Screw Pressing of Whole and Dehulled Flaxseed for Organic Oil

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ABSTRACT: Flaxseed oil, a rich source of dietary n-3 FA, is commonly obtained by cold pressing whole seed. Furthermore, flaxseed hulls are emerging as a valuable lignan-rich product for functional food use; therefore, the pressing characteristics of dehulled seed need to be understood. Screw press performance was measured for pressing of whole and dehulled flaxseed. When whole Omega flaxseed was pressed through a 6-mm choke, an inverse relationship between seed moisture content (6.1–11.6% range) and oil recovery (70.1–85.7%) was observed. However, peak oil recovery from pressing dehulled Omega flaxseed of 72.0% was found at 10.5% moisture content in the moisture content range of 7.7–11.2%. Although oil recovery from dehulled Omega flaxseed was lower than from whole Omega flaxseed, the weight of oil produced from dehulled Omega flaxseed per unit time was higher. The dependence of capacity on moisture content was less evident with the 6-mm choke than with the 8-mm choke. An inverse relationship between moisture content of whole flaxseed and oil and meal temperature was observed. The oil and meal temperatures from pressing dehulled flaxseed were significantly lower than those from whole flaxseed. Therefore, pressing dehulled flaxseed appears to offer advantages in organic flaxseed oil production.

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KEY WORDS: Capacity, dehulling, flaxseed oil, moisture content, oil productivity, oil quality, oil recovery, pressure, screw pressing, temperature.

Flaxseed (*Linum usitatissimum*) is unique among oilseeds because of its exceptionally high content of α-linolenic acid (ALA) and lignans. ALA is classified as an n-3 (ω-3) FA, a group that also includes long-chain metabolites of ALA. n-3 FA have anti-inflammatory, antithrombotic, and antiarrhythmic properties. These beneficial effects of n-3 FA have been shown in the secondary prevention of heart disease, hypertension, type 2 diabetes, and other medical conditions (1). Flaxseed contains 35 to 45% oil. Flaxseed oil contains 45 to 52% ALA (18:3n-3) (2). The seed embryo is the major oil storage tissue, containing 75% of the seed oil. The ALA content of flaxseed oil is high compared to established oilseeds in North America.

Solvent extraction and mechanical pressing are the leading methods for commercial oil extraction. Mechanical pressing is allowed by the organic food industry; however, solvent extraction with petroleum distillates, such as hexane, is not allowed (3). n-3 FA are sensitive to heat, oxygen, and light; thus, flaxseed is usually cold pressed. "Cold pressing" is not a well-defined term, and the legal definition is different or nonexistent in some countries. For example, in order to be labeled "cold pressed" in the United Kingdom, oil temperature when exiting the screw press should be less than 50°C (4). Pressing temperatures are rarely reported in scientific literature, with one report of exiting oil temperatures less than or equal to 70°C (5).

Mechanical screw presses typically recover 86 to 92% of the oil from oilseeds (5). Adjusting pressing parameters can improve oil recovery; for example, increasing the internal pressure results in a decrease of the residual oil in the meal (6). Oil recovery also can be enhanced by suitable pretreatment of the oilseed, i.e., cracking, dehulling, conditioning, flaking, and cooking (7). The importance of raw material moisture content in the screw press has been studied for a wide range of raw materials (5,7–10). Little has been published on screw pressing flaxseed for edible use. Singh and Bargale (8) found that adjusting moisture content and a soaking treatment can influence the oil recovery significantly when screw pressing flaxseed.

The common reasons for removing the hull of most oilseeds are to improve the flavor, to increase the protein content of the meal, and to increase oil productivity (7). However, flaxseed can also be dehulled to recover hulls for use as a lignan concentrate. Lignans offer protection against breast and colon cancer owing to their antiestrogenic and/or antioxidative effects (11). The meal from pressing dehulled flaxseed may be a good feed for nonruminants because of its low fiber content and high protein content, and because the residual oil may be a good source of ALA for fish and poultry (12,13). However, dehulled flaxseed (embryo) cannot be readily pressed using a process configured for pressing whole flaxseed because of the high oil content and low fiber content, which result in a particularly soft material.

The objective of this research was to obtain high flaxseed oil recovery from whole and dehulled flaxseed (embryo) by selecting suitable pretreatment and press parameters. Two pretreatments (moisture content adjustment and dehulling) and two press parameters (pressure and temperature) were studied to determine their effects on oil recovery, oil quality, capacity, and sediment content. Two commonly used edible varieties of flaxseed (Omega and Neche) were compared as well.

MATERIALS AND METHODS

Materials. Two varieties of flaxseed were used: a dark-brown variety (Neche) from Werth Certified Seeds (Lehr, ND) and a

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golden-yellow variety (Omega) from Reimer's Seed Farm (Carrington, ND). Seeds were stored at 5°C, and they were equilibrated overnight in sealed polyethylene bags at room temperature before use.

Conditioning. To increase moisture content, distilled water was sprinkled on the flaxseeds, which were thoroughly mixed by hand. The seed clumps formed by direct water addition were removed using a ⅜-in. (9.5-mm) sieve. To decrease moisture content, flaxseed was spread on a plate to a depth of less than 1.5 cm and then kept in a hot air oven at less than 50°C until the desired moisture content was attained. The conditioned flaxseed was stored in a closed polyethylene bag at 5°C for more than 5 d for equilibration.

Dehulling. Flaxseed (6.8% moisture content) was manually and continuously fed into a model VSH-8088 Huller (Codema, Inc., Maple Grove, MN) at 400 to 500 kg/h using a rotor tangential speed of 48 m/s. Fines were removed using a sifter (Rotex, Style No. 12; The Orville Simpson Co., Cincinnati, OH) with a 1.0 m long × 0.4 m wide 18-mesh screen. The embryo fraction was obtained from this sifted product by using a gravity table (Forsberg, Model 10-M2; Thief River Falls, MN).

Pressing. A Komet screw press (Model S 87G; IBG Monforts Gmbh & Co., Monchengladbach, Germany) was used to press the flaxseed in one pass. Samples were fed from the hopper to the press on demand by gravity. The length of the press barrel was 95.8 mm, and the constant i.d. of the press barrel was 75.1 mm. The length of the shaft was 198.3 mm, and the constant o.d. of the shaft was 53.7 mm. The choke (or die) at the meal discharge end of the screw press had an adjustable i.d. of 6 or 8 mm. An R8 shaft (16 mm flight-to-flight distance) was used to press whole flaxseed. An R11 shaft (21 mm flight-to-flight distance) was used to press flaxseed embryo. Shaft speed without loading was 24 rpm as measured by a phototachometer (AMETEK, model 1726; Mansfield & Green Division, Largo, FL). Three type T thermocouples were equally spaced along the length of the bottom of the barrel at 18-mm intervals. One additional type T thermocouple was attached to the outside of the choke, and the choke and the thermocouple were surrounded by 13-mm-thick fiberglass insulation. The barrel thermocouple nearest the press head indicated the discharge temperature of oil, and the thermocouple attached to the choke indicated the discharge temperature of the meal. Temperatures were logged with a CR10X data logger (Campbell Scientific, Inc., Logan, UT) along with the corresponding time at 10-s intervals and were also displayed in real time by a computer.

An electrical-resistance heating ring attached around the press head preheated the press head to 60°C for 30 min before press operation. The heating ring was not used during the steady pressing. Samples were introduced into the hopper sequentially in the order of decreasing moisture content. Steady pressing was assumed when the change of the oil temperature was less than 1°C for 30 s. Time to achieve steady pressing was about 5 min for the first sample, and about 1 min for each subsequent sample. In every test condition, duplicate crude oil and meal samples were collected in direct succession upon achieving steady pressing. The press time ranged from 2 to 3 min according to the sample size. Moisture content of the sample was measured before pressing. The crude oil and meal were weighed after pressing. The crude oil was also analyzed for sediment content, PV, conjugated dienes, and FFA, and the meal, for oil content.

Four series of experiments were carried out: (i) pressing of whole Omega with the 6-mm choke and sample moisture content ranging from 6.1 to 11.6% (dry basis, d.b.); (ii) pressing of whole Omega with the 8-mm choke and sample moisture content ranging from 6.1 to 11.6% (d.b.); (iii) pressing of whole Neche with the 6-mm choke and sample moisture content ranging from 6.1 to 13.4% (d.b.); and (iv) pressing of dehulled Omega with the 6-mm choke and sample moisture content ranging from 7.7 to 11.2% (d.b.).

Moisture content. Moisture content was determined together with any volatile material at 130°C for 3 h (AOCS Official Method Af 2-54) (14). This method, designed especially for flaxseed, was modified by using a coffee mill (Braun, Type 4041, Model KSM2(4); Naucalpan, Mexico) to grind the sample for 30 s.

Oil content. Oil content was determined by the weight of substances that are extracted by *n*-hexane (AOCS Official Method Af 3-54) (14).

Sediment content. Sediment, or foots, is the solid particles in the pressed oil. Sediment content was determined by vacuum filtration through Whatman #4-125 mm filter paper (9). The oil container and the solids remaining on the filter paper were rinsed with *n*-hexane, and then the filtered solids were dried and weighed.

Room-temperature hexane extraction. For the extraction of oil from whole or dehulled flaxseed for oil quality analysis, ground samples (12 g) were mixed with 175 mL hexane in a 250-mL Erlenmeyer flask. The flask was covered with Parafilm over the top and aluminum foil at the sides to keep out air and light. The mixture was stirred for 2 h, then filtered by gravity through Whatman #4 filter paper. The solids were rinsed once with 20 mL hexane. The hexane was evaporated using a rotary evaporator with the water bath temperature at no more than 34°C. The oil was transferred immediately to small amber glass vials, which were filled to the top so there was no headspace. The oil was stored in a dark cooler (5°C) and analyzed for PV within 24 h, and for FFA and conjugated dienoic acids within 48 h.

Oil quality. PV of oil was analyzed by the acetic acid/chloroform method (AOCS Official Method Cd 8-53) (14), FFA content was analyzed according to AOCS Official Method Ca 5a-40 (14), and percentage of conjugated dienoic acid was analyzed by spectrophotometer (AOCS Official Method Ti 1a-64) (14).

Calculations. Oil recovery was defined as the ratio of oil weight in the product oil to original oil weight in the seed that was pressed, and calculated from:

$$\text{oil recovery} = \left(1 - \frac{\text{weight of meal} \times \text{meal oil content}}{\text{weight of raw material} \times \text{raw material oil content}}\right) \times 100\% \quad [1]$$

Press capacity was calculated as the weight of product oil and meal collected in a known period of time. Residual oil in meal was calculated as the weight of oil extracted from the meal by hexane over the weight of meal. Oil productivity was calculated as the weight of oil less sediment weight collected in a known period of time.

Fraction of hull removed (FHR) was defined as the ratio of weight of pure hull removed to weight of hull initially present in the sample. The equation was deduced from the mass balance equation to obtain:

$$\text{FHR} = \frac{(x_d - x_w) \times (x_m - x_h)}{(x_d - x_h) \times (x_m - x_w)} \quad [2]$$

where x_w, x_d, x_m, and x_h denote the oil content of whole flaxseed, dehulled flaxseed embryo, pure embryo, and pure hull, respectively.

Data analysis. Flaxseed pressing was carried out in duplicate at each test condition. The average and the SD of results for each sample were calculated using Microsoft Excel (Redmond, WA). Regression analysis was performed using MiniTab 10.5 to determine the *P*-value. Two-factorial ANOVA analysis was carried out to test the significance of choke size, moisture content, and the interaction of choke size and moisture content on oil recovery and capacity by SAS Statistical Software, Version 6.12 (15). The Duncan group was also given by SAS. When comparing effects of moisture content for Omega vs. Neche, and for dehulled vs. whole flaxseed, a nested or hierarchical design was used, with the levels of moisture content nested under the levels of variety or dehulling condition (16). This was because the levels of moisture content were similar but not identical for different data sets. The nest design results were analyzed using SAS (15). Single-factor ANOVA was carried out by using SAS (15) to test the significance of moisture content on oil and meal temperature.

RESULTS AND DISCUSSION

Moisture content and choke size influence on press performance. The decrease of moisture content from 11.6 to 6.1% (d.b.) resulted in an increase of oil recovery from 70.1 to 85.7% when whole Omega flaxseed was pressed through the 6-mm choke (Fig. 1A). The 6.1% moisture content sample could not pass the 8-mm choke, so 6.6% became the lowest moisture content of the samples in this case. The decrease of moisture content from 11.6 to 6.6% increased the oil recovery from 62.0 to 76.9% when whole Omega flaxseed was pressed through the 8-mm choke (Fig. 1A). The relationships between moisture content and oil recovery were linear and were statistically significant for both the 6- ($P < 0.001$) and 8-mm ($P < 0.02$) choke. A similar trend was reported for cooked and uncooked crambe seed when moisture content ranged from 3.6 to 9.2% (d.b.) (10). However, other reports showed a peak in oil recovery at 7.5% (wet basis, w.b.) for rapeseed (5) and at 9.1% for hot-water-soaked linseed (flaxseed) (8).

One interesting phenomenon observed was that the 8-mm choke plugged at a higher moisture content than the 6-mm choke. Plugging or choking is a common problem with screw presses. The plugging problem limits the operational range of a screw press (5). This problem was particularly common at the beginning of press operation when pressing commenced without preheating. The first sign of plugging was that no meal came out of the choke, and then some meal slowly came out of the barrel with the oil. The oil output gradually tapered off and stopped. The screw shaft continued to rotate, and the press head became very hot due to friction within the press. To prevent this, we preheated the press head and logged the oil and meal temperature. The oil and meal temperatures increased when the moisture content of the flaxseed decreased, and they increased dramatically when the equipment plugged during the pressing of low-moisture seed. Therefore, samples were introduced in the order of decreasing moisture content to help the lower-moisture content samples run smoothly through the screw press. The plugging problem prevented the use of sample with lower moisture content, although the trend in Figure 1A suggested that a further decrease in moisture content would significantly increase the oil recovery.

The pressing capacity of the 8-mm choke was the highest when the moisture content was intermediate (9.7%) (Fig. 1B). The low capacity at low moisture content was due to the high friction resistance of the seed, and the moisture apparently behaved like a lubricant during pressing (10). The low capacity at high moisture content was due to bridging in the inlet of the screw press caused by clumps of flaxseed. Clumps were formed because the flaxseed surface became sticky when water was directly sprinkled on the flaxseed. The dependence of capacity on moisture content was less evident when using the 6-mm choke.

ANOVA analysis showed that both moisture content and choke size had a significant influence on the oil recovery and capacity (Table 1). The interaction of moisture content and choke size had a significant influence on the capacity but had no significant influence on oil recovery (Table 1). Duncan's multiple range test at the 0.05 significance level showed that the mean oil recovery from the 6-mm choke (76.6%) was significantly higher than that from the 8-mm choke (70.2%), but the mean capacity from the 6-mm choke (6.85 kg/h) was significantly lower than that from the 8-mm choke (7.68 kg/h).

TABLE 1
ANOVA for the Influence of Moisture Content, Choke Size, and the Interaction of Moisture Content and Choke Size on Oil Recovery and Capacity

Source of variation	df	F	P-value	$F_{0.05}$ crit.
Oil recovery result				
Moisture content	5	53.06[a]	<0.0001	3.11
Choke size	1	92.44[a]	<0.0001	4.75
Interaction	5	1.08[b]	0.4192	3.11
Error	12			
Total	23			
Capacity result				
Moisture content	5	37.36[a]	<0.0001	3.11
Choke size	1	43.74[a]	<0.0001	4.75
Interaction	5	27.31[a]	<0.0001	3.11
Error	12			
Total	23			

[a] $F > F_{0.05}$ crit. means significantly different.
[b] $F < F_{0.05}$ crit. means not significantly different.

The choke setting affected the pressure inside the press barrel. For example, a decrease in choke size resulted in an increase of internal pressure from 67 to 91 MPa, a decrease of residual oil in meal from 21.30 to 12.15%, and a decrease of capacity from 29 to 23 kg/h when pressing sunflower seed (6).

The sediment content of whole Omega flaxseed oil remained in a range from 1.0 to 2.5% of the weight of raw oil collected within the tested moisture content range (data not shown). The sediment content was highest at both the lowest and highest moisture contents. Jacobsen and Backer (6) reported that different choke settings had no significant influence on sediment content. Although sediment is sometimes retained in flaxseed oil for the purpose of marketing as "high-lignan" oil, the sediment is usually removed from the oil by settling and filtration. The amount of oil lost with the sediment depends upon the method of removal.

Variety influence. Two commonly used edible varieties of flaxseed, Neche and Omega, were compared using the 6-mm choke with all operational conditions set the same. These two varieties exhibited the same relationship between moisture content and oil recovery (Fig. 1A) and between moisture content and capacity (Fig. 1B). SAS analysis showed that variety did not influence the oil recovery significantly ($P = 0.82$), but the capacity with Omega was significantly higher than with Neche ($P < 0.02$) (Table 2). Moisture content significantly influenced both oil recovery and capacity ($P < 0.001$) (Table 2). Therefore, the comparison between Omega and Neche indicated that variety might be important, although only two varieties were studied here.

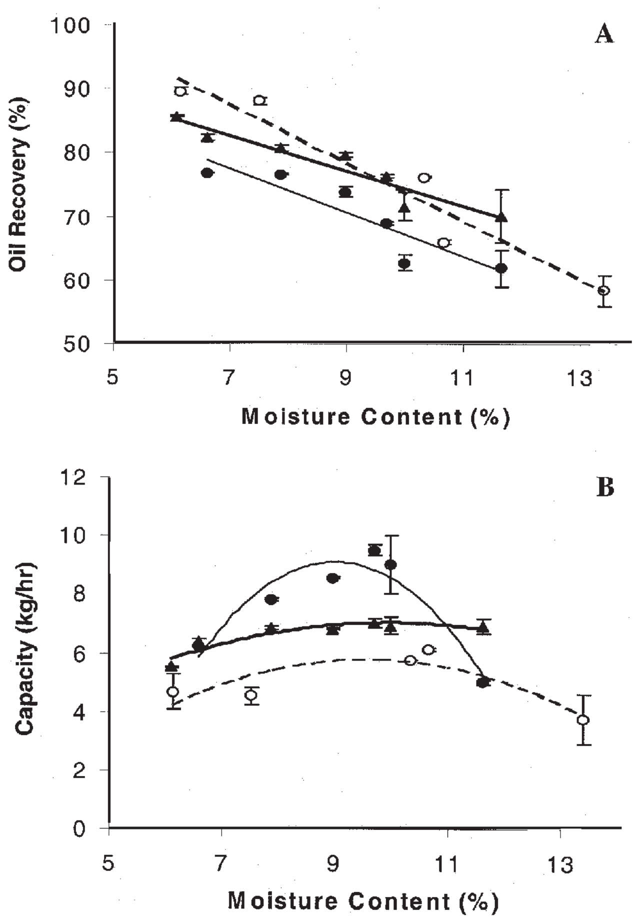

FIG. 1. Oil recovery (A) and capacity (B) of pressing whole flaxseed as influenced by moisture content, choke size, and variety. (●) Omega, choke size 8 mm; (▲) Omega, choke size 6 mm; (○) Neche, choke size 6 mm. Error bars represent the SD.

Pressing of dehulled Omega flaxseed. Dehulled flaxseed may be viewed as a co-product of processing flaxseed for lignan-rich hull. The dehulled flaxseed used in this study had 62% hull removed (FHR), as determined from Equation 2. The oil contents of dehulled flaxseed embryo, original whole flaxseed, pure hull, and pure embryo were 48.5, 41.8, 26.7, and 56.6%, respectively. The low fiber content and the high oil content of the dehulled flaxseed presented a challenge in pressing the dehulled flaxseed. The dehulled seed could not be pressed using the screw used to press whole seed; however, use of a screw with a greater flight-to-flight distance gave acceptable results.

Pressing of dehulled flaxseed resulted in a lower oil recovery than whole flaxseed (Fig. 2A). The relationships between moisture content and oil recovery also were different. A decrease of moisture content resulted in a progressive increase of oil recovery in the case of whole flaxseed, but a decrease in moisture content below 9.7% decreased oil recovery in the case of dehulled flaxseed. However, the highest oil recovery of 72.0% for dehulled flaxseed was similar to that of whole flaxseed at 9.7% (d.b.) moisture content. Dehulled Omega flaxseed with moisture content below 7.7% could not be pressed at a constant rate.

Figure 2A results do not account for the much higher oil content of dehulled flaxseed. Also, the capacity when pressing dehulled flaxseed was higher than that with whole flaxseed at the fixed screw speed in this study. The higher capacity mainly resulted from the greater flight-to-flight distance of the screw used, and from the low resistance inside the barrel because of the fiber removal. Thus, the oil productivity of pressing dehulled Omega flaxseed was much higher than that of pressing whole Omega flaxseed (Fig. 2B). A peak in productivity (4.2 kg/h) was found at 10.5% (d.b.) for dehulled Omega flaxseed; however, the peak productivity (2.3

TABLE 2
ANOVA for the Influence of Variety and Moisture Content (nested under variety) on Oil Recovery and Capacity

Source of variation	df	F	P-value	$F_{0.05}$ crit.
Oil recovery result				
Variety	1	0.056^a	0.8187	4.96
Moisture content (variety)	8	82.49^b	<0.0001	3.07
Error	10			
Total	19			
Capacity result				
Variety	1	10.61^b	0.0116	4.96
Moisture content (variety)	8	10.73^b	0.0005	3.07
Error	10			
Total	19			

[a] $F < F_{0.05}$ crit. means not significantly different.
[b] $F > F_{0.05}$ crit. means significantly different.

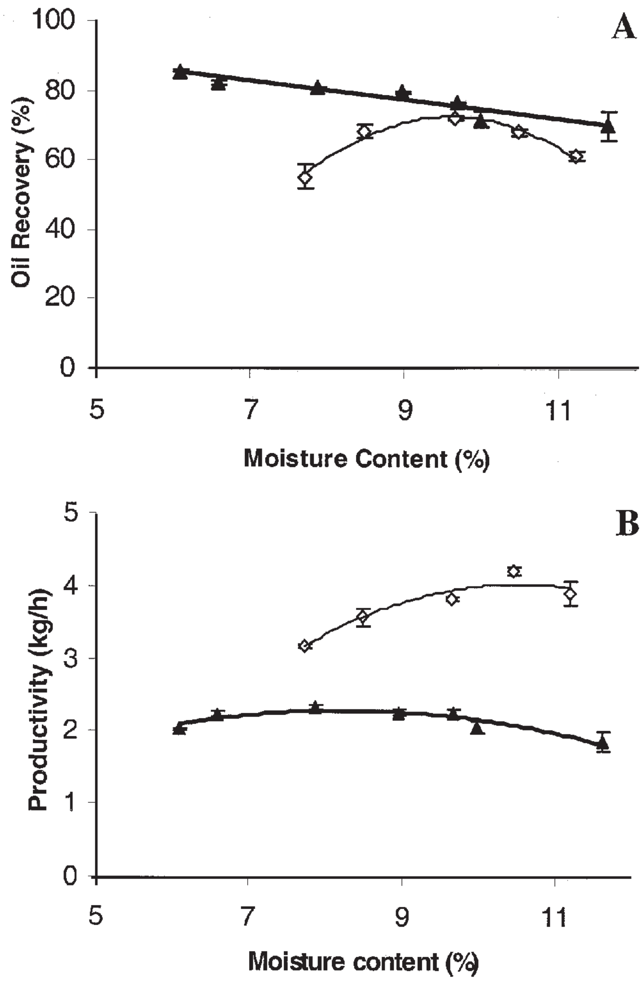

FIG. 2. Influence of dehulling on oil recovery (A) and productivity (B) of pressing Omega flaxseed. (▲) Whole Omega; (◇) dehulled Omega. Error bars represent SD.

kg/h) was at 7.9% (d.b.) for whole Omega flaxseed (Fig. 2B). The relationships between moisture content and productivity were statistically significant ($P < 0.1$) for both whole and dehulled Omega flaxseed. Dehulling condition and moisture content influenced the oil recovery, capacity, and productivity significantly (Table 3).

The trend of residual oil in the meal was inversely related to that of oil recovery when dehulled Omega flaxseed was pressed (Eq. 1). Thus, the lowest residual oil in the meal (20.7%) was achieved when the moisture content was 9.7% (d.b.), and the highest residual oil in the meal (30.3%) was obtained when the moisture content was 7.7% (d.b.). The residual oil in the meal from pressing whole Omega flaxseed was lower than the above results and in the range of 15.3 to 9.0%. However, the fiber content of meal from dehulled flaxseed should be much lower than that from whole flaxseed. This may be a big advantage for use in aquaculture and other nonruminant animal feeds, because high fiber content may reduce the nutrient intake and increase fecal waste production (12). Some fish species grow best when the lipid concentration of their feed is up to 20% (12). Also, the high ALA content of flaxseed oil in fish feed boosts levels of n-3 FA in the fish (17). Thus, the residual oil of meal from dehulled flaxseed may be advantageous for both fish and human nutrition.

TABLE 3
ANOVA for the Influence of Dehulling Condition and Moisture Content (nested under dehulling condition) on Oil Recovery, Capacity, Productivity, Oil Temperature, and Meal Temperature

Source of variation	df	F	P-value	$F_{0.05}$ crit.
Oil recovery result				
Dehulling condition	1	7.47[a]	0.0257	4.96
Moisture content (variety)	8	21.01[a]	<0.0001	3.07
Error	10			
Total	19			
Capacity result				
Dehulling condition	1	75.98[a]	<0.0001	4.96
Moisture content (variety)	8	12.14[a]	0.0003	3.07
Error	10			
Total	19			
Productivity result				
Dehulling condition	1	70.21[a]	<0.0001	4.96
Moisture content (variety)	8	24.39[a]	<0.0001	3.07
Error	10			
Total	19			
Oil temperature result				
Dehulling condition	1	36.70[a]	0.0003	4.08
Moisture content (variety)	8	1560.74[a]	<0.0001	2.18
Error	40			
Total	49			
Meal temperature result				
Dehulling condition	1	34.25[a]	0.0004	4.08
Moisture content (variety)	8	843.84[a]	<0.0001	2.18
Error	40			
Total	49			

[a] $F > F_{0.05}$ crit. means significantly different.

The sediment content of oil pressed from dehulled Omega flaxseed ranged from 2.5 to 3.5% of the weight of raw oil collected (data not shown). This was higher than the sediment content in oil from whole flaxseed, but with the same tendency toward being highest at both moisture content extremes.

Oil and meal temperature. The decrease of moisture content resulted in significant increases of both oil and meal temperature ($P < 0.0001$) when whole Neche flaxseed was pressed through the 6-mm choke (Fig. 3). When moisture content was higher than 7.5% (d.b.), the oil temperature ranged from 49 to 51°C, and the meal temperature from 60 to 62°C. The oil temperature satisfied the cold press requirement (4). When moisture content was lowered from 7.5 to 6.1% (d.b.), the oil and meal temperature increased significantly. The highest oil temperature was 67°C and was achieved by a sample moisture content of 6.1% (d.b.). A similar but higher oil temperature trend was reported for rapeseed, where the temperature decreased from 70 to 61°C when moisture content increased from 5.1 to 11.1% (w.b.) (5). Hoffmann (18) and Singh *et al.* (10) suggested that moisture acts as a lubricant during pressing; therefore, lowering the moisture content of seed increases friction.

The decrease of moisture content from 13.4 to 6.1% (d.b.) resulted in an increase of oil recovery from 58.5 to 89.7% when whole Neche flaxseed was pressed through the 6-mm

TABLE 4
Effects of Processing and Storage on Faxseed Oil Quality[a]

Source of sample[b]		PV (meq peroxide/1000 g oil)	FFA (% FFA as oleic)	Conjugated dienes (%)
Whole Neche				
M.C. 6.1% (d.b.)	(B)	0.20[b,c,d]	0.07[b]	0.15[a]
M.C. 13.4% (d.b.)	(B)	0.14[d]	0.09[b]	0.13[a,b]
Whole Omega	(A)	0.28[a,b]	0.08[b]	0.11[a,b]
Dehulled	(A)	0.24[a,b,c]	0.05[b]	0.08[b]
Dehulled (90 wk[c])	(A)	0.20[b,c,d]	0.23[a]	0.13[a,b]
M.C. 7.5% (d.b.)	(B)	0.31[a]	0.19[a]	0.15[a]
M.C. 10.9% (d.b.)	(B)	0.18[c,d]	0.18[a]	0.16[a]

[a]Values in the same column for each test with superscript roman letters in common were not significantly different by Duncan's multiple range test ($\alpha = 0.05$).
[b](A) Oil extracted by room-temperature hexane; (B) oil pressed by screw pressing; M.C., moisture content.
[c]Dehulled seed was stored in closed polyethylene bags at 5°C.

choke (Fig. 1A). However, the fact that increased oil recovery was accompanied by increased oil and meal temperature is a concern due to the heat-sensitive nature of the oil. The oil quality data from whole Neche seed pressing indicated very good quality and negligible differences between oil samples obtained at opposite temperature extremes (Table 4). Furthermore, we did not detect differences in appearance, odor, and color of oil that could be attributed to seed moisture content, choke size, or dehulling. Oil pressed from the Neche variety appeared darker than that from the Omega variety. Although differences in oil attributable to oil temperature were not observed, differences may become apparent over a normal storage life of 3 to 6 mon.

The oil temperature stayed in the range of 32 to 35°C, and the meal temperature stayed in the range of 47 to 51°C when the moisture content of dehulled flaxseed changed from 7.7 to 11.2% (d.b.) (Fig. 3). The oil and meal temperatures from pressing dehulled flaxseed were significantly lower than those from whole flaxseed (Table 3). The low and constant oil and meal temperature for dehulled flaxseed may be explained by the lower friction inside the screw press because of lower fiber content in the dehulled flaxseed than the whole flaxseed. The low oil temperature during the pressing of dehulled flaxseed may help processors satisfy the cold pressing requirement of organic oil.

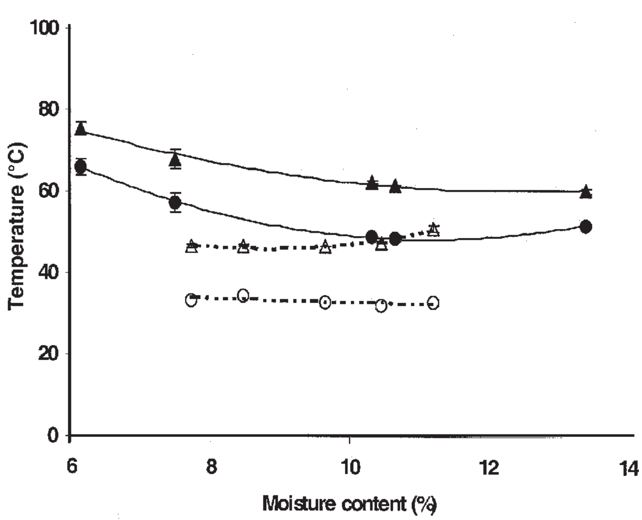

FIG. 3. Oil and meal temperature as influenced by moisture content and dehulling condition. (●) Oil, whole flaxseed; (▲) meal, whole flaxseed; (○) oil, dehulled flaxseed; (△) meal, dehulled flaxseed. Error bars represent the SD.

Additional pressing of dehulled Omega flaxseed, representing high- and low-moisture contents, was conducted 90 wk after the main body of tests to compare pressed oil quality with that from whole seed. The quality of oil pressed from dehulled seed was very acceptable, although the FFA content was significantly higher than that of oil from whole seed (Table 4). This increase resulted from the storage of the dehulled seed for 90 wk before pressing (Table 4), despite the use of closed polyethylene bags and storage at 5°C.

Pressing of dehulled and whole flaxseed showed significant differences. The oil recovery from pressing dehulled flaxseed was lower than that from whole flaxseed, but the oil productivity from pressing dehulled flaxseed was higher than that from whole flaxseed. Furthermore, the oil and meal temperatures from pressing dehulled flaxseed were significantly lower than those from whole flaxseed. Therefore, pressing dehulled flaxseed not only was possible but also may be beneficial in organic flaxseed oil production.

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