

Influence of Moisture Content and Cooking on the Bench Scale Screw Pressing of Corn Oil

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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). Currently, about 90% of the commercial corn oil produced in the United States is obtained from wet-milled corn germ. 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. 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. 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 and crambe.

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.

Our laboratory has recently started a research program to evaluate aqueous enzymatic extraction processes 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.

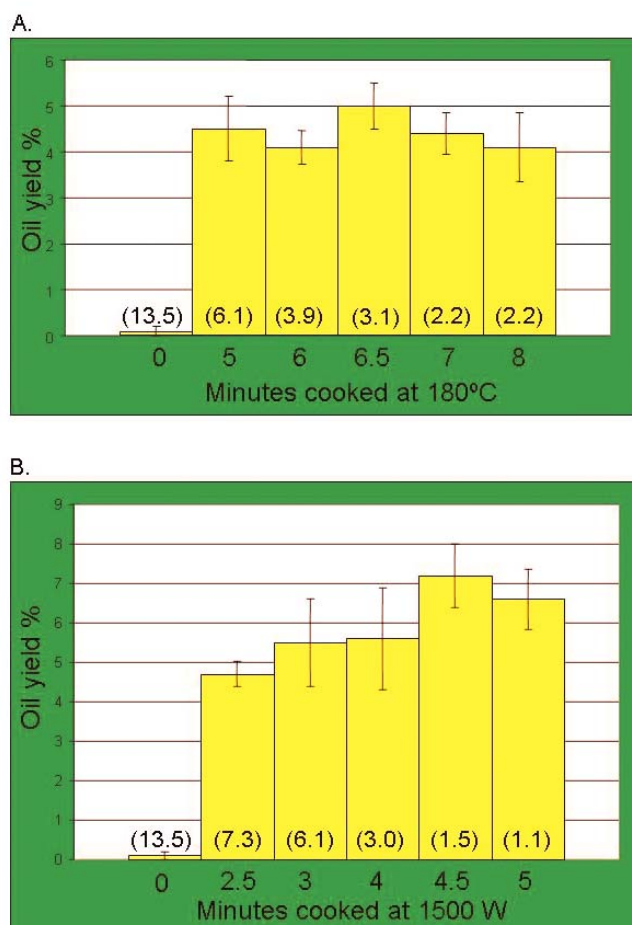


Figure 1. Oil yields (filtered) from corn germ obtained from a commercial dry mill. (A) Oil yields after cooking in a conventional oven for various times. (B) Oil yields after cooking in a microwave oven for various times. Numbers in parentheses are moisture contents (%) of germ after oven treatment.

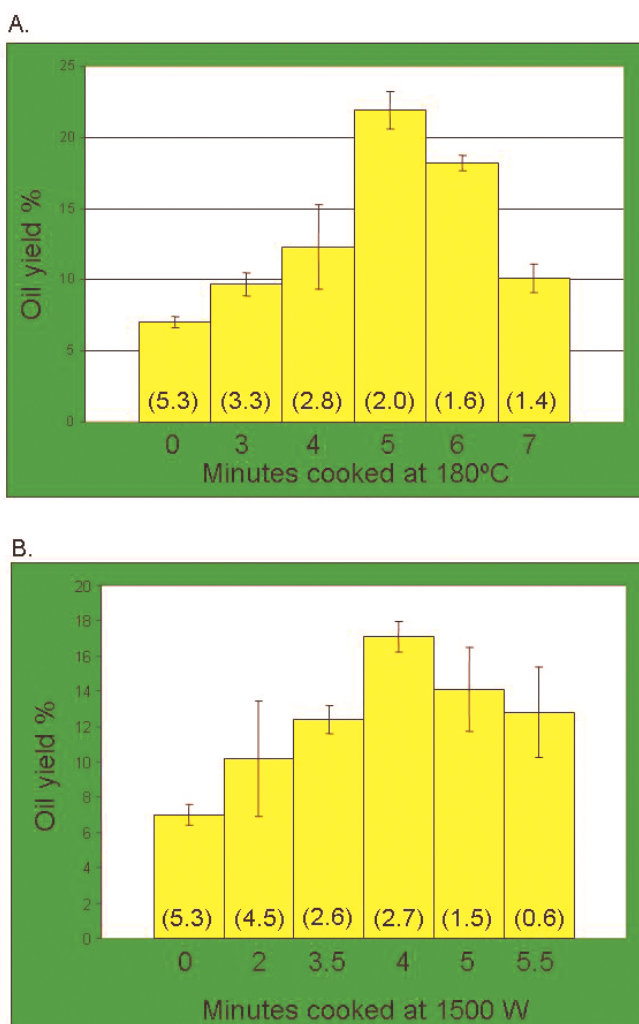


Figure 2. Oil yields (filtered) from corn germ obtained from a commercial wet mill. (A) Oil yields after cooking in a conventional oven for various times. (B) Oil yields after cooking in a microwave oven for various times. Numbers in parentheses are moisture contents (%) of germ after oven treatment.

Research Results

The results of our study showed that during preliminary pressing (with a bench scale Taby Model 20 Oil Press from Skeppsta Maskin AB, Orebro, Sweden, www.oilpress.com) of 200 grams of dry-milled corn germ (undried, ~13% moisture), no oil was obtained with uncooked germ (Fig. 1A). Cooking the germ at 180°C for 5–8 minutes before pressing resulted in yields of about 4 to 5% oil, with maximal yields after 6.5 minutes of heating at 180°C. 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 minutes, 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 total oil recovery (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 minutes 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 minutes) 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. 2). This increase in moisture occurred during shipping and storage. Cooking the germ at 180°C for 3–7 minutes before pressing resulted in yields of 10–22% oil, with maximal yields after 5 minutes 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 minutes resulted in slightly lower yields (in the range of 10 to 17% oil) than those obtained by 180°C cooking, with an optimal microwave cooking time of 4 minutes.

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 minutes of conventional oven cooking and at 5.0 and 5.5 minutes 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, 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.

Few other recent studies have compared corn oil obtained from both wet- and dry-milled germ. Other researchers have compared the differences in composition of corn oils from wet-milled germ and dry-milled germ obtained by supercritical CO₂ 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. Others' research has compared the effect of microwave vs. radiofrequency thermal pretreatment of rapeseeds and found that microwave cooking resulted in superior mechanical oil extraction.

Condensed version of article by Robert A. Moreau, David B. Johnston, and Kevin B. Hicks of the Eastern Regional Research Center, USDA, Agricultural Research Service, Wyndmoor, Pennsylvania. Full version of the article appeared in JAOCS, Volume 82, November 2005. Article references are available upon request. The authors would like to thank Omar J. Adams for expert technical assistance in conducting the screw pressing experiments. ■

ARS Researchers' New Method Simplifies Biodiesel Production

Not only are Agricultural Research Service scientists in Wyndmoor, Pennsylvania, working with corn oil, another group of researchers there has modified biodiesel production technology. Their method eliminates a step—and an air-polluting chemical—from the process of synthesizing the fuel.

Michael Haas, a biochemist with the Eastern Regional Research Center's Fats, Oils, and Animal Coproducts Research Unit, and colleagues developed the new approach.

In the U.S., soybean oil is the most prevalent starting material for biodiesel, though other vegetable oils, animal fat, and waste grease are used too. But soybean oil's relatively high cost results in biodiesel being expensive, which discourages wider adoption of this desirable, renewable fuel.

In biodiesel production, hexane, a colorless, flammable liquid derived from petroleum, is traditionally used to extract the oil from the soybeans. But hexane is an air pollutant, and its release is regulated by the U.S. Environmental Protection Agency. Working with ERRC biologist Karen M. Scott and chemists Thomas A. Foglia and William Marmer, Haas eliminated hexane from the process simply by skipping the oil-extraction step that relies on it. Instead, Haas explains, soybean flakes are incubated with methanol and sodium hydroxide—the same agents that would be used to process extracted oil.

“In the new method, soybean flakes are incubated in alkaline methanol, eliminating the need to isolate and purify the oil before transesterification.” (“Transesterification” is a reaction between fats and alcohol that forms the simple fatty acid esters that are biodiesel.) The lipids don't have to be isolated first because transesterification occurs in the raw soy flakes containing the oil.

Next, when the researchers collaborated with Andrew McAloon, a process modeler/cost engineer at their facility, to estimate and compare costs, they hit a snag. Without even accounting for the cost of the soy flakes or soy oil, a gallon of biodiesel produced by their new process was estimated to cost \$3.14—versus 38 cents per gallon if produced by the conventional process.

The researchers then noticed that their new method used considerably more methanol than is typically needed in biodiesel synthesis. They reasoned that the moisture naturally present in soybeans, as much as 10 percent in soy flakes, could be the reason behind the high methanol requirement. They found that by drying the flakes before starting the biodiesel synthesis, they could greatly reduce the required methanol volume. As a result, the estimated cost went down to \$1.02 per gallon.

Haas and his colleagues are presently refining their economic model to account

for income from selling the lipid-free, protein-rich flakes left after the biodiesel reaction for use as animal feeds and to account for cost differences between refined-oil and flaked-soybean starting materials. The group is also pursuing new research leads to further reduce the methanol requirement.

ARS has filed a patent application on the process. Haas is exploring use of this new method to produce biodiesel from the lipids in corn co-products from ethanol plants that use corn as a start-

Haas eliminated hexane from the process simply by skipping the oil-extraction step that relies on it.

ing material. In further work with the byproducts from ethanol plants—and with meat and bone meal—the research group has also defined conditions to achieve complete conversion of the oil in the feedstock to fatty acid methyl ester.

“New Method Simplifies Biodiesel Production,” by Jim Core, Agricultural Research Service Information staff, was originally published in the April 2005 issue of Agricultural Research magazine and has been adapted slightly for use in the Gazetteer.