HYDROTHERMAL PROCESSES FOR EFFECTIVE DEHULLING OF CANOLA

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INTRODUCTION

Loosening bondage between the outer shell and the endosperm of a seed is the first stage in a successful dehulling process. Separation of the shell from the endosperm can then be achieved by mechanical means followed by sifting or aspiration. Differential cooling or heating of the seed or a combination of these processes may enhance dehulling efficiency. The overall objective of the project is to determine the properties of canola seeds and establishing:

1. the optimum combination of temperature and moisture content of the equilibrated seed prior to dehulling, and
2. the optimum heat and mass transfer rates for arriving at the final optimum temperature and moisture content.

This paper presents a review of literature pertinent to seed conditioning and mechanical dehulling and the results of preliminary experiments on seed breakage after heating and cooling conditioning.

Seed Conditioning

Fennema and Powrie (1964) reported that biological materials contract when they are subjected to decreasing temperatures . Materials containing less water show a greater contraction, resulting in reduced elastic properties. Much of the work on pre–treatment of seed for dehulling purposes has been reported for soybean. Singer (1965) found that 1 to 2 % reduction in bean moisture content promotes dehulling. Pfost (1975) reported that the relative humidity of the drying air was found to be the most significant factor affecting the level of seed coat cracks in soybean. Cracks increased with an increase in drying air temperature, initial moisture content and drying rate and decreased with increased final moisture content and drying air relative humidity. Galloway (1976) pointed out that beans had to be dried to a proper moisture content and stored for days so that the hulls would separate from the cotyledons easily after cracking. White et al. (1980) found that the development of both seed coat crack and cotyledon crack in soybean were highly correlated to the relative humidity and initial moisture contents. Shyeh et al. (1980) showed that the heat treatment of beans at 93 C for 15 minutes broke the bond between hulls and cotyledon.

Dorell (1968) on field peas pointed out that more breakage of seed coat at lower moisture contents may be due to a change in either tissue elasticity or the binding between the cotyledon and the inner seed coat surface. Ehiwe et al. (1987) found that seed coat breakage in field pea is affected by moisture content, followed by seed temperature and cultivar. Seed coat breakage increased linearly with temperature and with decreasing moisture contents. Mazza and Campbell (1984) found that dehulling yield in buckwheat decreased as the water activity of the seed increased. Gunasekaran and Paulsen (1985) found that the lower temperature increased the breakage susceptibility values in corn. Thompson and Foster (1963) reported that the amount of breakage doubled when the temperature of the same samples of corn was reduced from 29^{o}C to 5.5 ^{o}C. Eckhoff et al. (1988) found that breakage susceptibility of corn increases exponentially with decreasing temperature. Herum and Blaisdell (1981) inferred that the breakage mechanism might be expected to change as water mobility changes in the product.

Specific research work on the mechanical properties and conditioning of canola (rapeseed) seeds is scarce. Davison (1975) found that the rupture strength of rapeseed in compression ranged from 13.7 N per kernel at 7.2% (w.b.) to 9.8 N per kernel at 17%. Rupture generally occurred when the kernels were deformed 20%. Davison et al. (1978) reported that the cotyledons in the rapeseed kernel act mainly as a liquid within the seed shell. Paulsen (1977) found out that the compressive force required to cause soybean seed coat rupture decreased as soybean moisture increased from 8% to 17%. He also pointed out that deformation and the seed coat rupture increased as moisture increased, suggesting that soybeans at higher moisture are softer and more susceptible to bruising. Dobrzanski and Szot (1989) reported that the highest values of the damaging force (600-700 N) were obtained for the wrinkle pea seeds in 14%-16% moisture content range, however, the highest values of damaging force for the smooth pea seeds achieved only 430 N for the same values of moisture. Addy et al. (1980) reported in their studies on mechanical properties in leaf cell rupture that dynamic loads are more effective in causing failure (rupture) than corresponding static loads.

MATERIALS AND METHOD

To study the effect of thermal treatments and moisture content on the breakage of canola seeds, samples at two moisture levels of 6% and 11% wet basis (w.b.) were subjected to heating or cooling treatments at different temperatures ranging from -50 ^{o}C to 100 ^{o}C for various periods of 10, 20 and 40 min. The treated samples were tested for breakage and analyzed for size distribution. Color measurements were performed to determine the fractions and hull separation.

Sample Preparation

Grade No. 1 Canola seeds (Westar, B. napus) at 6% moisture content (w.b.) were obtained from a commercial seed supplier in Saskatoon. The seeds were 1990 crop grown in Western Canada. Samples were cleaned with No. 14 sieve (1.4 mm) and placed in air-tight containers at 4^{o}C prior to tests. Half of the seeds were conditioned by adding distilled water to raise the moisture content to 11% (w.b.). The seeds were mixed gently every 10 min for 2 h to facilitate uniform moisture absorption. The samples were stored in air-tight containers at 4^{o}C.

The moisture content was determined by drying samples at 130^{o}C for 4 h in a convection oven according the ASAE Standard S352.2 (ASAE, 1989) for rapeseed.

Thermal Treatments

Heating treatments were conducted by placing samples of 100 g, in air-tight containers, in an air oven set at 50 ^{o}C or 100 ^{o}C. The samples were maintained at the temperature for 10 min, 20 min and 40 min.

Cooling treatments were performed by placing the samples in air-tight containers at -50 ^{o}C in dry ice or at -20 ^{o}C in deep freezer for 10 min, 20 min, and 40 min.

After treatments the samples were kept at room temperature for 2 h prior to breakage tests.

Breakage Test

The breakage tests were conducted with a Model CK-2M Stein Breakage Tester. This equipment consists of a cylindrical cup, 92 mm in diameter and 90 mm in height, and two-blade impeller rotating at 1725 rpm inside the cup. The impeller is controlled by a timer which can be set at 1 to 5 min. Samples of 100 g, retained on sieve No.14, were placed in the cup and subjected to abrasive impact by the impeller for 4 min. The samples were removed and sieved again with a No. 14 sieve. The overs were weighed and the difference between overs and sample weights were used to calculate the percentage breakage.

After the breakage tests, particle size analysis of the samples was performed according to the ASAE Standard S319.1 (ASAE, 1989).

Color Measurement

The color of the samples retained on different sieves was evaluated using a Hunterlab Spectrocolorimeter (HunterLab, LabScan 6000, Hunter Associates Laboratory, INC., Reston VI). The color was expressed in Hunter L a b system in which L is darkness or brightness (from 0 to 100), + a is redness (0 to 100), -a is greenness (0 to -80), +b is yellowness (0 to 70) and -b is blueness (0 to -80).

RESULTS AND DISCUSSION

Breakage and Particle Size Distribution

The results of breakage are presented in Table 1. The thermal treatments for the samples at 6% and 11% moisture contents had no significant effect ($p>0.01$) on total percent breakage of the seeds in the breakage tests. However, the moisture content of the samples had a significant effect on both the percent breakage and particle size distribution. 11% moisture content resulted in much less breakage in the seeds.

Table 1. Breakage of canola seeds on Stein Breakage Tester, as affected by thermal threatments (temperature and time) and moisture content. The breakage for untreated samples were 42.3% for 6% moisture content and 5% for 11% moisture content.

	Breakage, %					
Temp. ^{o}C	Moisture Content, 6%			Moisture Content, 11%		
	10 min	20 min	40 min	10 min	20 min	40 min
-50.0	41.3	41.5	37.5	6.1	5.0	9.7
-20.0	43.1	37.3	41.0	4.1	4.1	4.9
50.0	41.9	40.9	36.9	4.7	5.1	7.1
100.0	36.7	36.4	39.0	5.9	5.0	11.5

The results of particle size analysis for untreated samples are presented in Fig. 1 which represents typical trends of the size distributions for all samples. In general, there was much more breakage (though No.14 sieve) in the samples of 6% moisture content than that of 11% moisture content samples. The breakage for the untreated 6% moisture content sample was 42.3% as compared to 5.0% for the 11% moisture content sample.

It was observed that, for the 6% moisture content samples, the overs on No. 10 (2.0 mm opening) sieve were large intact seeds, while some of the seeds on sieve No. 14 (1.4 mm) were split or dehulled. Most of the dehulled cotyledons were concentrated on sieve No. 18 (1.0 mm) with very small portion of large pieces seed coat, while large pieces of seed coats were on sieve No. 20 (0.841 mm). About 60% to 80% of the overs on sieve No.30 (0.595 mm) were germs detached from canola seeds. The overs on No. 40 (0.425 mm) and pan were small fragments of seed coat and cotyledons.

As for 11% moisture content sample, the broken particles were generally large in pieces, and more sticky than that of 6% moisture content. Again, most of the dehulled cotyledons were on sieve No. 18. mixed with large pieces of seed coats. The overs on sieve No. 20 were mostly seed coat. Detached germs were concentrated on sieve No. 30. Small amount of cotyledons and seed coat fragments were on sieve No. 40. There was virtually nothing on the pan.

It seems that high moisture content makes seeds tougher and less susceptible to breakage. At high moisture content, the seed coat were soft and remained in large pieces when detached from the seeds. The broken cotyledons were also in relatively large pieces. At low moisture content, on the other hand, the seeds were brittle and components of the seeds including the hull broken into smaller fractions.

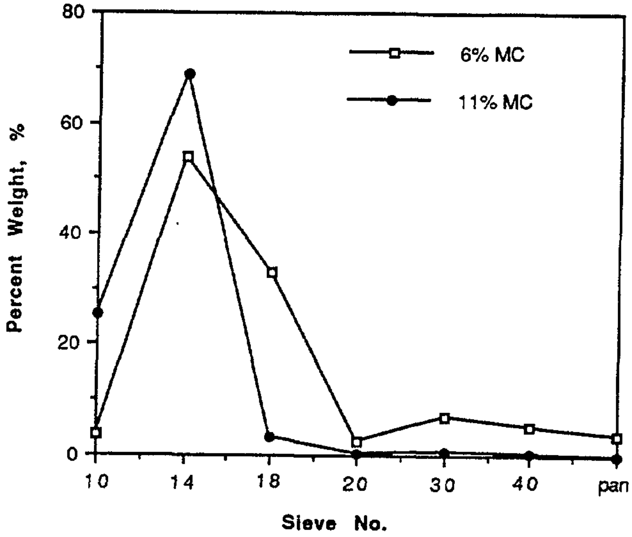

Fig. 1 Particle size distribution of canola seeds at 6% moisture content and 11% moisture content after breakage tests.

Color Analysis

The natural color of Westar intact canola seed coat was dark brown with a L value of about 18, and b value of 4. While the color of matured seed cotyledon was bright and yellow, characterized by a L value of about 40 and b value of 20. Values of a for both seed coat and cotyledons were similar, in the range from 2 to 5. Therefore, the value of L and b for a mixture can be used to describe the degree of dehulling and separation of seed coat from cotyledons.

The values of L and b for different particle size groups of untreated 6% and 11% (w.b.) moisture content samples are presented in Fig. 2. For 6% moisture content sample, values of L and b for the overs of sieve No. 14 were higher than that on No. 10 sieve. The lighter and yellower color was added by a small portion of broken and dehulled seeds. While for 11% moisture content samples, L and b values remained the same at this sieve, indicating no broken seeds on the NO. 14 sieves.

The values for L and b were reached the peaks at sieve No. 18 for both the moisture contents. These were due to very high concentration of dehulled cotyledons. For higher sieve numbers, L and b values for 6% moisture content samples decreased due to decreasing percentage of cotyledons and increasing portion of seed coats. The concentration of seed coat was the highest in the overs on sieve No. 40. However, this was not the case with 11% moisture content sample. The highest concentration of seed coat was in the overs of sieve No. 20 as indicated by the lowest value of both L and b.

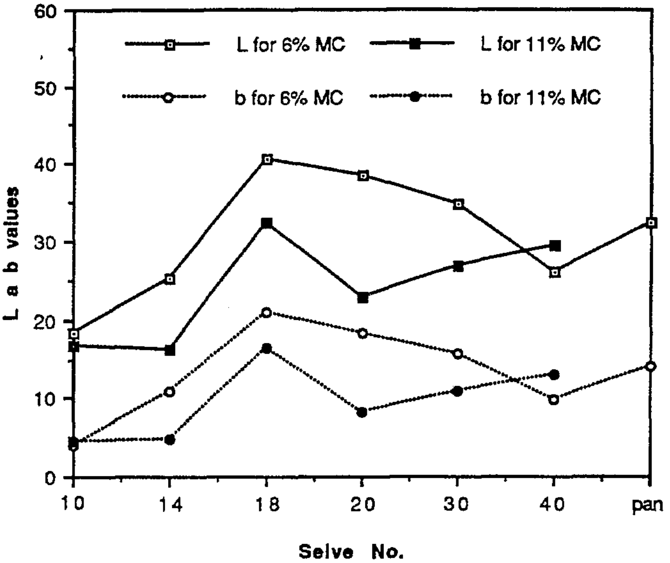

Fig. 2 Color measurement of canola seeds of different particle sizes.

From the above observations, it seems that the moisture content had significant effect on particle distributions of cotyledons and hulls after breakage. The 11% moisture content resulted in large pieces of hulls, typically concentrated on sieve No.20, and most of the hulls from 6% moisture content samples were reduced in size and concentrated on No. 40 sieve. However, the cotyledons from both moisture content samples were concentrated on the same sieve of No. 18.

The heat treatments on color measurements were not significant ($P>0.01$) which again indicates these treatment did not significantly affect breaking of canola seeds.

CONCLUSIONS

Moisture content has a significant effect on both the percent breakage and particle size distribution of canola seeds. The breakage was from 37% to 43% for the 6% moisture content samples and from 5 to 11% for the 11% moisture content sample. The 11% moisture content resulted in large pieces of hulls concentrated on sieve No.20. Hulls from 6% moisture content samples were reduced in size and concentrated on No. 40 sieve.

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