial corn dry mill (undried, produced in the mill with about 13% moisture). The germ samples (200 g each) were cooked for various times in either a conventional oven at 180°C or a microwave oven at 1500 W. Bench-scale single screw pressing was then performed. With the dry milled corn germ, no oil was obtained from the uncooked germ. A maximal yield of about 5% oil [26% of total oil recovery (TOR), relative to hexane extraction] was obtained by cooking the dry-milled germ for 6.5 min in a conventional oven at 180°C before pressing. A maximal yield of about 7% oil (37% TOR) was obtained by cooking the dry-milled germ for 4.5 min in a microwave oven at 1500 W before pressing. With the wet-milled germ, yields of about 7% oil (18% TOR) were obtained with the uncooked germ and yields increased to a maximum of about 22% oil (56% TOR) by cooking in a conventional oven at 180°C for 5 min or a maximum of about 17% oil (44% TOR) by cooking for 4 min in a microwave oven at 1500 W. These results indicate that microwave and conventional oven cooking are both effective pretreatments before pressing. Microwave preheating resulted in higher oil yields with dry-milled germ, and conventional oven pretreatment resulted in higher oil yields with factory-dried wet-milled corn germ.

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KEY WORDS: Corn, expeller, extraction, germ, maize, oil, press.

Dry kernels of grain corn contain low levels of oil (about 4%), but most of the oil is contained in the embryo or "germ" portion of the kernel. Corn germ is a co-product that is produced when corn is processed by either wet milling (a process developed to remove the starch from corn kernels efficiently) or dry milling (a process developed to remove the germ and bran from corn to increase the stability of corn grain products for food uses). Corn germ obtained from wet mills usually contains about 40–50% oil, and corn germ from dry mills usually contains about 20–25% oil (both yields expressed on a dry weight basis) (1). Currently, about 90% of the commercial corn oil produced in the United States is obtained from wet-milled corn germ (2). Almost all of the corn oil produced in the United States is obtained by either direct hexane extraction of the germ or a combination of prepressing/hexane extraction (1,3). Although pressing alone is sometimes used to obtain corn oil, the yields are lower and it is generally considered less cost efficient than hexane extraction (4). Although pressing has not been a major area of research in recent years, interest in pressing and especially cold pressing has recently been rekindled in the field of nutraceutical oils such as flaxseed (5) and crambe (6–10). Extrusion-expelling technology of soybeans is being used to produce soybean oil at some farm cooperatives and family-owned farms in the United States. Although the process has received considerable attention, still only about 1% of the soybean oil produced in the United States is obtained by mechanical means (11).

Our laboratory has recently started a research program to evaluate aqueous enzymatic extraction processes (12,13) to extract corn oil from corn germ without the use of potentially hazardous solvents ("green" processing). The current study was undertaken to explore the feasibility of prepressing some of the oil from the corn germ before aqueous enzymatic extraction. One rationale for this approach is that, in addition to economically removing some high-quality oil directly, the high temperatures and pressure associated with pressing may make it easier to remove the remainder of the corn oil from corn germ *via* aqueous enzymatic extraction methods.

MATERIALS AND METHODS

Samples of dry-milled corn germ (undried, ~13% moisture) were obtained from a commercial corn dry mill. Samples of wet-milled corn germ (dried at the mill to about 3% moisture) were obtained from a commercial corn wet mill. Both germ samples were stored in sealed containers at 4°C. On the day of the pressing, enough germ was removed from cold storage for that day's experiments and the germ was allowed to equilibrate to room temperature (~22°C), before cooking. Inconsistent results were obtained if cold germ was used.

Conventional oven cooking was conducted by spreading the germ (200 g) in a uniform layer in stainless steel baking pan (25 × 40 cm) and cooking it at 180°C in a Thelco Model 130 DM Laboratory Oven (Precision Scientific, Winchester, VA) for the specified time.

Microwave cooking was conducted by placing the germ (200 g) in a round Pyrex dish (19 cm diameter) in an Amana Radarange (1500 W, 2450 MHz) Microwave Oven (Maytag,

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Inc., Newton, IA) for the specified time. The microwave oven was not equipped with a turntable to rotate samples. During the microwave time range of 5–8 min, no burning or other signs of uneven cooking of the germ were observed.

After cooking, the mass of the cooked germ was measured (to determine moisture loss), and the hot germ was immediately poured into a Täby Model 20 Oil Press (Skeppsta Maskin AB, Örebro, Sweden). This press is heated with an electrical resistance-heating ring attached around the press head, set by the manufacturer to 100°C. Pressing was conducted at the highest screw speed setting and was conducted using the smallest orifice provided by the manufacturer. The crude oil was collected, filtered (Whatman #1 filter paper, 5 cm diameter) in a Buchner funnel with mild vacuum, and the mass of the filtered oil was measured. The yields of filtered oil (%) were calculated based on the 200-g fresh weight of germ before cooking and were not adjusted for moisture loss. Also, with a 200-g sample size of corn germ, about 30 g of germ remained in the screw portion of the press and was not pressed. The reported oil yields did not reflect this residual unpressed germ. Higher oil yields would thus be expected if larger sample sizes were pressed or if the yield values were based on dry weight rather than fresh weight.

Hexane extraction, to measure total oil recovery (TOR), was conducted by milling a 10-g sample of germ in a coffee mill (Krups, Model 203B) for 1 min. Triplicate 1-g samples were then extracted with 22 mL of hexane in a Dionex ASE 200 Accelerated Solvent Extractor (Sunnyvale, CA) using 11-cc extraction vessels, at 100°C and 1000 psi (14). Germ moisture content was measured using a 103°C convection oven according to AACC approved method 44-15A (15). Pressing experiments were performed in triplicate for each heat pretreatment. Each experiment was repeated at least two times. The data presented are the means and SD.

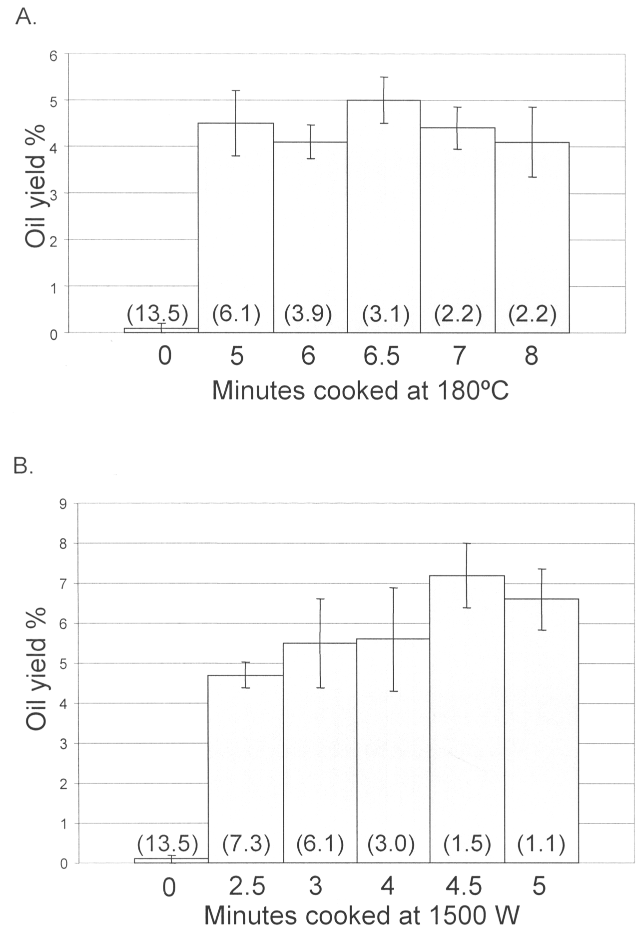

FIG. 1. Oil yields (filtered) from corn germ obtained from a commercial dry mill. (A) Oil yields after cooking in a conventional oven for various times. (B) Oil yields after cooking in a microwave oven for various times. Numbers in parentheses are moisture contents (%) of germ after oven treatment.

RESULTS AND DISCUSSION

During preliminary pressing of dry-milled corn germ (undried, ~13% moisture), no oil was obtained with uncooked germ (Fig. 1). Cooking the germ at 180°C for 5–8 min before pressing resulted in yields of about 4 to 5% oil, with maximal yields after 6.5 min of heating at 180°C (Fig. 1A). The effect of conventional oven cooking at other temperatures was evaluated, but we chose 180°C because most of the moisture was removed in less than 10 min, which was approximately the same time frame as for microwave cooking. Hexane extraction of the same dry-milled corn germ sample gave a yield of about 19% oil. The pressing yield of 5% oil represented about 26% of the TOR relative to hexane extraction. Examination of the moisture levels in the cooked germ indicated that the dry-milled germ should be cooked/dried at 180°C to a level of about 3% moisture for maximal oil yields. Microwave cooking of dry-milled corn germ from 2.5 to 5 min resulted in slightly higher yields (about 5–7% oil) than those obtained by 180°C cooking. The moisture content of the optimal microwave treatment (4.5 min) was about 1.5%, and its yield was about 7% oil (37% TOR). It is interesting that significant oil yields (4.7–7.1% oil) were obtained over a broad range of moisture contents (1.1–7.3%) with both conventional microwave cooking times.

Preliminary pressing of uncooked wet-milled corn germ resulted in yields of about 7% oil (Fig. 2). Although this germ was dried at the mill to a level of about 3% moisture, its moisture content often increased during shipping and storage. The moisture content of our wet-milled germ was measured as 5.3% immediately before pressing (Fig. 1). This increase in moisture occurred during shipping and storage. Cooking the germ at 180°C for 3–7 min before pressing resulted in yields of 10–22% oil, with maximal yields after 5 min of heating at 180°C (Fig. 2A). Hexane extraction of the same wet-milled corn germ sample gave a yield of about 39% oil. The pressing yield of 22% oil represented about 56% of the TOR relative to hexane extraction. Examination of the moisture levels in the cooked germ indicated that the wet-milled germ should be cooked/dried at 180°C to a level of about 2.0% moisture for maximal oil yields. Microwave cooking of wet-milled corn germ from 0 to 5.5 min resulted in slightly lower yields (in the range of 10 to 17% oil) than those obtained by 180°C cooking,

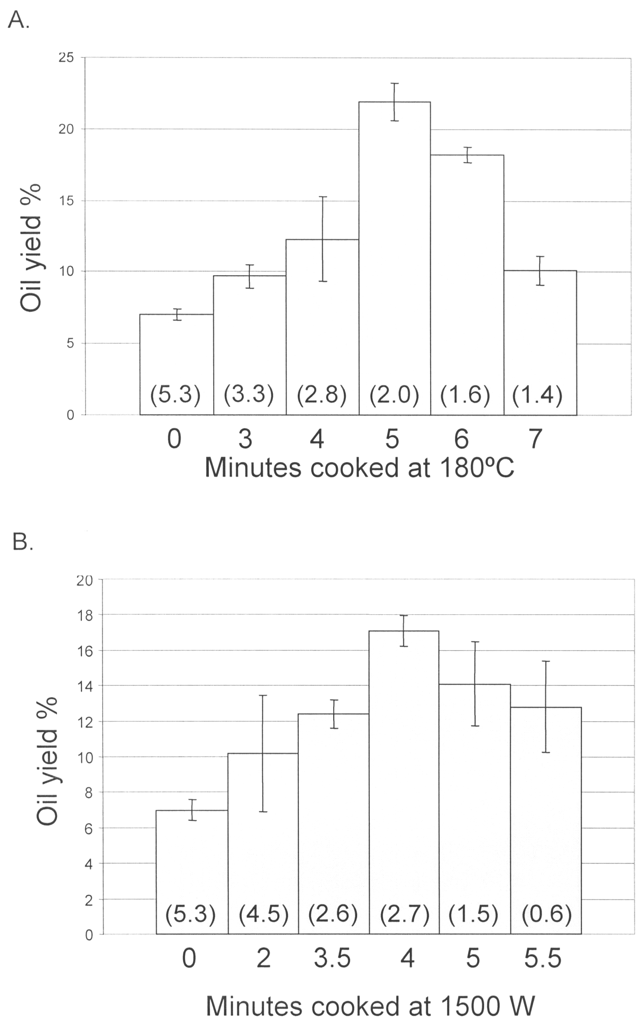

FIG. 2. Oil yields (filtered) from corn germ obtained from a commercial wet mill. (A) Oil yields after cooking in a conventional oven for various times. (B) Oil yields after cooking in a microwave oven for various times. Numbers in parentheses are moisture contents (%) of germ after oven treament.

with an optimal microwave cooking time of 4 min. The moisture content of the optimal microwave treatment was 2.7%. Unlike the case with dry-milled germ where oil yields remained relatively constant over a broad range of cooking times and moisture values, oil yields declined for wet-milled germ when moisture levels were reduced below about 2% (at 6 and 7 min of conventional oven cooking and at 5.0 and 5.5 min of microwave cooking).

Comparing the above results with dry-milled vs. wet-milled corn germ, microwave cooking appears to be more effective with dry-milled germ, but oven cooking appears to be more effective with wet-milled germ. Of course, it should be noted that wet-milled corn germ is routinely dried in the factory and the dry-milled germ is not. Since four of the seven major corn wet-milling companies in the United States (current member companies in the Corn Refiners Association) do not extract and sell corn oil, but instead dry their germ at the mill and ship it to hexane extraction facilities (16), factory-dried wet-milled germ is a product of commerce.

A major goal of this research was to compare the optimal cooking conditions to achieve maximal oil yields by prepressing corn germ from commercial wet and dry mills. The research was successful in identifying cooking conditions to effectively remove about half of the oil from corn germ from both wet and dry mills. This degree of oil removal is sufficient to evaluate the process from a prepressing standpoint and to use the partially de-oiled germ meal as a feedstock for our aqueous enzymatic extraction research program. The bench-scale press used in these studies was much smaller than pilot-scale presses, and it was not equipped to monitor and optimize internal temperatures and pressures during pressing. Therefore, optimized conditions and optimized pressing equipment would likely produce even higher yields of oil. It should also be noted that, because industrial screw presses are so much larger than our bench-scale press, the internal temperature and residence time of the corn germ in the industrial press may diminish or eliminate the need for a cooking pretreatment, depending on the size and internal surface area of the press. In their chapter on corn oil, Strecker *et al.* (17) note that in industrial applications wet-milled corn germ is pretreated (conditioned) by heating at 90—105°C to soften its intracellular structure and provide friction during flaking and pressing.

Few other recent studies have compared corn oil obtained from both wet- and dry-milled germ. List *et al.* (18) compared the differences in composition of corn oils from wet-milled germ and dry-milled germ obtained by supercritical CO_2 extraction, but we are not aware of comparable studies performed with either pressed or solvent-extracted oil from corn germ.

When comparing the effect of microwave cooking vs. conventional oven cooking, it is interesting to note that higher oil yields were achieved by microwave cooking of the dry-milled germ, whereas with the wet-milled germ higher oil yields were achieved after conventional oven cooking. A possible explanation for this effect is the difference in moisture content between the samples of dry-milled germ and wet-milled germ, with the former containing about 9% more moisture.

Because the common frequency (2450 MHz) used in microwave ovens heats oil more quickly than it heats water, it is not surprising that microwave cooking may be superior to conventional oven cooking for some applications (19). Oberndorfer and Lucke (20) compared the effect of microwave vs. radiofrequency thermal pretreatment of rapeseeds and found that microwave cooking resulted in superior mechanical oil extraction.

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