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Seed moisture dependent on physical properties of *Turgenia latifolia*: criteria for sorting

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Turgenia latifolia (T.L.) is an annual weed in wheat fields of Iran and Middle East region. Despite the separation process its seeds do not separate from wheat kernels in the milling process. Some physical properties of wheat kernels (cv. Sardari) and T.L. seeds, namely dimensions, equivalent diameter, sphericity, bulk density, true density, angle of repose and static coefficient of friction as a function of moisture content, 7% to 20.8% w.b. were investigated. There was significant difference between all physical properties of wheat and T.L. seeds and the effect of moisture content on these properties that was significant except for true density and length. True density varied nonlinearly from 1270 to 1300 kg/m^3 and from 970 to 1080 kg/m^3 for wheat and T.L. seeds, respectively, as their moisture content increased. Wheat and T.L. had the lowest static coefficient of friction on the plywood and steel surface, respectively. The highest static coefficient of friction was obtained on the aluminum surface for both of them. However, there was highly difference between the true density of wheat and T.L. seeds and the static coefficient of friction on the aluminum surface. Therefore, these properties can be used to design separation equipments.

Key words: Physical properties, separation, *Turgenia latifolia*, wheat

Nomenclatures

al	Aluminum	*Mc*	Moisture content, % w.b.
d_e	Equivalent diameter, mm	*st*	Steel
L	Length of kernel, mm	*T*	Thickness of kernel, mm
M	Mass of kernel, kg	*W*	Width of kernel, mm
V	Volume of graduated cylinder, m^3	ϕ	Sphericity of kernel, %
w	Plywood	ρ_b	Bulk density, kg/ m^3

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Introduction

Physical properties are important factors in solving problems associated with design specific machines or analysis of the behavior of the product during agricultural processes such as planting, harvesting, handling, threshing, sorting and drying. Solution to these problems involves having knowledge of physical and engineering properties of products (Irtwange and Ugbeka, 2002). In the milling process, it is an important operation to separate foreign materials from wheat grains. Many types of equipment have been designed to separate foreign materials from wheat grains using the physical differences between them. Separation of foreign materials from wheat kernels has been done in two phases: primary separation and secondary separation. But the moisture content of materials is different at these processes. In the primary separation process, the moisture content is in the range of 7-10 % w.b. and in the secondary separation process; it is in the range of 12-14 % w.b. Despite the separation process T.L. seeds do not separate from wheat grains in the milling process. In order to separate T.L. seeds from wheat grains, it is necessary to determine their physical properties. This knowledge may lead to some type of equipment can be designed and constructed to separate T.L. seeds from wheat kernels.

The physical properties of various seeds and fruits were measured such as sorrel seeds by Omobuwajo *et al*. (2000); terebinth fruits by Aydin and Ozcan (2002); Prosopis africana seeds by Akaaimo and Raji (2006); sugarbeet seeds by Dursun *et al.* (2007); peanut and kernel by Aydin (2007) and green soybean by Sirisomboon *et al.* (2007). But there is no information about the physical properties of T.L. seeds.

The objective of this study was to measure some moisture dependent physical properties of T.L. and wheat (cv. Sardary) kernels such as static coefficient of friction, dimensions, equivalent diameter, sphericity, bulk and true densities and angle of repose. Moisture content of seeds was considered in the range of 7% to 20.8% w.b., which spans the moisture range of harvested crop and milling operation.

Materials and methods

Sample preparation

Wheat and T.L. seeds were manually cleaned to remove foreign materials such as dust, dirt, stones, chaff and broken kernels. They were classified into two grades based on their length. Cut points being 6.92 and 7.54 mm for wheat and T.L. seeds, respectively. Grade A and grade B referred to above and below the cut point, respectively. The initial moisture content of seeds was determined at 103 ± 1 ºC for 19 h (ASAE standard, 1998). The initial moisture content of wheat and T.L. seeds were of 10% and 7% w.b., respectively. The seeds with higher moisture content were obtained by adding known amount of distilled water. The samples were kept at 5ºC for a week to enable the moisture to distribute uniformly throughout the seeds (Al-Mahasneh and Rababah, 2007). Wheat and T.L. seeds were left to get dry at 70 ºC and 30 ºC, respectively for different periods of times to obtain 5 levels of moisture content namely, 20.8%, 17%, 14%, 10% and 7% w.b.

Size and shape measurement

The three principal dimensions of 20 seeds of T.L. and wheat kernels (selected randomly) were measured using a digital vernier caliper (resolution: ± 0.01 mm). The equivalent diameter and sphericity were calculated by the three principal dimensions using Eqs. 1 and 2, (Mohsenin, 1978; Irtwange and Ugbeka, 2002).

$$d_e = (LWT)^{\frac{1}{3}} \qquad [1]$$

$$\phi = \frac{(LWT)^{\frac{1}{3}}}{L} \qquad [2]$$

Bulk and true density

Bulk density of wheat and T.L. seeds was measured using a graduated cylinder. The cylinder was filled and tapped 10 times to cause the seeds to settle. A sharp edge flat used to remove excess kernels or seeds to level the surface at the top of the cylinder (Jain and Bal, 1997). Bulk density was calculated using Eq. 3.

$$\rho = \frac{M}{V} \qquad [3]$$

True density was measured by toluene displacement method. The mass of seeds were measured and then poured in a pycnometer that was full of toluene. The true density of seeds was found as the ratio of their mass to the volume of toluene displaced by the seeds (Chakraverty and Paul, 2001).

Static coefficient of friction

The static coefficient of friction of wheat and T.L. seeds was determined on the plywood, steel and aluminum sheet. These surfaces were put on the titling table. A topless and bottomless circular cylinder, 50 mm in diameter and 50 mm in high, was placed on an adjustable tilting table and filled with seeds. The cylinder was raised slightly so as not to touch the surface. The surface with the cylinder resting on it was inclined gradually with a screw device until the cylinder began to slide. At this time, the angle of table surface was read from the graduated scale and the tangent of this angle is static coefficient of friction on that surface (Jain and Bal, 1997; Baryeh, 2002; Ozarslan, 2002; Yalcin *et al*., 2007).

Angle of repose

The angle of repose was measured using a wooden box half full of seeds mounted on a tilting table. The table was tilted until the seeds began to move leaving an inclined surface. At this time, angle of tilted table was measured as the angle of repose for samples (Mohsenin, 1978; Ghasemi *et al*., 2008).

Statistical analysis

Data analysis of length, width, thickness, equivalent diameter, sphericity, bulk density, true density and angle of repose for samples were carried out by a nested split plot form arranged in Completely Randomized Design (CRD). Wheat and T.L. seeds were as a main plot and moisture content levels were as a sub plot. Data analysis of static coefficient of friction of seeds was carried out by a nested factorial split plot form arranged in CRD. The first factor was type of seeds (wheat and T.L.) and the second factor was type of surfaces (aluminum, steel and plywood). These were as a main plot and the moisture content of seeds was as a sub plot. Mean comparison was carried out at 5% probability level. Data were analyzed by MSTATC and SPSS software.

Results and discussion

Size and shape

The results showed that there was significant difference between length, width, thickness, equivalent diameter and sphericity of wheat and T.L. seeds (at both grades, A and B). Also the effect of moisture content on these properties was significant, except for length of seeds. Equivalent diameter, sphericity and three principal dimensions of wheat and T.L seeds (at both grades) are shown in Table 1. It can be observed that these properties increased as the moisture content increased. This indicates that the seeds expend in length, width and thickness as the moisture content increased. But the rate of their expansion is different from each other. It could be due to the cell arrangement is different. This results are in agreement with published literatures for millet (Baryeh, 2002), African yam bean (Irtwange and Ugbeka, 2002) and for green wheat grains (Al-Mahasneh and Rababah, 2007).

Knowledge of sphericity values is essential to determine the shape and dimensions of screen mesh in designing of separation and cleaning equipments. Sphericity of wheat T.L. seeds was in the range of 55 to 56% and 51-53%, respectively. These low sphericity values shows that these seeds trend to slide rather than roll on specific surface (Al-Mahasneh and Rababah, 2007). On the other hand, it indicates that wheat and T.L. seed could not be assume as sphere therefore, separation of T.L. seeds from wheat kernels using separation equipment such as sieve or screen with circular holes will not be successful.

Despite the significant differences between the sphericity and dimensions of wheat and T.L. seeds, they could not be separated successfully in the cleaning and separation processes using sieves, because the dimensions of wheat and T.L. seeds are not too different from each other.

Table 1. Mean of dimensional characteristic of wheat and T.L. seeds.

Seed	Grade	Moisture content % (w.b.)	Length (mm)	Width (mm)	Thickness (mm)	Equivalent diameter (mm)	Sphericity (%)
Wheat	A	20.8	7.85	3.44	3.05	4.35	55
		7	7.63	3.31	2.92	4.19	55
	B	20.8	6.71	3.08	2.77	3.85	57
		7	6.69	2.98	2.65	3.74	56
T.L.	A	20.8	9.57	4.05	3.39	5.07	53
		7	9.49	3.87	3.30	4.94	52
	B	20.8	6.83	2.73	2.39	3.54	52
		7	6.76	2.66	2.37	3.46	51

True density

The analysis of variance showed that there was significant difference between the true density of wheat and T.L. seeds (at both grades). But the effect of moisture content on this property was not significant. The maximum value of true density for wheat kernels was related to grade B at the moisture content of 17% w.b and the minimum amount of it was obtained for grade A at the moisture content of 7% w.b. (1,315.77 and 1,274.55 kg/m^3, respectively). T.L. seeds had the maximum value of true density at grade B, at the moisture content of 20% w.b. and the minimum value at grade A at the moisture content of 7 % w.b. (1,057.64 and 958.02 kg/m^3, respectively). As shown in Fig. 1 the true density of wheat and T.L. seeds increased as the moisture content increased. It indicates that as the moisture content increased, the both of mass and volume of seeds increased, but the mass of seeds increased more than their volume. These results are in agreement with published literature for millet. Baryeh (2002) reported that the true density of millet increased from 1,555 to 1,712 kg/m^3, as the moisture content increased from 5 to 22.5% d.b. However, Ozarslan (2002) showed that as the moisture content increased from 8.33 to 13.78% d.b., the true density of cotton seeds decreased from 1,091 to 1,000 kg/m^3. Also, for African yam bean (Irtwange and Ugbeka, 2002), barbunia bean seeds (Cetin, 2007), green wheat grains (Al-Mahasneh and Rababah, 2007) and pea seeds (Yalcin *et al*., 2007), the true density was reported to decrease as the moisture content increased. Coskuner and Karababa (2007) indicated that as the moisture content increased from 7.1 to 12.82% d.b., the true density of coriander seeds decreased from 345 to 332 kg/m^3, and it increased from 332 to 349 kg/m^3, as the moisture content increased from 12.82 to 18.94% d.b.

True density of wheat kernels was higher than T.L. seeds and the difference between them was about 185 Kg/m^3 at all studied moisture content levels (Fig. 1). Therefore, this difference is large enough to separate T.L. seeds from wheat kernels using equipment which operate on the basis of true density.

Bulk density

As the moisture content increased from 7% to 20.8% w.b., the bulk density of wheat kernels was found to decrease from 889 to 735 kg/m^3 (Fig. 2). Increase in the moisture content leads to increase the both of weight and volume of kernels. But the rate of volume increasing was higher than weight. Therefore, the bulk density of wheat kernels decreased. The bulk density of T.L. seeds increased from 373 to 391 kg/m^3, as the moisture increased from 7% to 20.8% w.b. It indicates that the volume of T.L. seeds did not increase considerably as the moisture content increased. On the other hand, the results showed that there was significant difference between bulk density of wheat and T.L. seeds. Also the effect of moisture content on this property was significant at 1% probability level. Ozarslan (2002) showed that as the moisture content increased from 8.33 to 13.78% d.b., bulk density of cotton seeds decreased from 642 to 610 kg/m^3. Al-Mahasneh and Rababah (2007) reported that bulk density of green wheat grains decreased from 708.2 to 675.2 kg/m^3 as the moisture content increased from 9.3 to 41.5% d.b. This results are also in agreement with published literatures for African yam bean (Irtwange and Ugbeka, 2002), barbunia bean seeds (Cetin, 2007) and pea seeds (Yalcin *et al*., 2007). Knowledge of bulk density has an important role in hopper designing. But it cannot be useful to design separation equipments.

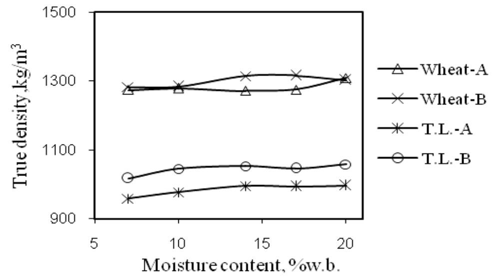

Fig. 1. True density variation against seed moisture content.

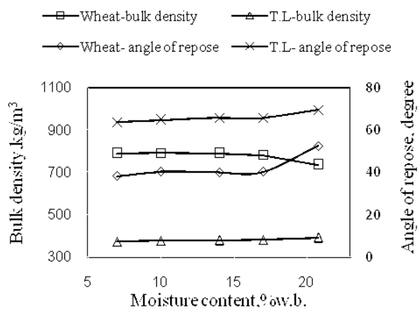

Fig. 2. Bulk density and angle of repose variation against seed moisture content.

Angle of repose

Wheat and T.L. seeds had significant difference between the angles of repose. The angle of repose for T.L. seeds was higher than wheat kernels (Fig. 2). It was due to differences in shape, size and surface properties of two kinds of seeds. The high sphericity values of wheat kernels in comparison with T.L. seeds lead to wheat kernels trend to roll on each other and have low angle of repose. The effect of moisture content on this property was significant at 1% probability level. The angle of repose for wheat and T.L. seeds increased from 38 °C to 52°C and from 63 °C to 69 °C, respectively as the moisture content increased from 7% to 20.8% w.b. Several authors have been measured this property for other grains. Baryeh (2002) reported that the angle of repose for millet grains increased from 34.5 °Cto 48.5 °C as the moisture content increased from 5% to 22.5%. Coskuner and Karababa (2007) showed that this property for coriander kernels varied from 24.9 °C to 30.7 °C as the moisture content increased from 7.1% to 18.94%. Jain and Bal (1997) and Ogunjimi *et al.* (2002) indicated that the angle of repose for pearl millet and locust bean seeds were in the range of 20 °C – 23 °C and 23 °C – 25 °C, respectively.

Static coefficient of friction

The analysis of variance showed that the main effects and interaction effects between kind of seeds and the materials of tilted surfaces on the static coefficient of friction were significant. Wheat and T.L. had the lowest static coefficient of friction on the plywood and steel surface, respectively (0.324 and 0.317) and the highest static coefficient of friction was on the aluminum surface for both of them (0.482 and 0.534). It was due to the surface properties of seeds. As shown in Fig. 3 as the moisture content increased from 7% to 20.8% w.b.; the static coefficient of friction of wheat kernels on the aluminum, plywood and steel surface increased from 0.428 to 0.535, 0.315 to 0.394 and 0.351 to 0.459, respectively. Also at the same range of moisture content, static coefficient of friction of T.L. seeds was in the range of 0.484 to 0.585, 0.325 to 0.473 and 0.287 to 0.360 on the aluminum, plywood and steal surface, respectively (Fig. 4). This is due to this fact that as the moisture content increased; the adhesion between the seeds and surfaces increased and led to increase the static coefficient of friction. Cetin (2007) reported that the static coefficient of friction of barbunia bean seeds increased linearly against surfaces of four structural materials, namely rubber (0.213–0.271), aluminum (0.161–0.222), stainless steel (0.147–0.207) and galvanized iron (0.169–0.246) as the moisture content increased from 18.33% to 32.43% d.b. Coskuner and Karababa (2007) showed that as the moisture content increased, the static coefficient of friction of coriander seeds increased nonlinearly from 0.435 to 0.877, 0.425 to 0.775, 0.379 to 0.839, 0.364 to 0.781, 0.344 to 0.650, and 0.325 to 0.694 for plywood, polypropylene knitted bag, polyvinyl chloride, galvanized iron, cast polypropylene and stainless steel surfaces, respectively.

Mean comparison also showed that at the moisture content of 7% and 10% w.b., the static coefficients of friction values of T.L. seeds on the aluminum surface was about 0.484 and 0.539, respectively. These values were higher than the static coefficients of friction of wheat kernels. Also there was significant difference between them at the both moisture content levels, 7% and 10% w.b. (Fig. 5). It is evident that T.L. seeds can be separated successfully from wheat kernels on the aluminum surface in the primary separation when the moisture content is in the range of 7-10% w.b.

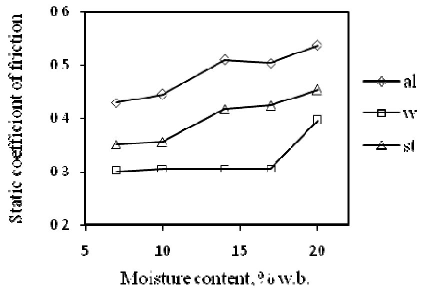

Fig. 3. Static coefficient of friction of wheat kernels on the different surfaces.

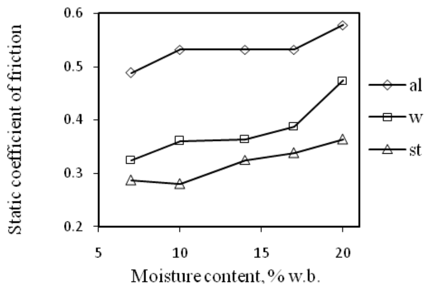

Fig. 4. Static coefficient of friction of T.L seeds on the different surfaces**.**

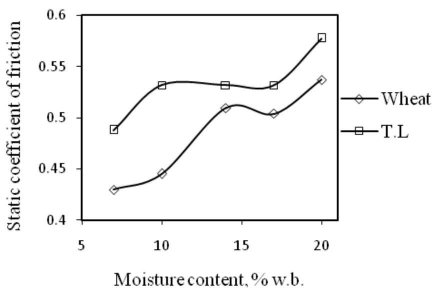

Fig. 5. Static coefficient of friction of wheat and T.L seeds on the aluminum surface.

Conclusion

Physical properties of T.L. seeds were significantly different from those of wheat kernels. Moisture content had significant effect on all physical properties of both wheat and T.L. seeds except for length and true density. The true density of wheat kernels was higher than T.L. seeds. The differences between the true densities of them were about 185 kg/m^3. It indicates that separation of T.L. seeds from wheat could be done according to this property. The static coefficient of friction values of wheat and T.L. seeds were different on the various surfaces. The maximum difference between them was obtained on the aluminum surface.

Consequently, the separation of T.L. seeds from wheat kernels based on this property should be done on this surface and in the primary separation when the moisture content of seeds is in the range of 7-10% w.b.

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