Dehulling of Canola by Hydrothermal Treatments

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ABSTRACT: Hydrothermal pretreatments for loosening the hull of Westar canola (*Brassica napus* L.) to promote dehulling of the seeds were investigated. The samples tested had on average 14.5% hull on a mass basis. Conditioning treatments involved soaking the seeds in distilled water or exposing the seeds to saturated steam. The moistened seed was treated with one of the following drying methods: unheated-air drying, infrared drying, and fluidized-bed drying. The dried grain was milled in an abrasive dehuller to break the hulls loose. The hulls were removed from the mix by aspiration. The treated seeds yielded a minimum of 11.4% to a maximum of 14.9% of the seed mass as the hull fraction. Nontreated seeds yielded 9.4% of the seed mass in hull fraction after abrasive dehulling and aspiration. Among treatments, raising the moisture content of the whole seed from 6 to 15% by exposure to steam, followed by drying in a fluidized bed, resulted in the maximum percent dehulling efficiency. The hull fraction contained about 24% crude fiber, 18% oil, and 18% protein on a dry-mass basis.
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Canola meal contains 38–43% protein and 13% crude fiber (1). The high content of crude fiber, and thus the low metabolizable energy content of the meal, is one factor that limits the use of canola meal in feed formulations. Because much of the fiber is in the hull, efforts are directed toward reducing the hull content of the meal (2).

The ease with which dehulling can be achieved depends mainly on adhesion of the hull to the endosperm (3). Soybeans and cottonseed are easily dehulled prior to oil extraction, and the resulting meal is a high-quality feed (4). The seed coat or hull of canola adheres tightly to the endosperm and embryo and is difficult to remove (5). The hulls remain with the seed during oil extraction. The presence of hulls in canola meal lowers its protein content and energy.

The objective of the present work was to investigate the effects of hydrothermal treatments on mechanical dehulling of canola seed. The physical and chemical characteristics of the fractions of the hull and cotyledon after dehulling were also investigated.

Review of literature. Stanley and deMan (6) dehulled canola by pneumatic attrition milling. The yield of fractions by mass of the seed processed was 50% cotyledon, 15.5% hull, and 4.5% fines. Schneider (7) reported that the removal of hull by entraining the seed in an air stream and projecting it at high velocity against baffle surfaces was not feasible for industrial applications because the process left a substantial portion of the intact hull with the cotyledon, and it also involved high energy consumption. He proposed a dehulling method involving confined deformation of the seed between two rigid surfaces.

Sosulski (5,8) used a wet-milling process by which, after soaking canola seeds in water, the wet seeds were dehulled by passing them between smooth rollers. The rolled mass was dried, and the hulls were removed with an air classifier. The hulls contained 24% oil, due to contamination with small particles of the embryo. Eapen *et al.* (9) noted that grinding whole canola seed in a stream of water produced intact endosperm and embryo from the hulls and allowed an efficient removal of the hulls after drying.

A commercial dehulling process, developed by CETIOM (Centre Technique Interprofessionel des Oleagineux Metropolitains, Comexol, France), consists of cracking the seed by impacting it against a target. Hull and cotyledon are separated in a fluidized-bed unit (10). Fitzpatrick (11) noted, from visual observation of the CETIOM dehulling process, that separation of the hulls and the kernels was not efficient. Fitzpatrick (11) also reported that the oil level in the hull fractions was in the range of 12 to 22% because the hull fraction contained cotyledon particles. Nevertheless, the dehulling process reduced the crude fiber level of the dehulled meal from 12.5 to 7.5%.

McCurdy and Fedec (12) studied the dehulling characteristics of a large seed variety *Brassica napus* vs. the small seed variety *B. campestris*. They also studied the influence of moisture content, seed temperature, and mill type on the efficiency of dehulling. They reported that seed variety affected the efficiency of the dehulling. Best results were obtained with seed at 7 to 8% moisture content when milled in a cracking mill. McCurdy and Fedec (12) reported that the protein

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content of the dehulled meal was 48.7%, and the residual oil content of the hulls was 27.7%.

EXPERIMENTAL PROCEDURES

Seed sample. No. 1 grade Westar canola seed (*B. napus* L.) from the 1990 crop grown in Western Canada was obtained from a commercial seed supplier in Saskatoon. The seed sample was cleaned in a 1.4-mm wire mesh sieve (No. 14) and stored in air-tight containers at 4°C. Moisture content of the seeds, determined according to the air oven method of the ASAE Standard Procedure S352.2 (13), was 6% wet basis.

To determine the hull content of the seed, 20 g of sound kernels was soaked in distilled water for 24 h. A small cut on the seed surface was made by a sharp knife, and pressure was applied by hand to push out the cotyledon. This facilitated the removal of cotyledon from the seed coat. The hulls were checked for any remaining cotyledon fraction. Pure hull and cotyledon samples were then dried in ambient air and weighed.

Seed conditioning. Hydrothermal treatments consisted of moistening followed by drying. The variables of the experiments were: (i) three soaking durations multiplied by three drying methods, and (ii) three steaming durations multiplied by three drying methods. The drying methods were unheated-air drying, infrared drying, and fluidized-bed drying.

Soaking. Three batches of canola, each weighing about 600 g, were immersed in distilled water at 22°C (±0.2°C). The water was drained from batch one, two, and three after 30, 60, and 140 min of soaking, respectively. Each batch was divided into three lots of about 200 g for drying.

Steaming. Three batches of canola, each weighing about 400 g, were placed in perforated cups made of galvanized steel. Saturated steam was throttled into batch one, two, and three for 15, 30, and 45 min, respectively. Each steamed batch was divided into three lots of about 133 g for drying.

Unheated-air drying. Moistened seed was spread in a single layer in a tray, and air was blown over the samples by a household fan at room temperature (22°C). The grain was stirred at 30-min intervals. Drying was completed when the seed moisture level was about 6%.

Infrared drying. Moistened seed was spread in a layer one or two kernels thick on a tray placed about 225 mm away from an infrared heat source (Ohaus moisture determination balance, Model 6010, rated at 1000 W; Ohaus Corp., Florham Park, NJ). Drying of the sample was monitored on the balance until the final moisture content reached 5.6 to 6.8%.

Fluidized drying. Moistened seeds were dried to 6% in a laboratory model of the Lab-line/PRL fluidized-bed dryer. The air temperature was set to 80°C. Temperature of the grain mass was measured with a digital thermometer by inserting the probe of the thermocouple in the grain mass at five to six locations immediately after stopping the dryer. The temperature was found to be in the range of 70 to 75°C.

Mechanical dehulling. An abrasive dehuller, developed by Reichert *et al.* (14), was used to loosen the hull from the canola seed. The device consists of a rotating abrasive disk and a series of sample cups. The cups are open at both ends and positioned such that the bottom edges of the cups are within 0.25–0.38 mm of the face of the abrasive disk. Because of the tangential rotation of the disk with respect to the grain kernels, this unit is called a tangential abrasive dehulling device (TADD).

For the dehulling test, the grain sample was placed in the cups, and the rubber-faced aluminum hinged cover plate was closed on top of the cups. With the disk's circular motion, grain kernels were dehulled as a result of abrasion. The dehulled fractions were removed from the sample cups with a vacuum sample collector and separated into cotyledon, fines, and hull fractions.

Separation of cotyledon, hull, and fines. A laboratory aspirator (McGill Bates, Rapsilver Supply Co. Inc., Brookshire, TX) was used for the separation of hulls from the milled sample. The aspirator consisted of a feed hopper, feed cone, blower, cyclone collector, and valves to control the fan speed and feed cone opening. The solid material flow was regulated by varying the opening of the feeding cone, which spread the material to a thin flow. A valve restricted or increased the air passage to the centrifugal collector and thereby controlled the air flow rate. More precise control of the air flow was obtained by a variable blower speed control. As the milled mix passed through the aspirator, hulls and fines were separated from the cotyledons by means of a controlled air current passing through the material. This fraction was collected in the cyclone collector and classified into fines and hull on a 0.6-mm sieve.

Chemical analysis. The whole seed and dehulled fractions (cotyledon, hull, and fines) were analyzed for protein, oil, crude fiber, and moisture content. Official methods of the AOAC (15) were followed for the determinations, including the Kjeldahl method (7.015) for protein, Goldfisch extractor (7.060) for oil, ceramic fiber filter method (7.066) for crude fiber, and oven method (7.007) for moisture content. Protein content was calculated by multiplying nitrogen content by the factor 6.25.

Bulk and kernel density. For bulk density measurements, Agriculture Canada's recommended grain test weight determination method (16) was used. A 0.25-L container was filled with the granular material, and the contents were weighed. Bulk density was the ratio of mass of the solids divided by volume. For particle density, the volume occupied by a measured mass of granular material was determined with an air comparison pycnometer (Model 930; Beckman Instruments Inc., Fullerton, CA).

Terminal velocity. A laboratory apparatus, consisting of a fluidization chamber and a variable speed blower, was assembled to measure the entrainment velocity of the seed fractions (17). A Plexiglas tube, 25 mm in diameter and 400 mm in length, was used as a fluidization chamber. Stainless-steel wire mesh was fixed at the bottom end of the tube to support the material. A seed sample of about 2 to 5 g was placed in the chamber. The bed depth of the sample in the chamber varied from 2 to 5 mm, depending upon the type of the fraction. The blower was started, and the flow of air was increased gradually until all the material was fluidized. The minimum air velocity was measured when the sample began to float. The maximum air velocity was measured when the sample suspended fully and expanded to the height of about 150 mm along the tube. The air velocity in the tube was measured with a calibrated hot-wire anemometer (Model 1650; TSI Corp. Minneapolis, MN).

Particle size. Major and minor diameters of 100 seeds were measured on an image analysis system. Roundness for the seeds was calculated as the ratio of minor diameter to major diameter. Mass of individual kernels was measured on an Ohaus electronic scale (0.1 mg). Particle size analysis of the fractions (cotyledon, hull) was performed by the sieving method specified by ASAE Standard S319.1 (13).

Scanning electron microscopy (SEM). SEM was used to investigate the effect of conditioning treatment on reducing the association between hull and cotyledons. To prepare for SEM tests, canola seeds were soaked in distilled water at room temperature for 30 min. In another treatment, seeds were steamed at 120°C for 30 min. Moistened samples were dried to 6% moisture content in the fluidized bed dryer at 75°C. A single kernel of the conditioned seed was sectioned and glued onto a circular aluminum stud. The specimen was immediately coated with gold in a S1508 Sputter Coater (Edwards High Vacuum, West Sussex, England). The micro structure of the section was viewed with a SEM 505 scanning electron microscope (Phillips, Eindhoven, The Netherlands) and photographed.

RESULTS AND DISCUSSION

Table 1 lists dimensions and mass of the canola seed used in the experiments. Seed size varied from a minimum of 1.42 mm to a maximum of 2.42 mm with an average roundness of 0.91 (sphere = 1). The coefficient of variation was about 9% for the minor diameters and the major diameters of the 100 seeds tested. The variation in the mass of the individual seeds was about 2.7%. This is an interesting result because it appears that, despite large variations in size, the kernel mass did not vary much.

Table 2 lists the moisture content of the canola seeds after soaking or steaming and the time required to dry the seeds to 6%. The moisture content after steaming was lower than that of the soaked seeds for the same period of treatment (30 min). The drying time with infrared heat was almost one order of magnitude shorted than the drying time in ambient air. Drying in a fluidized-bed dryer was about half of the infrared drying. Although heat application was more intense under the infrared unit, the grain had to be stirred occasionally to speed up the removal of stagnant moisture from the heated sample. Fluidized-bed drying was excellent for fast and uniform drying of grain.

TABLE 1
Dimensions and Mass of Canola Seed (cv. Westar)

	Diameter (mm)				Kernel mass
	Major	Minor	Average	Roundness	(mg)
Minimum	1.570	1.270	1.420	0.68	4.02
Maximum	2.600	2.270	2.420	0.99	4.32
Mean	2.073	1.875	1.976	0.91	4.17
Standard deviation	0.187	0.169	0.166	0.06	0.11
Coefficient of variation (%)	9.0	9.0	8.4	6.4	2.7

TABLE 2
Moisture Content of Soaked and Steamed Seed and Drying Times to Reduce Seeds to 6% Moisture Content by Different Drying Methods

	Treatment time and final moisture content		Drying time (min)		
Moistening method	Time (min)	Moisture content (%)	Unheated air	Infrared	Fluidized bed
Soaking in distilled water	30	20.7	760	85	30
	60	27.8	1370	115	50
	140	37.0	1655	155	63
Steaming with saturated steam	15	13.8	440	65	19
	30	14.6	475	70	21
	45	20.0	730	84	31

Table 3 lists yields of cotyledon, hull, and fines fractions of treated and nontreated seeds dehulled in the TADD. About 4% solids was lost in the TADD. The hull content of canola, as determined by manual dehulling, was 14.8% (n = 4) of the seed mass. The yield of hull fraction increased from 9.5% of the seed mass (1.9 g) for nontreated seed to 14.5% of the seed mass (about 2.5 g) for the moistened and hot-air dried seed. Longer soaking or steaming times did not improve the dehulling efficiency (17). The amount of fines generated was highest in the nontreated sample (1.6 g), followed by the steamed sample (1.2 g). The water-soaked sample yielded the least amount of fines (0.9 g).

The hull content for rapeseed and canola reported in the literature shows a variation from 15 to 20% of the seed mass (18). It appears that the canola seed samples used in the present study had a slightly thinner or lighter hull than those varieties for which the hull mass has been reported in the literature.

Chemical composition of whole seed and fractions. Table 4 lists the percentages of protein, oil, and crude fiber contents in the hull, cotyledon, and fines fractions. The hull moisture content was the highest, 8.3–11.9% in all samples. The cotyledon fraction had the lowest moisture content at 4.9–5.7%. The protein content of the cotyledon fraction of hand-dehulled seed was 28.1%. The protein content of the cotyledon fraction of the treated seed was slightly higher at 30.1%.

The oil content of the cotyledon fraction of nontreated dehulled seed (46.9%) was slightly lower than that of treated dehulled seed (49.3%). The fiber content in the cotyledon fraction of the nontreated seed was higher than the treated

TABLE 3
Average Yield of Seed Fractions for the Treated and Nontreated Seeds (standard deviations in parentheses)

Treatment	Drying method	Sample size (g)	Cotyledon fraction (g)	Hull fraction (g)	Fines fraction (g)
Soaked	Ambient	20.0 (0.0)	15.8 (0.1)	2.3 (0.1)	0.9 (0.1)
for 30 min	Infrared	20.0 (0.0)	15.9 (0.2)	2.8 (0.1)	0.7 (0.1)
(n = 4)	Fluidized	20.0 (0.1)	16.0 (0.1)	2.6 (0.1)	0.9 (0.1)
Steamed	Ambient	20.1 (0.1)	15.7 (0.1)	2.4 (0.0)	1.2 (0.0)
for 15 min	Infrared	20.0 (0.0)	15.3 (0.1)	2.6 (0.1)	1.1 (0.0)
(n = 4)	Fluidized	20.0 (0.0)	15.4 (0.1)	2.8 (0.0)	1.2 (0.0)
Nontreated					
(n = 4)		20.1 (0.0)	15.9 (0.1)	1.9 (0.0)	1.6 (0.0)
Soaked and		1.115 (0.007)	0.760 (0.071)	0.165 (0.003)	—
hand-dehulled		0.605 (0.006)	0.435 (0.007)	0.084 (0.002)	—
(n = 2)					

seed (7.3 vs. 3%). About 40% of the fiber content of the whole seed was found in the hull. The hull fraction also contained 13.2 to 19.1% oil. The average composition of the fine fraction included 39.9% oil, 26.7% protein, and 9.3% fiber. This composition resembles that of whole seed (17).

Physical properties of canola seed and its fractions. Table 5 lists the bulk density, particle density, porosity, geometric mean diameter, and entrainment velocity of the bulk seed and its dehulled fractions. Entrainment velocity varied with mass, shape, and size of the particles. Minimum entrainment velocity for the whole seed and cotyledon fraction was 0.98 m/s; the maximum velocity was 1.89 m/s. Minimum entrainment velocity for the hull and fine fractions was 0.75 m/s, and the maximum velocity was 0.94 m/s.

Particle density and entrainment velocity values of fine fractions and hull fractions were similar. Fine fractions, defined as smaller than 0.3 mm, were separated from the hull by sieving. The hull fractions were separated from the cotyledon fractions based on density because particle density and entrainment air velocity of the hull fraction was different than that of the cotyledon fraction.

Electron micrographs. Figures 1, 2, and 3 are SEM micrographs of nontreated and treated canola seeds. Figure 1 shows the cross-section of a nontreated seed. There is a slight dissociation of cotyledon from the hull but to a much lesser degree than in the steamed and soaked seeds (Figs. 2 and 3). Excessive damage to the internal part of the nontreated seed is not evident, whereas a large air gap was developed between cotyledon and hull in the steamed and soaked seeds (Figs. 2 and 3). In addition to hull-cotyledon disassociation, the internal structure in Figures 2 and 3 shows signs of cotyledon shrinkage and the separation of cotyledons and hulls. This differential shrinkage inside the seed coat (hull) probably leads to easier hull removal but may also cause breakdown of cotyledon during mechanical dehulling.

The cotyledon of the soaked seed (Fig. 3) appears denser than the steamed seed shown in Figure 2. This structural difference may explain the generation of relatively more fines during dehulling of the steamed seeds than of the soaked seeds. Because canola has a highly composite structure, each component of the seed expands or contracts to a different degree. As a result, internal stresses could have a favorable effect on the separation of hull and on the ensuing application of mechanical forces for dehulling.

In conclusion, experiments were conducted on the effect of preconditioning of the seed on the dehulling characteris-

TABLE 4
Chemical Composition of the Whole Seed and Dehulled Seed Fractions (standard deviations in parentheses)

Treatment	Fraction	Moisture content (%)	Protein content (%)	Oil content (%)	Crude fiber content (%)
None	Whole seed	5.2	28.5	44.5	9.5
Soaked, dried, dehulled (n = 9)	Cotyledon	5.7 (0.3)	30.1 (0.3)	49.1 (1.1)	2.6 (0.6)
	Hull	11.9 (1.1)	17.1 (1.0)	17.6 (1.5)	24.4 (3.1)
	Fine	6.7 (0.5)	26.8 (1.5)	39.7 (1.5)	9.5 (1.3)
Steamed, dried, dehulled (n = 9)	Cotyledon	5.0 (0.4)	30.0 (0.6)	49.5 (0.7)	4.4 (1.4)
	Hull	9.7 (0.7)	18.4 (0.7)	19.1 (2.5)	23.4 (3.6)
	Fine	5.9 (0.5)	26.6 (1.7)	40.6 (0.7)	8.5 (1.0)
Nontreated, dehulled mechanically (n = 3)	Cotyledon	5.2	29.5	46.9	7.3
	Hull	8.3	17.3	17.9	22.5

TABLE 5
Physical Properties of Whole Seed and the Fractions of Cotyledon, Hull, and Fines of Canola (cv. Westar) at 4.5% Moisture Content [standard deviations in parentheses (n = 10)]

Fraction	Bulk density (kg/m^3)	Particle density (kg/m^3)	Porosity (%)	Mean diameter (mm)	Entrainment velocity	
					Minimum	Maximum
Whole seed	680 (2)	1129 (4)	39.7 (0.1)	1.98 (0.16)	0.98	1.89
Cotyledon	554 (9)	1170 (6)	52.6 (0.8)	1.30 (0.08)	0.99	1.83
Hull	148 (2)	1279 (10)	88.4 (0.2)	0.75 (0.08)	0.68	0.85
Fines	302 (4)	1259 (16)	76.0 (0.3)	0.29 (0.14)	0.75	0.94

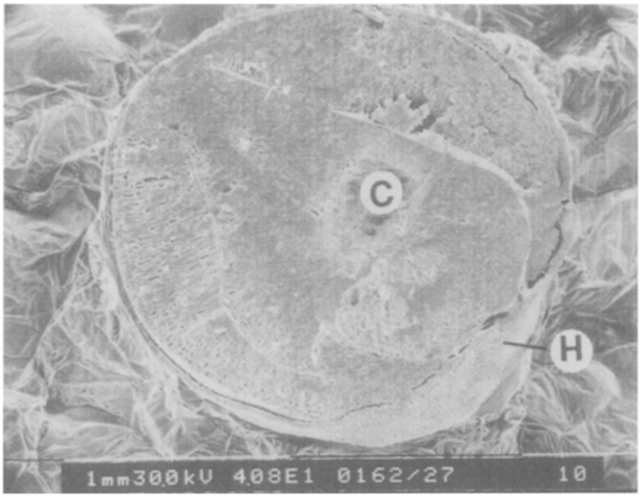

FIG. 1. Scanning electron micrograph shows close association of the hull and the cotyledon in a nontreated canola seed (magnification 43.9×). C, Cotyledon; H, hull.

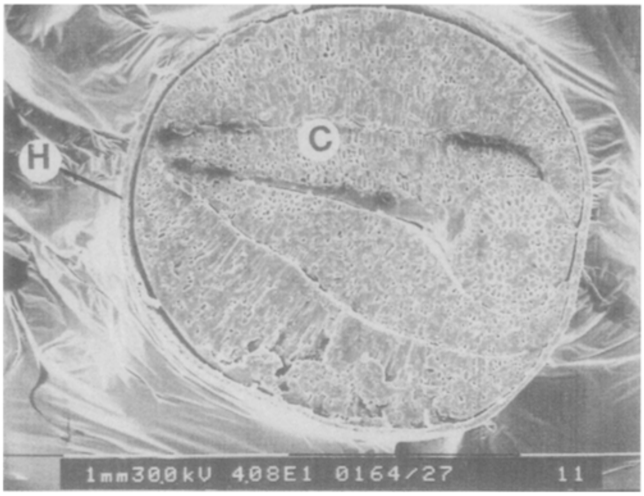

FIG. 3. Scanning electron micrograph shows close association of the hull and the cotyledon in a steamed and dried canola seed (magnification 43.9×). C, Cotyledon; H, hull.

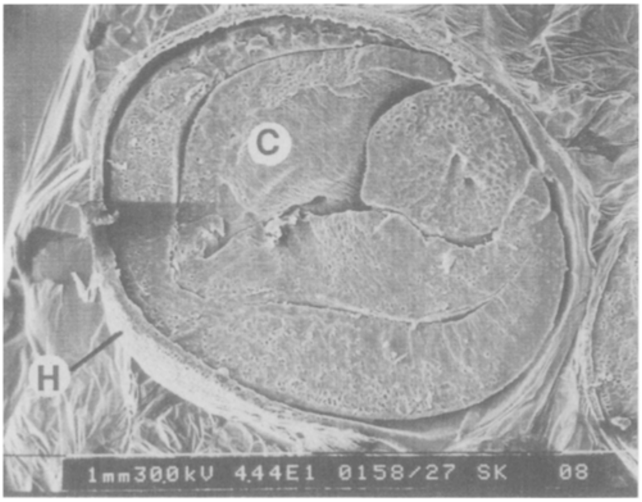

FIG. 2. Scanning electron micrograph shows disassociation of the hull and the cotyledon in a soaked and dried canola seed (magnification 43.9×). C, Cotyledon; H, hull.

tics of canola. Seeds were moistened with water or steam, dried, and milled in an abrasive dehuller. The milled samples were separated into cotyledon, hull, and fine fractions by air classification and sieving. The chemical compositions and physical properties of these fractions were determined. The following conclusions can be drawn from the experiments: (i) Hydrothermal treatments improve the mechanical dehulling of canola seed by producing a cleaner separation of hull and cotyledon. The fraction of fines generated during dehulling of the treated seed is less than that for the nontreated seed. (ii) Dehulling of nonconditioned seed reduces the meal fiber content from 9.5 to 7.5%, whereas dehulling of conditioned seed reduces it to 3.5%. However, hull removal results in a loss of about 6% of the total oil from canola seed. The composition of the fines fraction resembles the composition of whole seed and thus can be recycled in the oil extraction process. (iii) Dehulled fractions (cotyledon, hull, and fines) can be separated on the basis of differences in particle size and density. The hulls and fines differed in particle size and thus can be separated by sieving. Cotyledons and hulls can be separated on the basis of density.

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