Int. Agrophysics, 2010, 24, 81-84

INTERNATIONAL
Agrophysics
www.international-agrophysics.org

Note

Selected physico-mechanical properties of lentil seed

H. Bagherpour, S. Minaei, and M.H. Khoshtaghaza*

Department of Agricultural Machinery Engineering, Faculty of Agriculture, Tarbiat Modares University, Tehran, Iran

Received March 28, 2009; accepted June 29, 2009

A b s t r a c t. This study was conducted to investigate the physico-mechanical properties of lentil seed. The average diameter, thickness, thousand-grain mass, angle of repose and porosity of lentil seed increased by about 10, 8, 17, 10 and 6%, but both true and bulk density decreased by about 10 and 13%, respectively, with increase of moisture content from 8 to 20% w.b. Coefficient of static friction increased against surfaces of glass (by 31%), galvanized steel (by 33%), and plywood (by 17%) as the moisture content increased. Deformation, rupture energy and rupture force of lentil seed decreased with increasing moisture content. Compressive tests were conducted at loading rates of 1, 3, 6 and 10 mm min^{-1} at a moisture content of 8%. Results indicate that force required to crack the seed increased from 159.6 to 182.32 N as the loading rates increased from 1 to 10 mm min^{-1}, respectively. With this increase in loading rate, seed deformation showed a negative trend as it decreased from 0.61 to 0.18 mm.

K e y w o r d s: lentil seed, mechanical properties, loading rate

INTRODUCTION

Lentil (*Lens culinaris* Medik) is an annual plant of the legume family. Preserving and maintaining maximum quality during post-harvest operations is vitally important if the growing need for high protein food is to be met for an increasing world population (Vursavus and Ozguven, 2005). Dimensions are very important in the design of sizing, cleaning and grading machines. Bulk density and porosity are major parameters in the design of drying and storage systems (Dursun and Dursun, 2005). Knowledge of the coefficient of friction is necessary in designing equipment for solid flow and storage structures. Recent scientific developments have made better the handling and processing of bio-materials through electrical, optical, thermal and other techniques, but little is known about the basic physical characteristics of biomaterials. Such basic knowledge is important not only to the engineers but also to food scientists, plant breeders, processors and other scientists who may find new uses (Mohsenin, 1978). In recent years, physical properties have been studied for various crops, such as faba bean grains (Altuntas, 2007), lentil seed (Amin *et al.*, 2004), edible squash seed (Paksoy and Aydin, 2004) and red bean (Kiani Deh Kiani *et.al*., 2008).

The aim of this study was to investigate moisture dependent physical properties of lentil seed (variety Khorasan).

MATERIALS AND METHODS

The lentil seeds used for this study were obtained from several farms located in Ardebil region of NW Iran during 2008. For dehulling, the shell was cracked manually and then cleaned to remove all foreign materials and damaged seeds. The initial moisture content was determined by drying the lentil sample in an air ventilated oven at 103°C for 72 h (ASAE, 1993). Samples at the desired moisture content were prepared by adding calculated amounts of distilled water, thorough mixing, and then sealing in separate sealed plastic bags.

Moisture content (M_C) was chosen as: 8 (initial M_C), 12, 16, and 20% (close to that of unripe seed). Samples at the selected moisture content were sealed in separate plastic bags and stored in a refrigerator at 7°C for 72 h. Before each experiment, the required sample was removed from the refrigerator and kept sealed in ambient conditions for 24 h to equilibrate water and temperature throughout the sample. The sample was kept in the ambient environment in sealed conditions, so there was no change of moisture content (Amin *et al.*, 2004).

Lentil seed has a disc shape with dimensions of diameter (D) and thickness (T). The physical dimensions of lentil were determined by taking 100 seeds randomly and measuring the seed diameter and thickness at different moisture content using a digital caliper (CD-6"CS, Mitutoyo, Japan) with accuracy of 0.01 mm. 1 000 grains mass (M_{1000}) was

*Corresponding author's e-mail: Bagherpour258@yahoo.com

measured by an electronic balance (GF-600, A and D, Japan) with accuracy of 0.001 g. The true density (ρ_t) of grain is defined as the ratio of the mass of a grain sample to its volume. The grain volume was determined using the liquid (toluene) displacement method. Bulk density (ρ_b) is the ratio of grain mass to the volume of the sample container (Suthar and Das, 1996).

Angle of repose (ø) was determined by using an open ended cylinder (ϕ=15 cm, h= 60 cm). The cylinder was placed at the centre of a circular plate (ϕ=60 cm), and filled with seeds. The cylinder was raised slowly until the seeds formed a cone on the circular plate. The diameter and height of the cone were recorded and the angle of repose was calculated.

Coefficient of static friction (μ) for lentil seeds was determined against galvanized steel, plywood and glass surfaces at different moisture content. An aluminium box of 150 mm length, 100 mm width and 40 mm height, without base and lid, was filled with the sample and placed on an adjustable tilting plate, faced with the test surface. The sample container was raised slightly so as not to contact the surface. The slope of the test surface was increased gradually until the box just started to slide down, at which time the angle of tilt was read from a graduated scale. For each repetition, the sample in the container was emptied and refilled with a new sample.

Rupture strength (F) of lentil seed was determined by the testing machine (H50 K-S, Hounsfield, England). A constant deformation rate of 3 mm min^{-1} was applied (ASAE, 2005) to compress the seed along the diameter. Force-deformation curves were plotted in order to determine the rupture force and deformation at rupture point. Energy absorbed (E) by the sample was determined by calculating the area under the force-deformation curve (Altuntas and Yildiz, 2007).

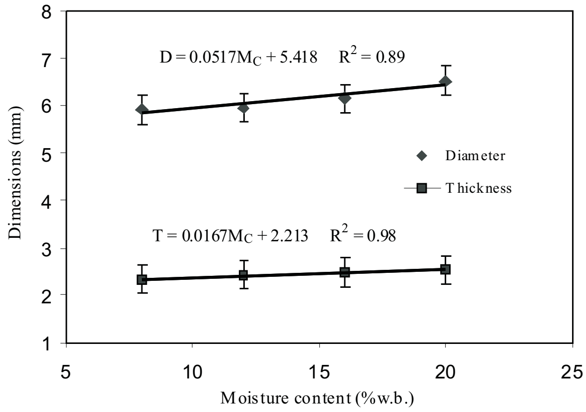

Fig. 1. Dimensions of lentil seed as affected by moisture content.

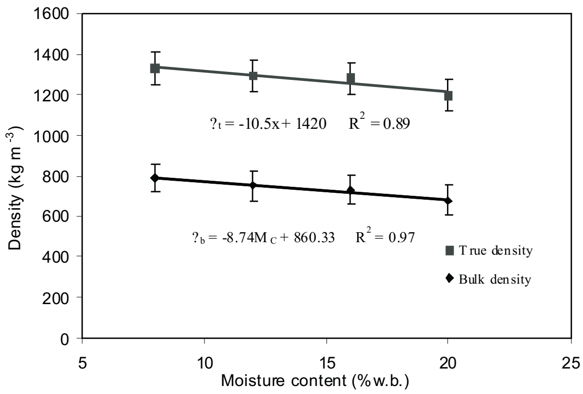

Fig. 2. Lentil seed density variation with moisture content.

RESULTS AND DISCUSSION

The mean diameter and thickness of lentil grains at different moisture content are presented in Fig. 1. The two axial dimensions gradually increased with increasing moisture content. Average diameter and thickness of lentil seed varied from 5.91 to 6.53 and 2.34 to 2.54 mm, respectively, as the moisture content increased from 8 to 20% w.b. Differences among the values were found to be statistically significant at the 5% level. Amin *et al*. (2004) and Kiani Deh Kiani *et al*. (2008) found similar results for lentil seed and red bean grain, respectively.

Bulk density and kernel density of lentil seed decreased from 790 to 680 and 1330 to1194 kg m^{-3}, respectively, when moisture content increased from 8 to 20% (w.b) as presented in Fig. 2. This is due to the fact that with increasing moisture content, the increase in seed volume was higher than its weight increase. Similar decreasing trends were reported by Tabatabaeefar (2003) for wheat and Kiani Deh Kiani *et al.* (2008) for red bean grains.

The 1 000 grains mass increased from 56.1 to 64.1 g ($p<0.05$) when the moisture content increased from 8 to 20% (Table 1). The increase of 1 000 grains mass is in conformity with the findings of Tabatabaeefar (2003), Amin *et al*. (2004) and Kiani Deh Kiani *et al*. (2008) for wheat, lentil and red bean grains, respectively.

Porosity (ε) of the lentil seed increased from 40.6 to 43.05%. A similar increasing trend in porosity was found by Amin *et al*. (2004) for lentil seed. Altuntas and Yildiz (2007) and Kiani Deh Kiani *et al*. (2008) reported similar trends in the case of faba bean and red bean, respectively.

A linear increase of repose angle from 28.09 to 31.05° was observed with increasing moisture content. The obtained results were similar to those reported by Amin *et al.* (2004) and Altuntas and Yıldız, (2007) for lentil seed and faba bean, respectively.

Rupture energy generally decreased with increasing in moisture content. The energy absorbed for seed rupture decreased from 51.14 to 10.11 Nmm with moisture content

T a b l e 1. Mean values and standard deviations of some properties of lentil seed

Moisture (% w.b.)	M_{1000} (g)	Porosity (%)	Repose angle (°)	Energy (Nmm)	Force (N)	Deformation (mm)
8	56.3±0.646	40.60±0.489	28.09±0.216	51.12±0.955	159.60±0.346	0.641±0.035
12	60.7±0.647	41.81±0.251	29.50±0.370	38.64±0.981	137.60±0.080	0.561±0.010
16	64.1±0.881	42.82±0.352	30.17±0.184	15.14±0.967	111.10±0.081	0.272±0.010
20	63.0±0.606	43.05±0.160	31.05±0.369	10.11±0.765	75.71±0.191	0.268±0.002

increasing from 8 to 20% w.b. The decrease in absorbed energy with moisture content was found to be statistically significant at the 5% level. This decrease may be due to softening of the seed at higher moisture content. These findings are similar to those reported for cumin seed (Singh and Goswam, 1998) and pine nut (Vursavus and Ozguven, 2005).

The force required to initiate seed rupture at different moisture content is given in Table 1. It can be observed from the table that the force required to initiate seed rupture decreased linearly from 159.6 to 75.71 N as the moisture content increased from 8 to 20% w.b. The small rupture force at higher moisture content might have resulted from the fact that the grains have soft texture at higher moisture content. Singh and Goswam (1998), Altuntas and Yildiz (2007) and Kiani Deh Kiani *et al*. (2008) also reported a decrease in rupture force when moisture content increased for Cumin seed, faba bean and red bean, respectively.

The coefficient of static friction increased with increasing moisture content on all three surfaces (Fig. 3). Coefficient of static friction of lentil seed ranged from 0.247 to 0.326, 0.288 to 0.337 and 0.269 to 0.360, for glass, plywood and galvanized steel, respectively. The relationships between coefficients of static friction and moisture content on all surfaces are given in Table 2. Similar results were reported by Tabatabaeefar (2003), Coskun *et al*. (2006), and Tekin *et al*. (2006) for wheat seed, sweet corn and Bombay bean, respectively.

The effect of loading rate (V) at 8% moisture content on the force needed to cause seed rupture and its deformation are shown in Fig. 4. At 1 mm min^{-1}, force and deformation at seed rupture were obtained to be 159.60 N and 0.61 mm. These were 182.32 N and 0.18 mm at 10 mm min^{-1}, respectively. Therefore, it could be deduced that rupture force increased but deformation decreased with increasing loading rate. Differences between values were statistically significant at the 5% level. The results are similar to those reported by Burubai *et al*. (2007) for African nutmeg.

Deformation (D_r) at seed rupture, as given in Table 1, decreased from 0.64 to 0.26 mm as moisture content increased from 8 to 20%. Corresponding values had a significant

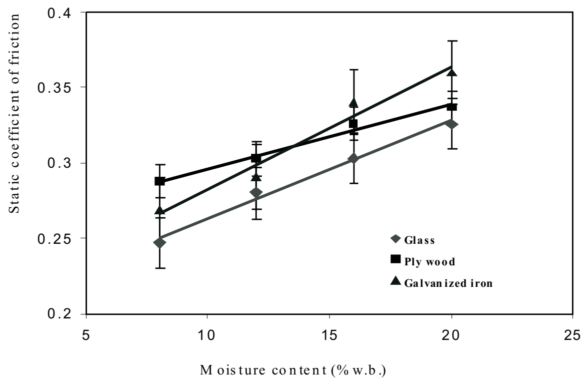

Fig. 3. Effect of moisture content on coefficient of static friction of lentil seed against various surfaces.

T a b l e 2. Linear relationships between coefficient of static friction of lentil seed and moisture content

Material	Equations	R^2
Glass	$\mu = 0.0065\ M_c + 0.198$	0.99
Plywood	$\mu = 0.0043\ M_c + 0.254$	0.98
Galvanized steel	$\mu = 0.008\ M_c + 0.2023$	0.97

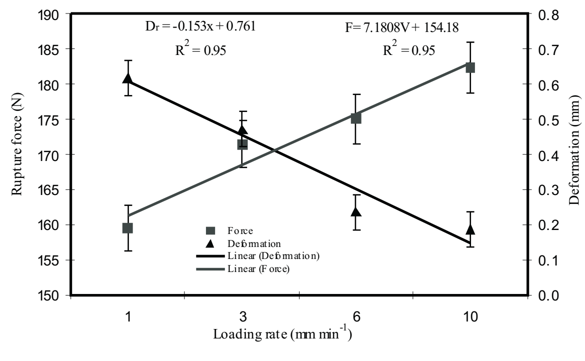

Fig. 4. Effects of loading rate on failure force and deformation.

difference at the 5% level. Although the results were similar to those reported by Vursavus and Ozguven (2005) for Pine Nut, a different trend was reported by Kiani Deh Kiani *et al.* (2008) for red bean grain. This is due to the fact that with increasing moisture content, the elastic limit of lentil seed decreased. Also, the lentil seed is thinner than bean seed so that with increasing moisture content it becomes tender and the force required to crack the seed decreases.

CONCLUSIONS

1. Average diameter, thickness, 1 000 grains mass, angle of repose and porosity of lentil seed increased from 5.91 to 6.53, 2.34 to 2.54 mm, 56.1 to 65.9 g, 28.09 to 31.05° and 40.6 to 43.05% with increase of moisture content from 8 to 20% w.b.

2. True density and bulk density decreased from 1 330 to 1 194 and 790 to 680 kg m^{-3}, respectively, with increasing moisture content.

3. Coefficient of static friction increased from 0.247 to 0.326, 0.288 to 0.337 and 0.269 to 0.360, for glass, plywood and galvanized steel surfaces, respectively.

4. Rupture force decreased from 159.6 to 75.71 N as the moisture content increased from 8 to 20% w.b.

5. Average rupture force of 159.6 and 182.32 N, absorbed energy of 51.8 and 16.2 Nmm, and deformation of 0.61 and 0.18 mm were recorded at loading rate of 1 and 10 mm min^{-1} (8% moisture content), respectively.

REFERENCES

Altuntas E. and Yildiz M., 2007. Effect of moisture content on some physical and mechanical properties of faba bean (*Vicia faba* L.) grains. J. Food Eng., 78, 174-183.

Amin M.N., Hossain M.A., and Roy K.C., 2004. Effects of moisture content on some physical properties of lentil grains. J. Food Eng., 65, 83-87.

ASAE Standards, **1993.** S352.2. Moisture measurement- unground seed and seeds. St. Joseph, MI, USA.

ASAE Standards, **2005.** S352.2. Compression test of food materials of convex shape. St. Joseph, MI, USA.

Burubai W., Akor A.J., Igoni A.H., and Puyate Y.T., 2007. Effect of loading rate and preheating time on the strength properties of African nutmeg (*Monodora myristica*). Int. Agrophysics, 21, 317-322.

Coskun M.B., Yalcin I., and Ozarslan C., 2006. Physical properties of sweet corn seed (*Zea mays saccharata* Sturt.). J. Food Eng., 74, 523-528.

Dursun E. and Dursun I., 2005. Some physical properties of caper seed. Biosys. Eng., 92, 237-245.

Kiani Deh Kiani M., Minaei S., Maghsoudi H., and Ghasemi Varnamkhasti M., 2008. Moisture dependent physical properties of red bean (*Phaseolus vulgaris* L.) grains. Int. Agrophysics, 22, 231-237.

Mohsenin N.N., 1978. Physical Properties of Plant and Animal Materials. Gordon and Breach Press, New York, USA.

Paksoy M. and Aydin A., 2004. Some physical properties of edible squash (*Cucurbita pepo* L.) seeds. J. Food Eng., 65, 225-231.

Singh K.K. and Goswam T.K., 1998. Mechanical properties of cumin seed (*Cuminum cyminum* L.) under compressive loading. J. Food Eng., 36, 311-321.

Suthar S.H. and Das S.K., 1996. Some physical properties of karingda (*Citrus lanatus* (thumb) Mansf) grains. J. Agric. Eng. Res., 65, 15-22.

Tabatabaeefar A., 2003. Moisture-dependent physical properties of wheat. Int. Agrophysics, 17, 207-211.

Tekin Y., Isýk E., Unal H., and Okursoy R., 2006. Physical and mechanical properties of Turkish goynuk Bombay beans (*Phaseolus vulgaris* L.). Pakistan J. Biol. Sci., 9, 2229-2235.

Vursavus K. and Ozguven F., 2005. Fracture resistance of pine nut to compressive loading. Biosys. Eng., 90(2), 185-191.