2000

Soybean Mechanical Damage Detection

David VanUtrecht
*Iowa State University*

Carl J. Bern
*Iowa State University*, cjbern@iastate.edu

Ibni Hajar Rukunudin
*Iowa State University*

Follow this and additional works at: [http://lib.dr.iastate.edu/abe_eng_pubs](http://lib.dr.iastate.edu/abe_eng_pubs)

Part of the [Agriculture Commons](http://lib.dr.iastate.edu/abe_eng_pubs), and the [Bioresource and Agricultural Engineering Commons](http://lib.dr.iastate.edu/abe_eng_pubs)

The complete bibliographic information for this item can be found at [http://lib.dr.iastate.edu/abe_eng_pubs/454](http://lib.dr.iastate.edu/abe_eng_pubs/454). For information on how to cite this item, please visit [http://lib.dr.iastate.edu/howtocite.html](http://lib.dr.iastate.edu/howtocite.html).

This Article is brought to you for free and open access by the Agricultural and Biosystems Engineering at Iowa State University Digital Repository. It has been accepted for inclusion in Agricultural and Biosystems Engineering Publications by an authorized administrator of Iowa State University Digital Repository. For more information, please contact digirep@iastate.edu.
Soybean Mechanical Damage Detection

Abstract
The sodium hypochlorite and indoxyl acetate tests were compared as methods for quantifying the mechanical damage of soybeans. These methods were selected from six described in the literature. Soybeans at 7 and 21% moisture content were damaged in a Stein Breakage Tester and the remaining whole soybeans were subjected to the two tests. Sodium hypochlorite indicates damage by causing soybeans with cracked hulls to swell whereas the indoxyl acetate test utilizes a dye to stain soybeans with scratched or cracked hulls. The indoxyl acetate test was found to be more sensitive, but the sodium hypochlorite test yielded more consistent data. The hypochlorite test was selected as a suitable test for soybean mechanical damage quantification.

Keywords
Soybean damage, Mechanical damage, Seedcoat

Disciplines
Agriculture | Bioresource and Agricultural Engineering

Comments
SOYBEAN MECHANICAL DAMAGE DETECTION

D. VanUtrecht, C. J. Bern, I. H. Rukunudin

ABSTRACT. The sodium hypochlorite and indoxyl acetate tests were compared as methods for quantifying the mechanical damage of soybeans. These methods were selected from six described in the literature. Soybeans at 7 and 21% moisture content were damaged in a Stein Breakage Tester and the remaining whole soybeans were subjected to the two tests. Sodium hypochlorite indicates damage by causing soybeans with cracked hulls to swell whereas the indoxyl acetate test utilizes a dye to stain soybeans with scratched or cracked hulls. The indoxyl acetate test was found to be more sensitive, but the sodium hypochlorite test yielded more consistent data. The hypochlorite test was selected as a suitable test for soybean mechanical damage quantification.

Keywords. Soybean damage, Mechanical damage, Seedcoat.

Mechanical damage incurred during harvest and handling can lower the value of soybeans by increasing susceptibility to further mechanical damage and by speeding deterioration due to enzymatic and fungal activity during storage. A method is needed to quantify the mechanical damage state of soybeans so that effects of damage on deterioration during storage can be determined.

U.S. GRADES FOR SOYBEANS

Official United States grading criteria for soybeans account for damage by setting limits on the weight percentages of heat-damaged soybeans, total damaged soybeans, foreign material, and splits allowed for each grade number (USDA, 1992). Weight percentages of foreign material and splits adequately describe the sample fraction that is not whole soybeans. Foreign material consists of all matter in the sample that passes through a 3.2-mm (8/64-in.) round-hole sieve, plus all matter other than soybeans remaining in the sieved sample after sieving. Splits are soybeans with more than 25% of the bean removed and that do not have other damage. The damage and heat-damage criteria consider visible effects of ground contact, weather, disease, frost, mold, insects, and heat. Thus, with the exception of insect wounds, none of the grading criteria account for mechanical damage to whole soybeans.

MECHANICAL DAMAGE MEASUREMENT METHODS

Many methods of quantifying mechanical damage of grain and oilseeds have been reported in the literature. A discussion of several of these methods follows.

Chowdhury Method. A method of quantifying mechanical damage of corn kernels based on colorimetry and indirect measurement of the surface area of corn endosperm exposed by breaches in the pericarp was developed by Chowdhury (Chowdhury and Buchele, 1976). In this method, 100-g samples of test corn are soaked for 30 s in fast green FCF dye solution which stains starch (Johansen, 1940). Rinsing with distilled water removes dye not bonded to starchy areas exposed by breaches in the pericarp. The corn is then bleached with a 0.01 N solution of NaOH that extracts dye from the starch. This solution is then placed in a colorimeter where its light absorbency is measured on a scale of zero to 100. A greater concentration of dye causes a higher absorbency reading, and signifies greater mechanical damage.

The Chowdhury test was used on soybeans by Rukunudin and Perez-Munoz (1995), who found that NaOH was unable to extract fast green FCF dye from soybeans and that the resolution of the colorimeter was insufficient to yield precise values of soybean mechanical damage. They suggested that a device such as a HunterLab colorimeter be used to directly analyze the color of stained soybeans instead of using the extraction solution. One reason fast green FCF dye was not effective with soybeans is that, unlike a kernel of corn, a soybean has little additional starch exposed due to a seedcoat breach. If there are seedcoat breaches, the dye tends to be pulled under the seedcoat where it is difficult to extract with NaOH.

Computer Vision. With computer vision, a digital image of each seed is analyzed by a computer program which locates discoloration and cracks. This method has proven very accurate in determining fungal and physical damage in corn and soybeans (Steenshoek, 1998; Gunasekaran et al., 1988). However, to detect soybean seedcoat and cotyledon cracks, each seed must be placed under the camera in a prescribed manner. This procedure is time consuming and inaccurate. An automatic positioning...
device has been developed for corn, however, which overcomes some of these problems (Casady, 1989). Although this method is accurate, it involves sophisticated computer-camera systems, which are difficult to duplicate, and require a high degree of technical skill to operate.

Acoustic Method. With this method, each soybean is dropped onto an acoustic transducer. This impact induces an impulse wave in both the transducer and the seed that is sensitive to several seed properties. The wave form is recorded and analyzed by a computer program that can define the soybean’s quality. Soybeans damaged by disease have broad variations in the low frequency range, quantifiable by thresholding the error of fit in a curve fitting procedure (Misra et al., 1990). This method has not been shown capable of quantifying different levels of seedcoat mechanical damage.

Tetrazolium Test. The tetrazolium test is commonly used to determine soybean germination (Grabe, 1970). A sample of soybeans is presoaked for 8 to 12 h in a paper towel wetted with distilled water and then soaked in a solution of tetrazolium (C19H15N4Cl) for an additional 3 to 4 h. Live portions of a seed turn to a reddish color. If a seed has been damaged, tissue exposed because of a break in the seedcoat will not be alive and will not change color. If critical areas of the seed are dead, the seed will not germinate. Presence of unstained areas also indicates severe damage to tissue usually dies when exposed to the environment. Mechanical damage is quantified by determining the percentage of soybeans in the test sample with unstained areas.

Indoxyl Acetate Test. Indoxyl acetate (C10H9NO2) is a biological dye used to stain cells for analysis. It has been used with whole soybeans (French et al., 1962). In this test, soybeans are soaked in a 0.1% indoxyl acetate solution and then sprayed with an ammonia solution. If there is a scratch or a rupture in the seedcoat, indoxyl acetate will penetrate the parenchyma tissues of the inner layer of the seedcoat. Enzyme activity in these cells then hydrolyzes the indoxyl acetate and causes indigo to be deposited. Ammonia vapor facilitates the process (Paulsen and Nave, 1979). The seeds are then visually inspected for the indigo stain and separated by hand. The level of damage is based on the percentage of stained soybeans or the intensity of indigo color on the soybeans.

Hypochlorite Test. A simple technique known as the hypochlorite test has been used to obtain an estimate of soybean mechanical damage (Young, 1968; Gutormson, 1992). Household bleach is used to prepare a 1% sodium hypochlorite (NaOCl) solution. One-hundred soybeans are submerged in this solution. Mechanically damaged soybeans with a cracked seedcoat soak up the solution and swell to two or three times their original size in about 10 min. Swollen soybeans can be visually differentiated from sound soybeans. This method is fast and easy but does not indicate the level of damage to an individual soybean. A soybean with a small crack swells just as much as a soybean with a large crack.

Objective

The objective of this research was to identify the most appropriate method for quantifying soybean mechanical damage, considering speed, ease of use, apparatus requirements, repeatability, and ability to differentiate among a range of damage levels.

Procedure

Preliminary tests were conducted on mechanically damaged soybeans using several damage detection methods. Two of these methods were chosen for more extensive testing which formed a basis for selecting the most appropriate mechanical-damage detection method. All moistures are percent wet basis (% w.b.), and all were measured using a Dickey-john model GAC-2000 moisture meter.

Test Soybeans

Kruger 2525 soybeans were combine harvested at 21% moisture at the ISU Agronomy and Agricultural Engineering Research Center 15 km west of Ames, Iowa, during the 1994 harvest season. Cleaning was performed using a Carter-Day model XT3 Dockage Tester (CEA-Carter-Day Company, Minneapolis, Minn.) equipped with a 13-mm square-hole sieve, a 3.2-mm round-hole sieve, and a 4-mm × 19-mm slotted sieve. Half of the test lot was air-dried at ambient air temperature to 7% moisture after cleaning. The 7 and 21% moisture levels are the lower and upper bounds of moisture levels being studied in the storability study. The soybeans were stored at –18°C until use.

Producing Soybeans with Controlled Mechanical Damage

A Stein breakage tester (SBT) model CK2-M (Fred Stein Laboratories, Atchison, Kans.) was used to induce controlled mechanical damage to soybeans to be tested for mechanical damage in the lab.

To better define SBT effects, samples of the 7 and 21% moisture Kruger 2525 soybeans were placed in the SBT in order to increase mechanical damage. Four different time periods (0, 1, 2, and 4 min) were used to produce four damage levels. Each test consisted of a sample of 100 g of soybeans at one moisture content subjected to one of the beating times. Each test was repeated three times. Sieving the sample with a 3.2-mm round-hole sieve and separating all splits after the SBT treatment revealed that the percentage of foreign material splits increased with time in the SBT for soybeans at 7% moisture (fig. 1). No foreign material or splits were produced from the 21%-moisture soybeans. The higher moisture soybeans did, however, sustain seedcoat damage as will be seen in the damage testing. Additional whole soybeans were prepared for damage testing by SBT treatment followed by removal of fines and splits.

Extraction of FCF Fast Green and Safranin O Dyes

When Chowdhury attempted to use his method on sorghum (DeKalb E57a at 10% moisture), he found that the NaOH dissolved the pericarp, so he successfully substituted ethanol as an extraction agent (Chowdhury, 1978). This substitution was tested with soybeans. Nine 15 g samples of whole soybeans of unknown variety at 9% moisture were soaked in 0.1% fast green FCF dye for 2 min and then rinsed with distilled water for 1 min. The samples were then soaked for another 2 min in different
concentrations of ethanol. Ethanol did not effectively remove fast green FCF dye from the soybeans. Close examination of soybeans stained with fast green FCF dye revealed that dye stained the underside of the seedcoats and not the exposed cotyledons, thus confirming results reported by Johansen (1940) and Smith and Circle (1972).

The soybean cotyledon contains a higher percentage of crude protein than the hull (Smith and Circle, 1972), therefore, Safranin O dye was tested because it binds to protein (Johansen, 1940). In preliminary trials, however, Safranin O proved to be unsatisfactory because it was also pulled under the seedcoat by capillary action, and tended to stain the entire soybean. Furthermore, Safranin O was nearly impossible to extract with solutions of NaOH or ethanol. These dye methods were not considered further because of their poor ability to differentiate among different damage levels.

**TETRAZOLIUM**

Preliminary tests with tetrazolium showed that this method was not consistent in indicating seedcoat cracks. Furthermore, it required several hours of presoaking and soaking. This testing method was eliminated from further consideration.

**COLORIMETER TESTS**

A HunterLab colorimeter (Hunter Associate Laboratory, Reston, Va.) and a Chowdhury colorimeter (MC Instruments, 1301 Baitinzer Court, Sun Prairie, Wis.) were used to estimate damage levels of stained soybeans by spectral analysis. The Chowdhury colorimeter is simpler and less expensive than the HunterLab instrument. A test was conducted to compare effectiveness of the two instruments. Whole soybeans at 7% and 21% moisture were used. Samples at six time intervals (0, 1, 2, 3, 4, and 5 min in the Stein Breakage Tester) for the two moisture contents (7% and 21%) were treated and then sieved with a 3.2-mm round-hole sieve. This removed the fines but left in any splits. Forty grams of the sieved soybeans were submerged in 100 mL of 1% indoxyl acetate solution for 10 s, then taken out, placed on a paper towel, and sprayed with a 20% ammonia solution for another 10 s. After drying, they were again submerged in a 0.5% concentration of NaOH to extract the indigo dye from the soybeans. This solution was then analyzed in both colorimeters.

Assuming that whole soybeans incur progressively more mechanical damage with additional time in the SBT (an assumption supported by hypochlorite and indoxyl acetate results to be discussed later), neither colorimeter yielded encouraging results. Chowdhury colorimeter readings trended upward with SBT time for 7% moisture soybeans, but showed no trend with 21% moisture soybeans. The Hunter Lab colorimeter did not distinguish among SBT times with 21% moisture soybeans. Readings with 7% moisture soybeans showed a linear trend, within a narrow (4 unit) range.

Considering these poor results and the comparative complexity of these methods, they were both eliminated from further consideration.

**INDOXYL ACETATE**

Preliminary indoxyl acetate tests with SBT-damaged soybeans provided encouraging results. Although the stain was not as intense as fast green FCF or Safranin O, it consistently stained only the scratched or cracked portion of the hull.

**HYPOCHLORITE TEST**

Preliminary tests conducted with 7% and 21% moisture whole soybeans previously subjected to SBT treatment revealed that the hypochlorite test works on both wet and dry soybeans, and differentiates among whole soybeans subjected to different SBT test times. Speed, ease of use, and apparatus requirements were acceptable.

**INDOXYL ACETATE VERSUS HYPOCHLORITE**

After considering all of the preliminary trials, the indoxyl acetate and hypochlorite methods were chosen for further study and comparison. Both require human visual inspection, but the inspection is not problematic since swollen or stained soybeans are easy to distinguish from normal soybeans.

**EXPERIMENTAL DESIGN**

The experiment was set up as a totally randomized split plot design. Four SBT damage levels (0, 1, 2, 4 min) and two moisture content levels (7 and 21%) of Kruger 2525 soybeans were tested by each of the two testing methods. The order of testing was completely random. One hundred whole soybeans were used for each test. Three repetitions of each combination were conducted for a total of 48 tests.

**PROCEDURE**

For the indoxyl acetate test (IAT), the procedure was carried out as described by Paulsen and Nave (1979). One-hundred soybeans were soaked for 10 s in a 0.1% concentration of indoxyl acetate, prepared by dissolving indoxyl acetate granules in 200 proof ethanol. The soybeans were then removed, spread out on a paper towel, and sprayed for 10 s with a 20% ammonia/distilled water solution. After this, the soybeans were allowed to air dry (Paulsen and Nave, 1979). All of the above steps were carried out under a laboratory hood because of the strong ammonia odor.
After drying, any amount of dye visible on the soybean classified the soybean as damaged. The percentage of damage was the number stained out of 100.

The hypochlorite test (HT) was carried out as described by Gutormson (1992). First, a 1:5 dilution of household bleach to water was prepared to obtain a 1% sodium hypochlorite solution. Then 100 whole soybeans were submerged in this solution. After 10 min, swollen seeds were identified and counted as damaged. The percentage of damage was the number of swollen soybeans out of 100.

RESULTS AND DISCUSSION

Results are graphed in figures 2 and 3. The 7% moisture soybeans registered a higher degree of damage than the 21% moisture soybeans with both tests. This suggests that the 7% moisture soybeans were more brittle and their hulls were more susceptible to scratches and cracks. The high moisture soybeans were more resilient and, thus, able to absorb the impact of the propeller in the SBT without incurring splits and excessive hull cracking.

At zero SBT time, the HT indicates about half as much damage as the IAT. This tendency is due to its reaction to a scratched, but uncracked, hull. In such cases, IAT will indicate damage, the HT will not. This characteristic favors the HT for our intended purpose of relating mechanical damage to deterioration during storage, since cracks will likely be more closely related to deterioration rate than scratches. The graphs suggest that after a 4-min SBT time, the seedcoats of scratched 21% moisture soybeans are cracked since HT damage approximately equals IAT damage.

The mean IAT damage level actually decreases between 1 and 2 min in the SBT. This possibly indicates that some soybeans defined as damaged by IAT after 1 min broke up and were removed as splits and fines after 2 min in the SBT. Statistical analysis showed that:

• For both the HT and IAT tests, damage for 7% moisture soybeans is significantly greater than for 21% soybeans.
• In all four cases, the linear models are adequate.
• The slopes of all four regression lines are greater than zero.
• The slopes for 7% moisture and 21% moisture soybeans are not significantly different for the IAT.
• The slope for 7% moisture is significantly greater than the 21% moisture slope for the HT.

Considering our selection criteria, the HT is superior for our purposes. Its speed, ease of use, repeatability, and apparatus requirements are all satisfactory. Its tendency to detect cracked but not scratched hulls is most appropriate for our use with a soybean storage deterioration study. As evidenced by its significantly different slopes between 21% and 7% moisture soybeans, the HT is better able to detect more damage with a greater time in the Stein Breakage Tester. Although the HT seems to be the better choice, none of the test results show the IAT to be unsuitable for use.

The appendix contains a suggested procedure for numerically defining the particulate fractions and mechanical damage level of a sample of soybeans.

CONCLUSION

The hypochlorite test was judged to be the best among considered tests for quantifying mechanical damage of whole soybean samples in a study of stored soybean deterioration. Its 13- to 15-min time requirement is acceptable. The procedure is simple, and only basic lab apparatus is required. Tests showed that the hypochlorite test can differentiate among damage levels of 7 and 21% moisture whole soybeans subjected to varying times in a Stein Breakage Tester.

REFERENCES


APPENDIX
Suggested procedure for defining particulate fractions and mechanical damage of a soybean sample.

1. Obtain a representative sample of soybeans of at least 250 g.
2. Divide this sample by using a Boerner divider to obtain an analytical portion of approximately 125 g.

3. Sieve this portion by using a 3.2-mm (8/64-in.) round-hole sieve. Foreign material consists of all material passing through the sieve plus all matter other than soybeans remaining on top. Express foreign material as the percentage weight of foreign material in the analytical portion.

4. Sieve what remains of the analytical portion after foreign material is removed by using a 4-mm × 19-mm (10/64-in. × 3/4-in.) slotted sieve. Splits consist of all material passing through the sieve plus all soybeans on top of the sieve with more than one-fourth of the bean removed. Express splits as the percentage weight of splits in the analytical portion.

5. Draw three samples of 100 soybeans from what remains of the analytical portion after splits and foreign material have been removed. Soak each sample in a 1% sodium hypochlorite (household bleach) solution. After 10 min, visually determine how many soybeans from each sample have swollen. Express percentage mechanical damage as the average number of swollen soybeans from the three samples.

6. Define the particulate fractions and mechanical damage of the soybean sample as the percentage foreign material, percentage splits, and percentage mechanical damage.