NOTE

Determination of the Breakage Susceptibility of Lentil Seeds[1]

JUMING TANG,[1,2] SHAHAB SOKHANSANJ,[1] and FRANK SOSULSKI[3]

ABSTRACT

Cereal Chem. 68(6):647–650

The Tangential Abrasive Dehulling Device and the Stein Breakage Tester were compared as methods for assessing the susceptibility of lentil seeds to breakage. Seed moisture content, operating time, and machine adjustments were the variables. Both devices were able to differentiate breakage susceptibility of lentil seeds at appropriate moisture levels under proper operating conditions. The Tangential Abrasive Dehulling Device required less operating time (2 min) and smaller samples, but the Stein Breakage Tester provided more consistent results at an operation time of 4 min. In general, breakage susceptibility of lentil seeds increased with decrease in moisture content and temperature.

Grain lentil (*Lens culinaris* Medik.) is a high-protein (22–34%) pulse crop used primarily for direct human consumption (Hughes and Swanson 1986). About 80% of lentil production in Canada is destined for foreign markets. One of the major problems experienced in mechanized harvesting and handling of grain lentil is mechanical damage to the seeds. Damaged lentil commands a lower price in the export market and is vulnerable to attack by insects and mold.

In general, methods for assessing breakage susceptibility of grains fall into two categories: visual inspection and instrumental methods. Visual inspections, involving assessment of stress cracks inside grains, are often aided by chemical staining, candling procedures, and, more recently, image processing (Paulsen et al 1981, Zayas et al 1990). These methods are straightforward, but identifying cracks in individual kernels of a reasonable sample size is time-consuming. With instrumental methods, damage susceptibility of grains is assessed by subjecting the grains to impact and/or abrasive loads in mechanical devices that simulate the type of loads grains would be subjected to during normal harvest, postharvest handling, and transport situations. A number of mills have been developed to measure the susceptibility of grains (especially corn) to mechanical breakage. However, the Stein Breakage Tester is the only commercially available device for routine measurements and has been adopted by the AACC as the standard device for measuring corn breakage susceptibility (Method 55-20) (AACC 1983). This method requires 100 g in each sample and no fewer than three replicates to produce reliable results.

A recent method based on the Tangential Abrasive Dehulling Device (TADD) was developed by Reichert and Ehiwe (1987) for assessment of seed coat durability of field pea. The TADD method requires only a few grams of seeds, and several samples can be tested simultaneously. The requirement of small sample size is appealing, especially for research applications.

The grading method in the Canadian grain grading system (Canadian Grain Commission, 1987) employs visual examination of split and broken kernels. No method is available to assess potential breakage in lentil seeds during handling before the grain reaches foreign markets.

The objective of the present study was to investigate the applicability of the Stein tester and the TADD for assessing the susceptibility of grain lentil to mechanical breakage.

MATERIALS AND METHODS

Sample Preparation

Fresh Laird lentil samples were grouped into six moisture levels varying from 8.2–18.6% (wb). The three lots with highest moisture contents were harvested by hand from swathed plots. The three

[1]Department of Agricultural Engineering, University of Saskatchewan, Saskatoon, Canada, S7N 0W0.
[2]Present address: Department of Food Science, Acadia University, Nova Scotia, Canada, B0P 1X0.
[3]Department of Crop Science and Plant Ecology, University of Saskatchewan.

lots at lower moisture levels were prepared by drying the 14.9% moisture lots in a thin-layer dryer at 30°C and 5% rh for varying periods of time. Lentil seeds were then sealed in air-tight plastic jars and stored for two weeks at 4°C to ensure uniform moisture distribution within each moisture group. In determining moisture content, whole lentil samples of about 16 g were dried in an air oven at 130°C for 24 hr, and the moisture contents were calculated according to ASAE (1990) Standard S352.2.

TADD

The TADD consisted of a cup plate, a rotating disk, and a hinged lid (Fig. 1). The plate has eight bottomless sample cups (i.d., 55.6 mm; height, 34.9 mm) evenly distributed at a radius of 100 mm. The rotating disk is made of an aluminum plate with a rubber pad bound on the top surface. The length of operation is controlled by a built-in timer. Details of this equipment are provided in Reichert et al (1986). During operation, sound lentil seeds in the cups were simultaneously subjected to abrasive and impact actions of the rotating disk driven by an electric motor at 1,750 rpm. After each run, intact seeds were counted, and the number of broken seeds was determined by calculating the difference between the numbers of seeds that were intact before and after the run.

The effects of operation time on breakage susceptibility of lentil seeds using the TADD were evaluated at three moisture levels: 10.6, 12.2, and 18.6% (wb). Samples of 45 seeds each, at each level of moisture content, were placed randomly in sample cups, and seed breakage was assessed at several intervals between 20 and 450 sec of operation. The tests were repeated in quadruplicate. A new rubber disk surface was installed for each test.

A 2 × 2 factorial test was also conducted to examine the influence of cup-disk clearance and the effect of disk surface wear condition. The two clearances were 0.15 and 0.45 mm. A new rubber surface was compared with one that had undergone 4 hr of continuous operation. The moisture content of the samples was 10.6%, and operation period was 2 min. Four samples were tested simultaneously, each consisting of 45 sound seeds.

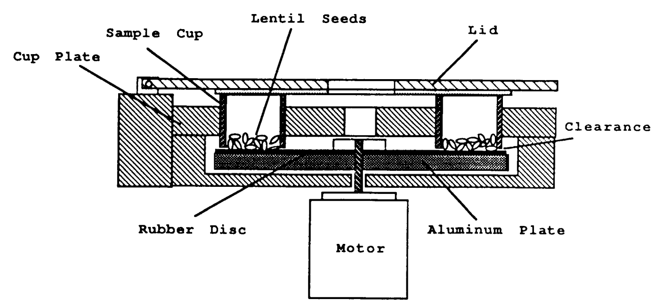

Fig. 1. Schematic diagram of the Tangential Abrasive Dehulling Device (TADD).

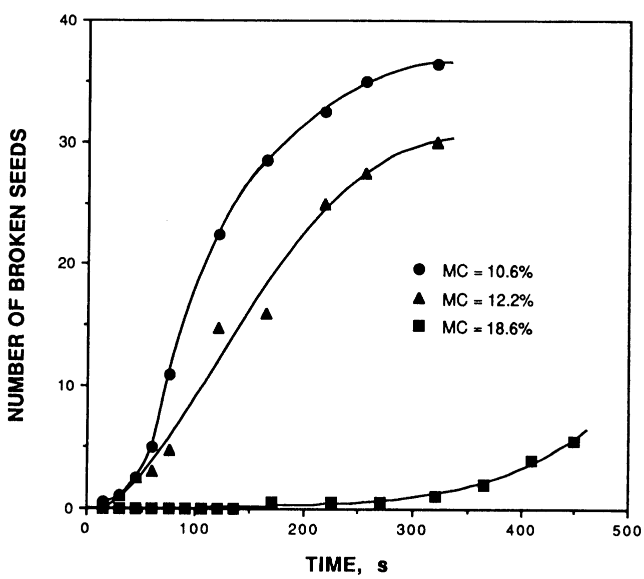

Fig. 2. Effects of the TADD operation time and seed moisture content on the number of broken seeds (45 seeds per sample) at 22°C, averaged over four replicates.

Stein Tester

The Stein tester (Model CK-2M, Fred Stein Laboratories, Atchison, KS) consisted of a two-blade impeller rotating at a speed of 1,725 rpm inside a cup that was 92 × 90 mm. Lentil samples of about 100 g each were presieved on a 4.76-mm round-hole sieve, placed in the cup, and milled for preset durations. The milled samples were then resieved on the same sieve, and overs were weighed. Preliminary tests showed that 40 cycles on the 4.76-mm round-hole sieve were adequate to separate the seeds with varying degrees of mechanical damage. Breakage susceptibility (BS, %) was calculated as follows:

$$BS = \frac{(\text{weight before mill} - \text{weight of overs})}{\text{weight before mill}} \times 100 \quad (1)$$

To eliminate possible systematic drifting in test values due to initial heating of the Stein tester, about 100 g of lentil seeds was impacted in the tester for 10 min before each series of tests.

A number of exploratory tests with lentil seeds indicated that the Stein tester operation time had the greatest influence on the uniformity of the results. Lentil samples at 12.2% moisture content were tested for 1, 2, 3, 4, and 5 min, with four replications, in random order. The effect of two temperatures (22 and −25°C) on the Stein tester results was also investigated. Samples at −25°C were conditioned in a walk-in freezer for 24 hr before the tests.

RESULTS AND DISCUSSION

TADD Method

The effects of operation time on the breakage of lentil seeds at three moisture levels (10.6, 12.2, and 18.6%) are illustrated in Figure 2. The scattered data points represent averages over four replicates. The standard deviations (SDs) for the replicates ranged from 0 to 3. The percentage of damaged seeds increased with duration of operation and with decrease in seed moisture content. The results reveal that the susceptibilities of breakage in lentil seeds at moisture levels of 10–18% can be differentiated after about 2 min of milling on the TADD.

The test results reported in Table I show the influence of cup-disk clearance and disk surface wear condition on seed breakage after 2 min of milling. The results of four replicates were consistent, with the coefficient of variation (CV) of each treatment varying from 3 to 10%. The magnitude of cup-disk clearance had no significant effect on test results ($P > 0.05$). However, a significant difference ($P < 0.05$) was noted between the results for the two rubber surfaces. Breakage on the new rubber surface was about three times the breakage on the old surface, which had undergone 4 hr of wear.

The physical condition of the rubber surface was examined with the scanning electron microscope. Micrographs A–C in Figure 3 show the rubber surfaces of the rotating disk in the TADD after 0, 4, and 40 hr of operation, respectively. The surface

TABLE I
Effect of Cup-Disk Gap and Disk Surface Condition on Lentil Breakage After Treatment with Tangential Abrasive Dehulling Device[a]

Clearance (mm)	Broken Seeds, No.	
	New Surface	Old Surface[b]
0.15	22.5 ± 0.7	7.5 ± 0.7
0.45	22.5 ± 2.1	8.0 ± 0.8

[a] Average ± SD of four replicates of 45 seeds at 10.6% moisture content; treatment time, 2 min.
[b] The old surface had undergone 4 hr of continuous operation.

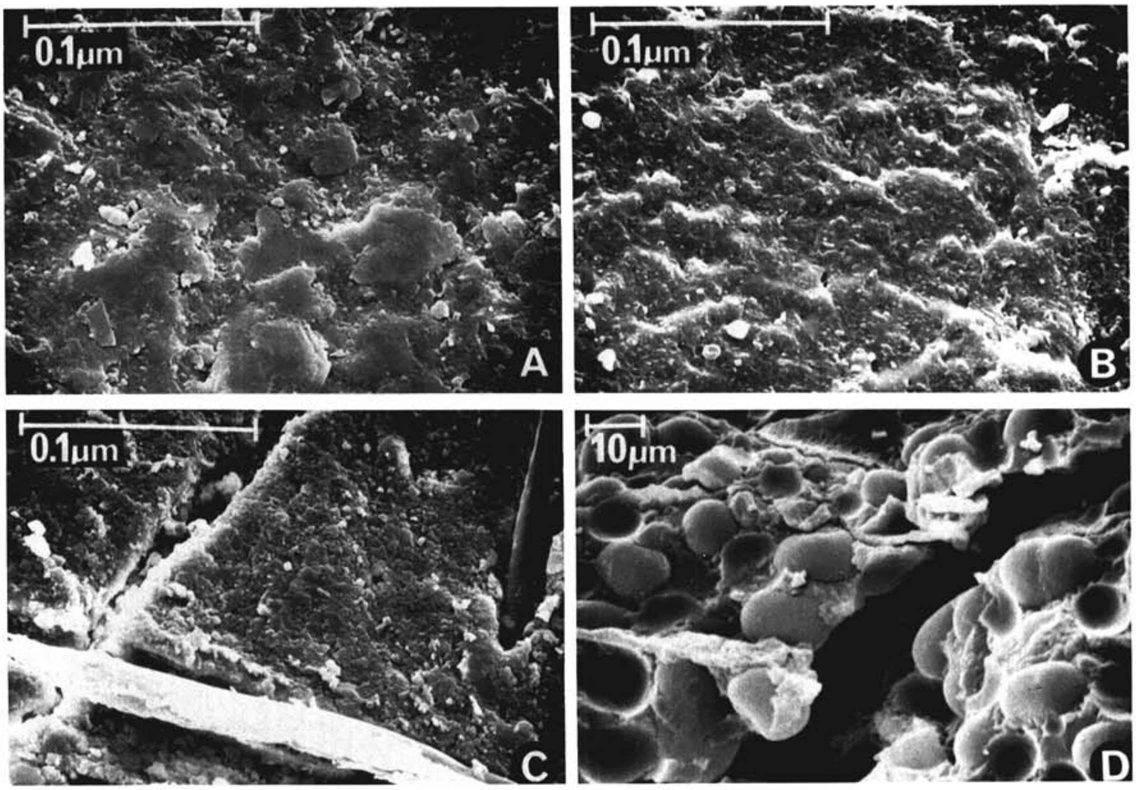

Fig. 3. Scanning electron micrographs. **A,** surface of a new rubber pad used in the TADD; **B** and **C,** surface of the rubber pad after 4 and 40 hr of operation, respectively; **D,** fracture in a lentil cotyledon at 10.5% moisture content (wb).

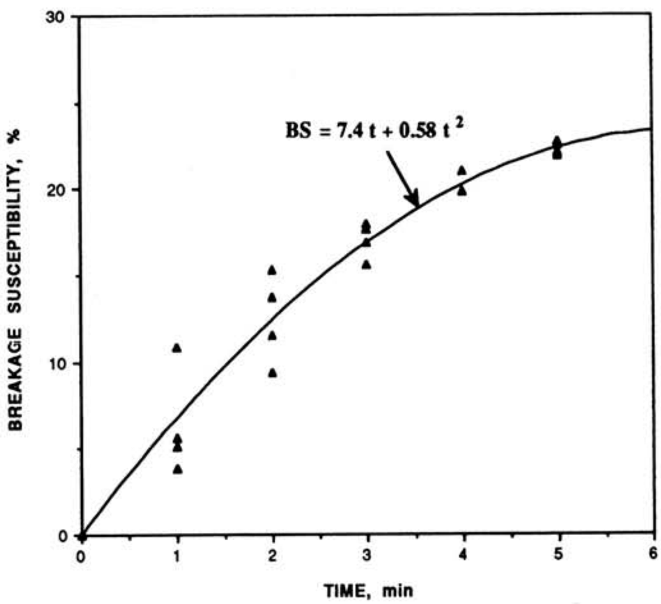

Fig. 4. Effect of operation time of CK-2M Stein Breakage Tester on the breakage susceptibility of lentil seeds at 12.2% moisture content, with four replicates.

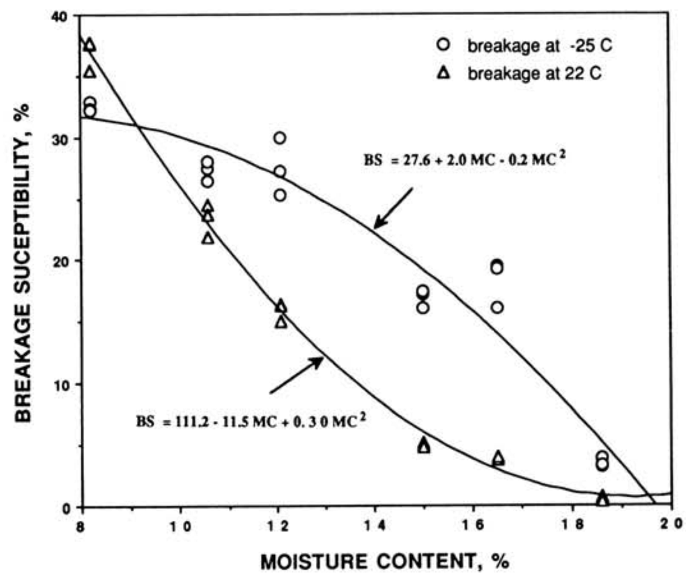

Fig. 5. Effect of moisture content and temperature on breakage of lentil seeds for the CK-2M Stein tester operated for 4 min, with three replicates.

of the new rubber pad was rough to the depth of about 0.05 mm (Fig. 3A). The surface was significantly smoothed after 4 hr of operation (Fig. 3B) and thus resulted in much less breakage of lentil seeds (Table I). After 40 hr of operation, the rubber surface was damaged to the extent that the reinforcing fibers were exposed (Fig. 3C). Therefore, the condition of the disk surface changed with length of operation, resulting in drifting test results. To overcome this drawback, either a new rubber pad should be installed for each test, or a more durable elastic surface material should be selected.

Stein Tester Method

With the Stein tester, the percentages of broken seeds increased with duration of operation (Fig. 4). The lentil seed breakage (BS, %) at 22°C and 12.2% moisture content was related to operation time (t, min) of the Stein tester by the following best-fit regression equation:

$$\mathrm{BS} = 7.4\,t + 0.58\,t^2 \qquad R^2 = 0.93 \tag{2}$$

Variation in the test results of four replications decreased with operation time (Fig. 4). The CVs were 54, 21, and 12% for operation periods of 1, 2, and 3 min, respectively. When operation time was increased to 4 min, the corresponding CV was reduced to 3.2%. Further reduction in CV was not significant when the operation period was increased to 5 min (CV = 2.3%). It seemed that 4 min was sufficient for evaluating the susceptibility of lentil seeds to mechanical breakage using the Stein tester. Under this condition, using the tester resulted in lower CVs for replicates than using the TADD for 2 min (CV = 3–10%).

Figure 3D shows a scanning electron micrograph of a typical fractured surface and a fracture in the cotyledon of a broken lentil seed as the result of seed breakage in the Stein tester. The fracture developed along the interfaces between starch granules and protein matrix.

Effect of Moisture Content and Temperature on Breakage

The effects of moisture and temperature on the susceptibility of lentil seeds to breakage using the Stein tester for 4 min are shown in Figure 5. The seed moisture contents were varied from 8.2 to 18.6%, and the tests were conducted at seed temperatures of 22 and −25°C. At 22°C, the SD in percent breakage varied from 0.14% to 1.3% for the 18.6 and 10.5 % moisture treatments, respectively. However, the results were less uniform among the three replicates at −25°C (SD = 0.6–2.8% breakage).

Both moisture content and temperature had a marked influence on the test results. In general, the percent of broken seeds increased as seed moisture decreased. At room temperature, this increase was dramatic when the moisture content was less than 15%. Breakage in samples was higher at −25°C than at room temperature for the same moisture content, except when the moisture content was less than 10%. The greater breakage in seeds with higher moisture content at −25°C could be attributable to crystallization of available free water. Miller et al (1979) observed similar behavior for soybeans in the Stein tester.

The dependency of breakage susceptibility of lentil seeds (BS, %) on moisture content (MC, %) was expressed by the following best-fit equations for temperatures of 22 and −25°C, respectively:

$$BS = 111.2 - 11.5\ MC + 0.30\ MC^2 \qquad R^2 = 0.99 \text{ at } 22°C \qquad (3)$$

$$BS = 27.6 - 2.0\ MC - 0.2\ MC^2 \qquad R^2 = 0.96 \text{ at } -25°C \qquad (4)$$

The above equations apply to seed moisture content of about 8–19%.

CONCLUSIONS

Experiments showed that the TADD, operating for 2 min, provided consistent results and differentiated susceptibility of lentil seeds at different seed moisture contents less than 18.6%. The TADD required small samples (a few grams) and could be used to test eight samples simultaneously. However, the surface condition of the rubber pad changed with length of operation time, and a more durable elastic surface material should be selected before using it for routine testing. The Stein tester also provided consistent test results. For good consistency in test results, it is recommended that this device be used at an operation time of 4 min at room temperature (22°C).

The susceptibility of lentil seeds to breakage was affected by seed moisture content and temperature. In general, this susceptibility increased with decreases in moisture content and temperature.

ACKNOWLEDGMENTS

This project was partially funded by the Saskatchewan Pulse Crop Development Board and by operating grants from the Natural Sciences and Engineering Research Council of Canada to S. Sokhansanj.

LITERATURE CITED

AMERICAN ASSOCIATION OF CEREAL CHEMISTS. 1983. Approved Methods of the AACC. Method 55-20, approved November 1981. The Association: St. Paul, MN.

AMERICAN SOCIETY OF AGRICULTURAL ENGINEERS. 1990. Standard S352.2. The Society: St. Joseph, MI.

CANADIAN GRAIN COMMISSION. 1987. Official Grain Grading Guide. Office of the Chief Grain Inspector, Inspection Division. The Commission: Winnipeg, ON.

HUGHES, J. S., and SWANSON, B. G. 1986. Microstructure of lentil seeds (*Lens culinaris*). Food Microstruct. 5:241-246.

MILLER, B. S., HUGHES, J. W., and POMERANZ, Y. 1979. Measuring the breakage susceptibility of soybeans. American Society of Agricultural Engineers, Paper No. 79-3560. The Society: St. Joseph, MI.

PAULSEN, M. R., NAVE, W. R., and GRAY, L. D. 1981. Soybean seed quality as affected by impact damage. Trans. ASAE 24:1577-1582, 1589.

REICHERT, R. D., and EHIWE, A. O. F. 1987. Variability, heritability and physicochemical studies of seed coat durability in field pea. Can. J. Plant Sci. 67:667-674.

REICHERT, R. D., TYLER, R. T., YORK, A. E., SCHWAB, D. J., TATARYNOVICH, J. E., and MWASARU, M. A. 1986. Description of a production model of the Tangential Abrasive Dehulling Device and its application to breeders' samples. Cereal Chem. 63:201-207.

ZAYAS, I., CONVERSE H., and STEELE, J. 1990. Discrimination of whole from broken corn kernels with image analysis. Trans. ASAE 33:1642-1646.

[Received April 29, 1991. Accepted August 13, 1991.]