

BREAKAGE SUSCEPTIBILITY OF WHEAT AND TRITICALE SEEDS RELATED TO MOISTURE CONTENT AND IMPACT ENERGY

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ABSTRACT. Mechanical damage of seeds due to harvest, handling and other process is an important factor that affects the quality and quantity of seeds. Seed damage result in lower grain value, storability problem, and reduced seed germination and seedling vigor and subsequent yield of crops. The objective of this research was to determine the effects of moisture content and impact energy on the breakage susceptibility of wheat and triticale seeds. The experiments were conducted at five moisture contents of 7.5, 12, 17, 22 and 27% w.b. and at the impact energies of 0.05 and 0.1 J. The percentage of breakage of both wheat and triticale seeds increased as impact energy increased. The analysis of variance showed that there was a significant difference between breakage susceptibility of wheat and triticale seeds at the 1% probability level. Triticale seeds had more breakage than wheat seeds. For both wheat and triticale seeds as the moisture content of the seeds increased, the amount of the percentage breakage of seeds decreased as a polynomial. The average values of percentage breakage of wheat seeds decreased from 43.81 to 19.88% as the moisture content increased from 7.5 to 27%. Over this same moisture content range the percentage breakage of triticale seeds varied from 81.34 to 37.77%. Below the moisture contents of 17% for the wheat and 22% for the

triticale the percentage breakage of seeds increased dramatically.

Key words: Wheat, triticale, mechanical damage, harvesting, handling, processing, moisture content, impact energy.

INTRODUCTION

Harvesting and postharvest operations negatively influenced quality of seeds. Harvesters and other machines that used during harvest, transport, storage and processing caused significant mechanical damage to seeds i.e. skin rupture, seed fracture etc. The damage resulted from mechanical interaction between biological material (seeds) and steel, rubber etc. (working elements of machines). Most authors admit that damage to seeds occurs mainly in the course of harvest and transport, where the seeds are subject to accidental impact.

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The mechanical resistance to the impact damage of seeds among other mechanical and physical properties plays a very important role in the design and operational parameters of equipment relating to harvesting, threshing, handling and other processing of the seeds (Baryeh, 2002). Impact damage of seeds depends on a number factors such as velocity of impact, seed structural features, seed variety, seed moisture content, stage of ripeness, fertilization level and incorrect settings of the particular working subassemblies of the machines. Among above factors, the seed moisture content and impact velocity are important factors influencing the damage. Some researchers found a significant influence of the impact velocity and moisture content upon the seed damage and found that the damage increases significantly as the energy of the impact increases and as the moisture content decreases (Baryeh, 2002; Parde *et al.*, 2002).

Impact damage to seeds has been the subject of much research due to the loss in product quality incurred during harvesting, handling and processing. Researchers have used different impact damage assessment devices to conduct impact tests on seeds. Many studies have been conducted to determine the mechanical damage to seeds, such as: Fraczek and Slipek (1998) on wheat, Kim *et al.* (2002) on maize, Parde *et al.* (2002) on soybean seed, Sosnowski (2006) on bean seed, Szwed and Lukaszuk (2007) on

rapeseed and wheat kernels, Khazaei *et al.* (2008) on wheat seed, Khazaei (2009) on white kidney bean, Shahbazi (2011) on chickpea seed, Shahbazi *et al.* (2011a) on pinto bean, Shahbazi *et al.* (2011b) on navy bean and Shahbazi (2012) on wheat seed.

Information on the breakage susceptibility of wheat and triticale seeds related to moisture content and impact energy is limited. Therefore, the objective of this study was to investigate the effects of moisture content on the breakage susceptibility of wheat and triticale seeds under impact loading.

MATERIALS AND METHODS

The wheat and triticale seeds used for the present study were obtained from a field in the Lorestan University that were cultivated in same condition, during the 2011 cultivation season. After attaining optimum maturity, samples of seeds were harvested by hand and cleaned in an air screen cleaner. The initial moisture content of wheat and triticale seeds were 7.5 and 6.8% (wet basis) respectively, determined with ASAE S352.2 (ASAE Standards, 1988). Higher moisture content samples were prepared by adding calculated amounts of distilled water, then sealing in polyethylene bags, and storing at 5°C for 15 days. Samples were warmed to room temperature before each test and moisture content was verified. Sample mass was recorded with a digital electronic balance having an accuracy of 0.001 g.

The laboratory apparatus used to impact seeds, operated in a way similar to the impacting energy instruments used by Asoegwu (1995), Kim *et al.* (2002) and Oluwole *et al.* (2007) (Fig. 1). An

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aluminum drop bar (800 mm length; 25 mm external diameter; 0.2 kg) was inserted into a steel tube (750 mm length; 27 mm internal diameter; 29 mm external diameter). The steel tube had 4 mm diameter holes drilled at 5 cm intervals from 5 to 60 cm. The drop height of the aluminum bar was manually controlled by a pin inserted in the hole in the middle of a steel tube. The steel tube was clamped to a laboratory stand. Because the seed naturally lies on its length (Fig. 1) and also preliminary tests showed that impacts to the side of the seeds resulted in significantly more splits than impacts to top, the test seed was placed in the horizontal orientation on the base plate. The aluminum bar dropped, hitting the seed when the pin was manually removed

at the given drop height. The impact energy on seed depends on the mass and drop height of the aluminum bar. The impact energy was determined using the following equation:

$$E_i \approx Mg(H-W) \quad (1)$$

where: E_i is the impact energy (J), M is the mass of the drop bar (0.2 kg), g is the acceleration due to gravity (9.8 m/s^2), H is the drop height from base plate (m), and W is the width (m) of seed (Fig. 1). In this experiment, the drop heights used for the drop tester were selected after preliminary experimentation (data not shown). The fixed drop heights of the aluminum bar were 2.5 and 5 cm, so the impact energies on seeds were 0.05 and 0.1 J.

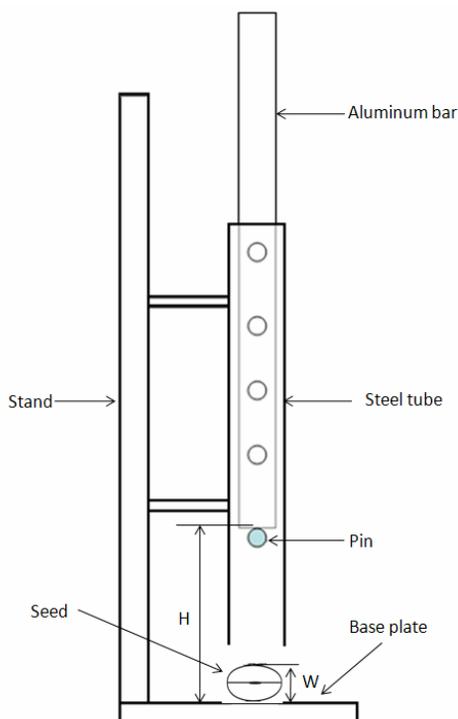


Figure 1 - Schematic diagram of the impact test apparatus

In this study, the effects of impact energy (at: 0.05 and 0.1 J) and of seed moisture content (at: 7.5, 12, 17, 22 and 27% wet basis) were studied on the percentage breakage of wheat and triticale seeds. The range of seeds moisture is from 7.5 to 27% as this includes the normal range of moisture levels during harvesting and postharvest processing for seeds (Khazaei *et al.*, 2008). The factorial experiment was conducted as a

randomized design with three replicates. For each impact test, 100 seeds were selected randomly from each sample and impacted by using the impact device. After each test, damaged seeds include the broken, cracked, and bruised seeds were accurately identified and sorted by visual inspection. A handheld magnifying glass was used to augment the visual inspection. The percentage of seed damage was calculated as:

$$\text{Seedbreakage} = \frac{(\text{Weight of damaged seeds})}{(\text{Weight of total seeds (damaged + undamaged)})} \times 100 \quad (2)$$

Experimental data were analyzed using analysis of variance (ANOVA) and the means were separated at the 5% probability level applying Duncan's multiple range tests in SPSS 17 software. The nonlinear regression program of SAS (SAS, 2001), was used to find and fit the best general models to the data and develop empirical models that explain the relationship between percentage of seed damage and the experimental variables.

RESULTS AND DISCUSSION

Analysis of variance indicated that there was a significant difference between the percentage breakage of wheat and triticale seeds of at 1% probability level ($P < 0.01$). In addition, the effects of seed moisture content and impact energy on this property were significant (*Table 1*). Seed (kind) had the most influence ($F=1679.58$) but impact energy ($F=754.49$) and seed moisture content ($F=407.27$) had the least, respectively, within the ranges studied for variables (*Table 1*). The interaction effects of the seed \times moisture content, seed \times impact energy, moisture content \times impact energy and the interactions

effect of the three independent variables significantly influenced the percentage breakage of seeds at 1% probability level ($P < 0.01$) (*Table 1*).

The values for the percentage breakage of seeds at different test conditions are presented in *Table 2*. The greatest percentage breakage of seeds in *Table 2* was obtained as 95.04% in the triticale seeds for impact energy of 0.1 J at the moisture content of 7.5%, while the lowest percentage breakage of seeds was found to be 10.58% in the wheat seeds for impact energy of 0.05 J at a moisture content of 27% (*Table 2*).

The moisture content had high effect on the percentage breakage of both wheat and triticale seeds. As follows from the data in *Table 2*, for all the impact energies considered, the percentage breakage of both wheat and triticale seeds decreases with increase in their moisture content. These results confirm that, as the moisture content has significant effects on the elastic properties of materials of plant origin, it also has a bearing on the effects of impact damage. At higher moisture contents,

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the elasticity of seeds will increase, which causes that their firmness increase, thus, causes greater absorption of energy during impact and increases the resistance to damage. On the other hand, at lower moisture contents, the seeds are more brittle, thus, more prone to physical damage caused by impact. Similar

decreasing trends for percentage breakage of seeds by increasing the moisture content were reported by Szwed and Lukaszuk (2007) for rapeseed and wheat, Khazaei *et al.* (2008) for wheat seed, Khazaei (2009) for white kidney bean, and Shahbazi (2011) for chickpea seed.

Table 1 - Analysis of variance (Mean square) for the percentage of seeds breakage as affected by crop kind, moisture content and impact energy

Source	DF	Mean Square	F
Seed (S)	1	13729.568	1679.580**
Moisture Content (MC)	4	3329.251	407.278**
S x MC	4	216.562	26.493**
Impact Energy (IE)	1	6167.554	754.496**
S x IE	1	292.693	35.806**
MC x IE	4	41.843	5.119**
S x MC x IE	4	64.812	7.929**
Error	40	8.174	

: significant at the 0.01 probability level

Table 2 - Percentage of seeds breakage as a function of crop kind, moisture content and impact energy

Crop	Moisture content (%)	Percentage breakage of seeds	
		Impact energy (J)	
		0.05	0.1
Wheat	7.5	37.76 (1.29)	57.87 (3.48)
	12	26.73 (3.38)	38.27 (2.94)
	17	16.32 (2.84)	30.73 (3.28)
	22	8.42 (0.96)	29.34 (1.96)
	27	10.58 (2.18)	21.17 (3.45)
	Mean	18.68(9.78)	35.21(11.72)
Triticale	7.5	81.63 (4.09)	95.04 (5.59)
	12	58.73 (6.63)	80.69 (4.56)
	17	40.55 (3.63)	70.25 (7.65)
	22	26.54 (3.78)	56.32 (3.050)
	27	23.79 (2.63)	52.42 (3.05)
	Mean	44.78(12.69)	71.61(20.13)
Total Mean		33.35(20.88)	53.61(22.79)

Data in parentheses are standard deviation.

As follows from the data in *Table 2*, for all the moisture contents and impact energies that were studied (at the same condition of impact tests), triticale seeds had more breakage than wheat seeds. The average value of the percentage breakage of wheat seeds at different test conditions in *Table 2* was obtained 26.94% (data not shown) while its value for triticale seeds was obtained 58.20%.

As shown from in the *Table 2* the values of the percentage breakage of seeds increased with increasing impact energy. Increasing the impact energy from 0.05 to 0.1 J caused an increase in the percentage breakage from 18.68 to 35.21% and from 44.78 to 71.61% for wheat and triticale seeds, respectively (*Table 2*). The mean values of the total percentage breakage of seeds at 0.05 J impact energy was 31.73% and its value for 0.1 J impact energy was 53.42% (*Table 2*).

The results of Duncan’s multiple range tests for comparing the mean values of the percentage breakage of seeds at different moisture contents is presented in *Fig. 2*. It is evident from *Fig. 2* that the percentage breakage of seeds decreased as a quadratic function, with increase in their moisture content (*Fig. 2*). Many researchers have also reported similar results for the other crops (Parde *et al.*, 2002; Szwed and Lukaszuk, 2007; Khazaei *et al.*, 2008; Khazaei, 2009). With increasing the moisture content from 7.5 to 27%, the mean values of the percentage breakage significantly decreased by 2.53 times. The average values for the percentage breakage were found to be 62.57, 51.10, 40.71, 33.82 and 24.64% for moisture contents of 7.5, 12, 17, 22 and 27%, respectively. The mean values of the percentage breakage at the different moisture contents had significant differences ($P<0.05$) base on the Duncan’s multiple range tests (*Fig. 2*).

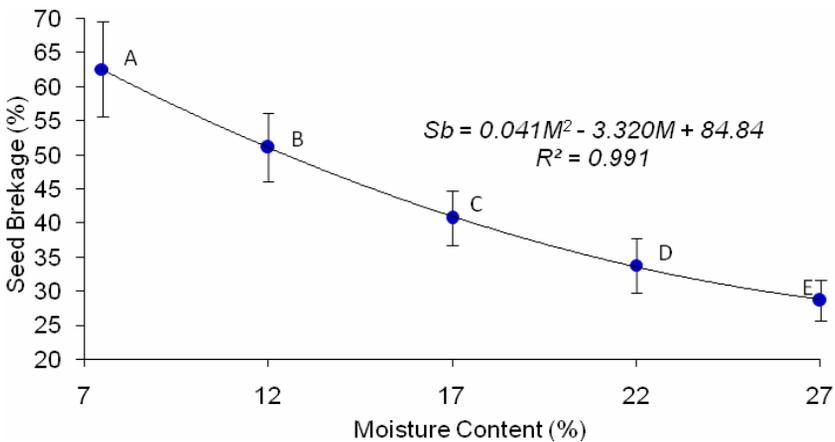


Figure 2 - Effects of moisture content on the percentage breakage of seeds. Averages with the same letter have no significant difference at the 5% probability level.

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Fig. 3 shows the wheat seeds breakage vs. moisture content. The average values for the percentage breakage of wheat seeds were found to be 43.81, 32.49, 23.52, 19.88 and 15.51% for moisture contents of 7.5, 12, 17, 22 and 27%, respectively. There is an exponential relationship between breakage and moisture content of wheat seeds with an R^2 value of 0.994. The slope of the curve distinctly changes at about 17% moisture content, with little breakage above that moisture and greatly

increasing breakage below that moisture, indicating that optimal harvesting, handling and processing of wheat seeds would be above this moisture content. According to numerous studies, there exists a certain optimum level of moisture content for each variety at which, under the effect of impact forces, there occurs a minimum of damage to the seeds (Szwed and Lukaszuk, 2007). Therefore, in the current study the optimum level of moisture for wheat seeds was about 17%.

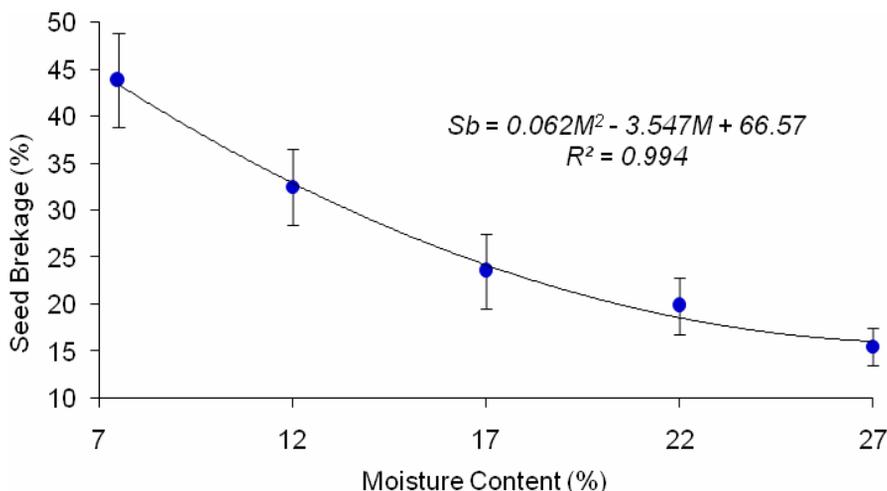


Figure 3 - Percentage breakage of wheat seeds at different moisture contents

Fig. 4 shows the triticale seeds breakage vs. moisture content. The average values for the percentage breakage of triticale seeds were found to be 81.34, 69.71, 55.40, 44.77 and 37.74% for the moisture contents of 7.5, 12, 17, 22 and 27%, respectively. There is an exponential relationship

between breakage and moisture content of triticale seeds with an R^2 value of 0.991. The curve slope decreases at about 22% moisture content, indicating that the optimum level of moisture for triticale seeds would be above this moisture content.

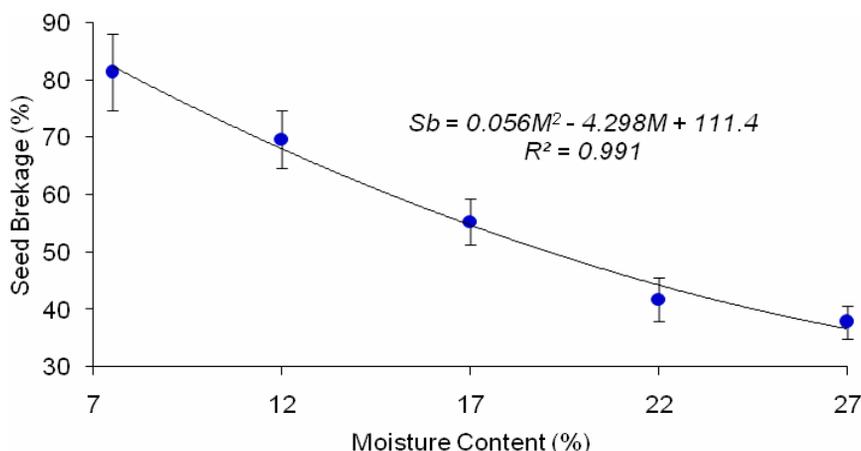


Figure 4 - Percentage breakage of triticale seeds at different moisture contents

CONCLUSIONS

There was a significant difference between the percentage breakage of wheat and triticale seeds of at 1% probability level ($P < 0.01$). It was found that the percentage breakage of wheat and triticale seeds was increased linearly with impact energy. Increasing the impact energy from 0.05 to 0.1 J caused an increase in the percentage breakage of seeds from 18.68 to 35.21% and from 44.78 to 71.61% for wheat and triticale seeds, respectively. The results showed that an increase in moisture content of both wheat and triticale seeds led to a decrease in the percentage breakage of seeds as a quadratic function. The average values of the percentage breakage of wheat and triticale seeds varied from 43.81 to 19.88%, and 81.34 to 37.77%, respectively, as the moisture content increased from 7.5% to 27%. For all moisture contents and impact

energies that were studied, triticale seeds had more breakage than wheat seeds. The optimum level of moisture, where impact damage was minimized, for wheat seeds was about 17% and for triticale seeds was about 22%.

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