Moisture-dependent physical and mechanical properties of hawthorn (*Crataegus aronia*)

Zahra Azizi, Ali Nejat Lorestani*, Farzad Jaliliantabar, Zeinab Azizi

(*Agricultural Machinery Department, Faculty of Agriculture, Razi University, Kermanshah, Iran*)

Abstract: In this study, some important physical and mechanical properties of the hawthorn and the effect of moisture on them were investigated. The effect of moisture at two levels (64.01% and 70.1%, w.b.) on the geometric dimensions (length, width, thickness, arithmetic mean diameter, geometric mean diameter, degree of sphericity, surface area, projected area, criteria projected area, mass, volume and the apparent), true density, porosity, coefficient of static friction and coefficient of rolling on three levels (wood, glass and galvanized) and mechanical properties obtained by impact testing machine using a randomized factorial design was evaluated by software SPSS18. Results indicate that moisture has an effect on the physical properties of the hawthorn. The moisture content of 70.1% of all physical properties except the true density and porosity values is greater than 64.01% moisture there. Coefficient of static friction with increasing moisture increased and coefficient of rolling decreased. Moisture has an effect on the mechanical properties of hawthorn also. With increasing moisture, all the mechanical properties except dL in F_{max} decreased (dL is changing the shape of the force and F_{max} is the maximum force).

Keywords: hawthorn, physical properties, maximum force at impact, mechanical properties, moisture content

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1 Introduction

Hawthorn (*Crataegus aronia*), a prickly plant that normally reaches five feet in length grows on sunny slopes of mountains and forest lands throughout the world (www. Pezeshk. Us).

Determining the physical and mechanical properties of agricultural products as the basis for the design and manufacture of machinery and transport equipment as well as grading and processing of agricultural products, has always been considered. To primarily design for agricultural machinery, regardless of the parameters will be incomplete and lead to poor results (Tavakkoli Hashtjin, 2003).

Measurement of physical and mechanical properties of hawthorn for the proper design for handling, transport, separation, drying and other processes required to appear. There is little information on the physical properties of the hawthorn. The purpose of this study was to evaluate the physical and mechanical properties of hawthorn in the moisture level of 64.01% and 70.1% and effects of moisture content on physical and mechanical properties.

2 Materials and methods

Many hawthorns (unripe and ripe) were purchased from local market in Iran (Kermanshah) and were transferred to the university laboratory properties. One hundred and twenty hawthorns were randomly selected from each category to determine moisture content, and the samples were put into an oven at 104°C for 24 hours. Experiments were performed at room temperature.

To measure the dimensions of hawthorn, 120 hawthorns were randomly selected first and then later measured using a 0.01 mm size caliper. Accurate mass was measured using a digital scale with 0.1 g. The following formula was used to calculate the mean

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* **Corresponding author: Ali Nejat Lorestani,** Agricultural Machinery Department, Faculty of Agriculture, Razi University, Kermanshah. Email: ali.lorestani@gmail.com.

diameters (Mohsenin, 1980):

$$D_g = (a.b.c)^{1/3} \quad (1)$$

$$D_a = \frac{a+b+c}{3} \quad (2)$$

where, D_g is the geometric mean diameter, mm; D_a is the arithmetic mean diameter, mm; a is the length, mm; b is the width, mm and c is the thicken, mm.

To determine the coefficient of spherical formula provided by Mohsenin (1980) was used:

$$sph = \frac{D_g}{a} \times 100 \quad (3)$$

Surface area and of the fruit were criteria projected area calculated by using the following relationship (Mohsenin, 1980):

$$S = \pi (D_g)^2 \quad (4)$$

$$cpA = \frac{P_A + P_B + P_C}{3} \quad (5)$$

where, S is the surface area, mm^2; cpA is the criteria projected area, mm^2; P_A is the surface vertical to a, mm^2; P_B is the surface vertical to b and P_C is the surface vertical to c, mm^2.

The appearance (R_a) was obtained from the following equation: (Altuntas et al., 2005)

$$R_a = \frac{a}{b} \times 100 \quad (6)$$

To calculate the volume and true density of fruit (ρ_t) the water displacement method was used (Mohsenin, 1980). To obtain the criteria projected area the device was used to measure leaf area meter and levels were measured in the perpendicular direction.

To measure the mass density, mass and volume of the container was filled with hawthorn. Fruits with constant speed were thrown from a height 150 mm. Fruits pouring from a height of 150 mm with the container during filling, cause effects of sedimentation during store (Kashaninejad et al., 2006). After filling the container, additional fruit was removed. Experiments with five replicates were performed to determine the density.

Mass density of the grain mass (m_b, g) ratio within the total volume (V_t, mL) was calculated using the following equation (Mohsenin,1980):

$$\rho_b = \frac{m_b}{V_t} \quad (7)$$

The following formula was used to calculate the porosity (Mohsenin, 1980; Jalilian Tabar and Lorestani, 2012):

$$\varepsilon = \left(1 - \frac{\rho_b}{\rho_t}\right) \times 100 \quad (8)$$

Mass density for moisture 64.01 (g/mL) was equal to 0.51 and for moisture70.1 (g/mL) was equal to 0.45.

To measure the coefficient of static friction and the coefficient of rolling, the static coefficient of friction measuring device was used in the laboratory. These coefficients were measured at three levels of wood, galvanized and glass. To measure the coefficient of rolling, hawthorn was placed on the device. When the hawthorn turns on the surface, the device uses sensors embedded in it, giving us the coefficient of rolling. To measure the coefficient of static friction, first metal cube that has no head and the bottom, was placed on a ramp and hawthorn was placed inside it. Angle of the ramp, as the electric was increased to move the cube down (Cube is not in contact with the ramp) (Fraser et al., 1978; Shepherd and Bhardwaj, 1986; Dutta et al., 1988; Nimkar et al., 2005). The experiments were repeated with 20 coefficients.

To obtain mechanical parameters such as modulus of elasticity, impact testing device that is connected to a computer was used. To help test the software configuration and chart of the applied force-deformation were recorded for each test.

Mechanical parameters of the fruit in both the horizontal and vertical velocities in this system 10, 15 and 20 mm min^{-1} each with six replicates are obtained.

3 Results and discussion

Summary analysis of variance testing on the physical properties of hawthorn in Table 1 is presented. Statistical analysis of the effect of moisture on the geometric dimensions (length, width, thickness, arithmetic mean diameter, geometric mean diameter, levels image, mass, volume, degree of sphericity, surface area, criteria projected area and the appearance) showed significant differences between the figures (at 5% level) (Askari Asli-Ardeh et al., 2011).

Table 1 Analysis of variance of the physical properties of hawthorn

Physical properties	Mean squares
a (mm)	177.831*
b (mm)	109.202*
c (mm)	255.049*
m (mm)	7.135*
V (mm)	21.301*
P_A (mm)	31586.087*
P_B (mm)	373395.237*
P_C (mm)	41039.811*
ρ_t (mm)	7.696*
D_g (mm)	185.945*
D_a (mm)	175.611*
S (mm)	1881709.715*
sph (%)	77.913*
cpA (mm^2)	34865.713*
R_a	0.017*
ε	582.498*

Note: * $P < 0.05$.

All traits except the true density, porosity increased with increasing moisture content.

Within increasing moisture content, arithmetic mean diameter and geometric mean diameter significantly increase (Al-Mohasneh and Rababah, 2007; Garnyak et al., 2008; Selvi et al., 2006; Işik and Ŭnal, 2007).

Surface and volume increases with increase in moisture (Al-Mohasneh and Rababah, 2007; Askari Asli-Ardeh et al., 2011).

As said mass density (bulk density) decreased with increasing moisture content (Garnayak et al., 2008; Shepherd and Bhardwaj 1986; Dutta et al., 1988; Gupta and Prakash, 1990; Carman, 1996). The true density decreases with increasing moisture content (Cetin, 2007), but reported by Aviara et al. (2005), Yalçin and Özarshan (2004), Garnayak et al. (2008), Askari Asli-Ardeh et al. (2011), true density increased with increasing moisture content.

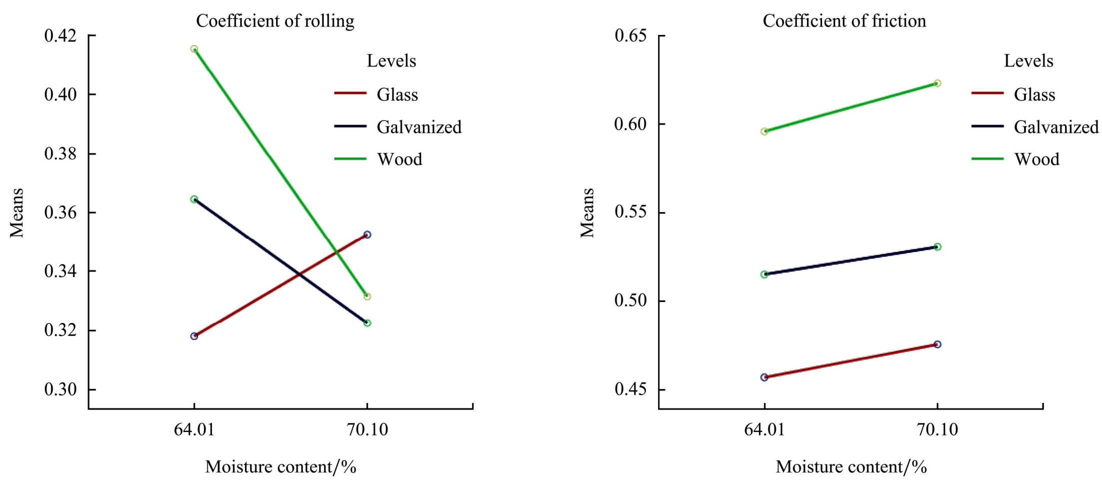
Porosity decreases with increasing moisture content (Visvanathan et al., 1996), but the report by Gupta and Das (1997), Ogat (1998), Garnayak et al. (2008), Selvi et al. (2006), Işik and Ŭnal (2007), porosity increased with increasing moisture content. Analysis of variance coefficient of static friction and rolling coefficient in Table 2 is presented. The results indicate significant effect of level on coefficient of friction and moisture×level on coefficient of rolling.

Table 2 Analysis of variance (mean squares) of coefficient of rolling and coefficient of friction

Source	Coefficient of friction	Coefficient of rolling
Moisture	0.012	0.028
Level	0.414*	0.032
Moisture×Level	0.001	0.72*

Note: * $P < 0.05$.

Figure 1, the coefficient of rolling and the coefficient of friction average value chart shows different levels of moisture. According to these charts all levels have increased coefficient of friction with increasing moisture (Reddy and Chakravertty, 2004; Al-Mahasneh and Rababah, 2007; Gubta and Das, 1997; Singh and Goswami 1996; Nimkar and Chattopadyay, 2001; Aydin, 2003; Calisir et al., 2004) if the coefficient of rolling on all surfaces except glass surface is reduced with increasing moisture.



a. Rolling curve b. Friction curve

Figure 1 Average coefficient of rolling curve and friction curve in terms of moisture in different levels

According to the chart, the wood that has the highest coefficient of friction and the glass has the lowest coefficient of friction (Amin et al., 2003; Garnayak et al., 2008; Shepherd and Bhardwaj, 1986; Dutta et al., 1988; Kulkelko et al., 1988; Visvanathan et al., 1996).

Analysis of variance in the mechanical properties of hawthorn in Table 3 is presented. The results indicate significant effect of moisture on all properties. Mode of exposure is effective in all cases except *dL* in F_{max}. Interaction speed and mode of exposure were effective only on the *dL* in F_{max}.

Interaction of three factors: moisture, speed and mode of exposure were effective only on the modulus of elasticity. Where, *W* is the work done of the force.

Table 3 Analysis of variance (mean squares) of mechanical properties

Source	*dL* in F_{max}, mm	F_{max}, N	Modulus of elasticity, Gpa	*W* in F_{max}, N·mm
Moisture	32.805*	13006.1570*	0.230*	100094.565*
Mode of exposure	2.645	13560.300*	0.038*	38370.502*
Speed	4.969	826.052	0.003	4573.184
Moisture×Mode of exposure	0.347	1232.561	0	3913.028
Moisture×Speed	3.947	431.595	0.003	501.897
Speed×Mode of exposure	11.191*	935.96	0.006	5654.562
Moisture×Speed×Mode of exposure	3.822	512.861	0.022*	607.839

Note: * $P < 0.05$.

Figure 2, the average value of *dL* in F_{max} relative moisture chart shows in both horizontal and vertical mode. According to these charts in speed of 10 (horizontal) and speed of 20 (vertical) *dL* in F_{max} has the highest increase. This means that *dL* in F_{max} increases with increasing speed in vertical mode and decreases with increasing speed in horizontal mode.

Figure 3, the average value of F_{max} relative moisture chart shows in both horizontal and vertical mode. According to these charts in speed of 15 (horizontal) and speed of 20 (vertical) F_{max} has the highest reduction. This means that F_{max} decreases with increasing speed in both horizontal and vertical mode.

Figure 4, the average value of modulus of elasticity relative moisture chart shows in both horizontal and vertical mode. According to these charts in speed of 10 (horizontal) and speed of 20 (vertical) modulus of elasticity has the highest reduction. This means that modulus of elasticity decreases with increasing speed in vertical mode and increases with increasing speed in horizontal mode.

As it can be seen in Figure 5, the average value of *W* in F_{max} relative moisture chart shows in both horizontal and vertical modes. According to these charts in speed of 15 (horizontal and vertical) *W* in F_{max} has the highest increase.

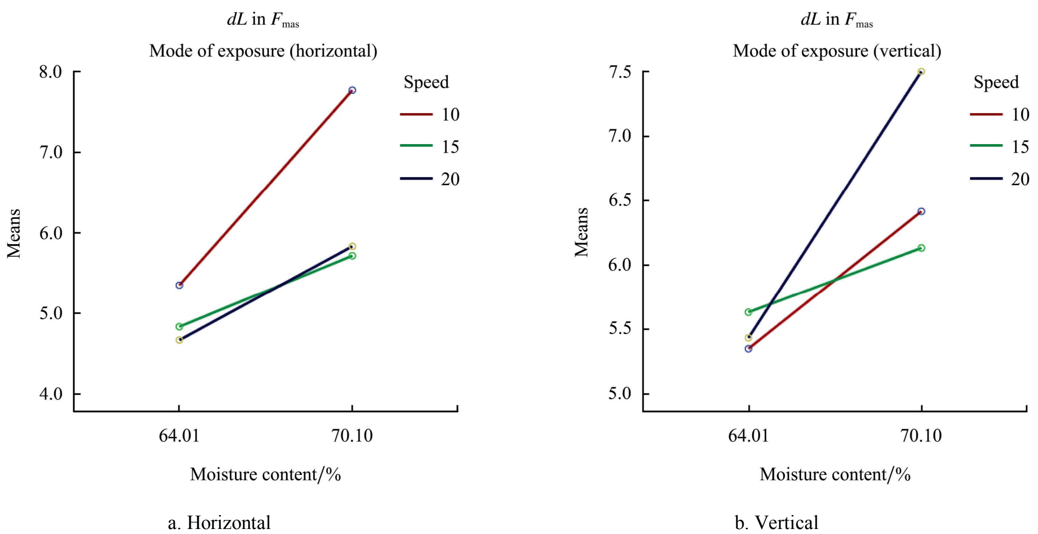
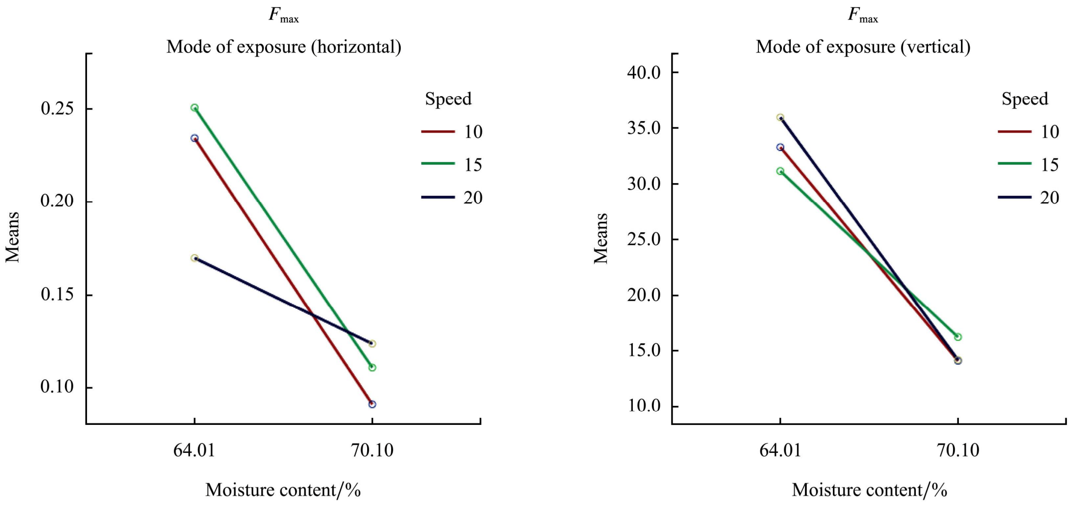
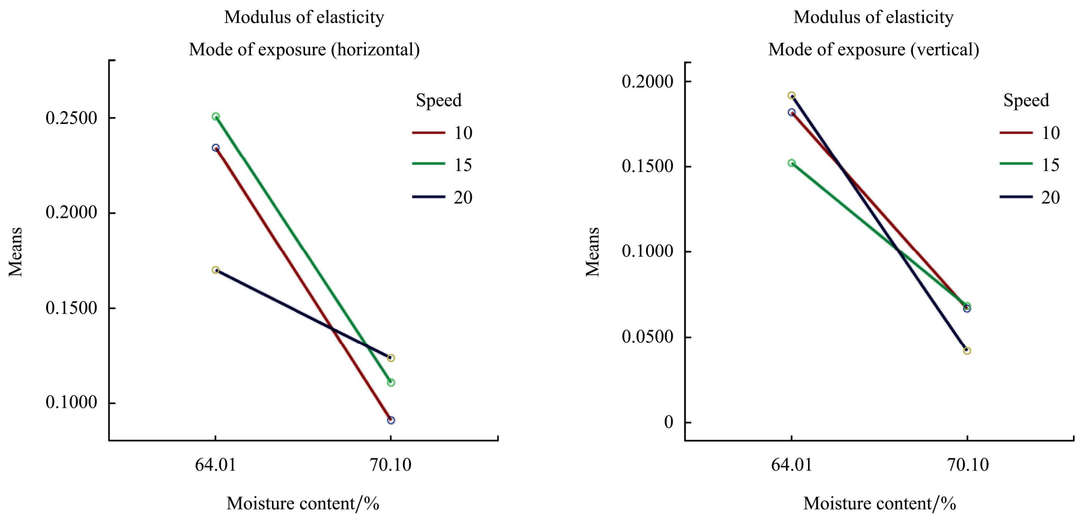


Figure 2 Average *dL* in F_{max} curve in terms of moisture in mode of exposure



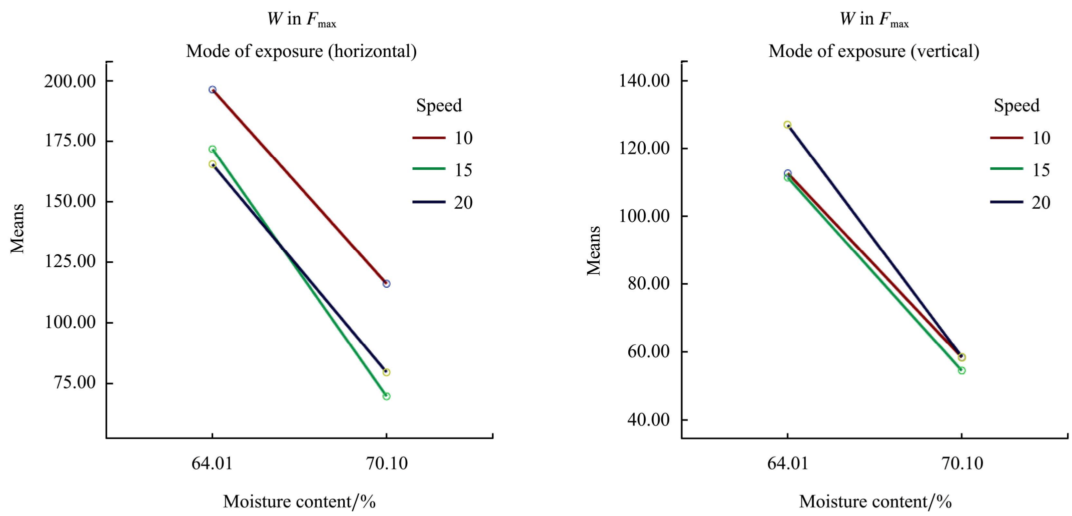
a. Horizontal b. Vertical

Figure 3 Average F_{max} curve in terms of moisture in mode of exposure



a. Horizontal b. Vertical

Figure 4 Average modulus of elasticity curve in terms of moisture in mode of exposure



a. Horizontal b. Vertical

Figure 5 Average W in F_{max} curve in terms of moisture in mode of exposure

4 Conclusions

With the study on the effect of moisture on physical properties of hawthorn it was found that moisture has a significant effect on physical properties of hawthorn. The results showed that moisture on the characteristics of the surface area and spherical has the most effective and on the characteristic of apparent has the least effective.

Analysis of variance results of coefficient of friction and coefficient of rolling showed that levels have a significant effect on coefficient of friction and the interaction of moisture and levels have a significant effect on coefficient of rolling.

According to analysis of variance of mechanical properties of hawthorn, the interaction three elements (moisture, speed and mode of exposure) have a significant effect on modulus of elasticity and moisture has a significant effect on all factors and speed has a significant effect on any of the factors. With increasing moisture, all the mechanical properties decreased except dL in F_{max}.

Nomenclature

P_C	surface vertical to c, mm^2
R_a	Appearance
CPA	criteria projected area, mm^2
ρ_t	true density of fruit, g cm-
m_b	grain mass, g
V_t	total volume, cm^3
ρ_b	mass density, g cm^{-3}
ε	Porosity
F_{max}	maximum force, N
dL	changing the shape, mm
W	work done of the force, N.mm
M	fruit mass, g
V	fruit Volume, cm^3
D_g	geometric mean diameter, mm
D_a	arithmetic mean diameter, mm
Sph	coefficient of spherical
S	surface area, mm^2
a	length of fruits, mm
b	width of fruit, mm
c	thickness of fruit, mm
P_A	surface vertical to a, mm^2
P_B	surface vertical to b, mm^2

References

Al-Mahasneh, M. A., and T. M. Rababah. 2007. Effect of moisture content on some engineering properties of green wheat. *Journal of Food Engineering,* 79(4): 1467-1473.

Altuntaş, E., E. Özgöz, and Ö. F. Taşer. 2005. Some physical properties of fenugreek (Trigonella foenum-graceum L.) seed. *Journal of Food Engineering,* 71(1): 37-43.

Amin, M. N., M. A. Hossain, and K. C. Roy. 2003. Effects of moisture content on some physical properties of lentil seeds. *Journal of Food Engineering,* 65(1): 83-87.

Askari Asli-Ardeh, E., S. Shojaei, and S. shakarbeygi. 2011. Determination of some mechanical properties of three paddy varieties in different moisture levels. *Iranian Journal of Food Science and Technology,* 7(4): 99-106.

Aviara, N. A., E. Mamman, and B. Umar. 2005. Some physical properties of Balanites aegyptiaca nuts. *Biosystems Engineering,* 92 (3):325-334.

Aydin, C. 2003. Physical properties of almond nut and kernel. Journal of Food Engineering, 60(3): 315-320.

Calisir, S., T. Marakoglu, H. Ogut, and O. Ozturk. 2004. Physical properties of rapeseed. *Journal of Food Engineering,* 69(1): 61-66.

Carman, K. 1996. Some physical properties of white lupin. *Journal of Agricultural Engineering Research,* 69(3): 87-92.

Cetin, M. 2007. Physical properties of barbunia bean (Phaseolus vulgaris L. cv. 'Barbuniz') seed. *Journal of Food Engineering,* 80(1): 353-358.

Dutta, S. K., V. K. Nema, and R. K. Bhardwaj. 1998. Physical properties of gram. *Journal of Agricultural Engineering Research,* 39(4): 259-267.

Fraser, B. M., S. S. Verma, and W. E. Muir. 1978. Some physical properties of fababeans. *Journal of Agricultural Engineering Research,* 23(1): 53-57.

Garnayak, D. K., R. C. Pradhan, S. N. Naik, and N. Bhatnagar. 2008. Moisture-dependent physical properties of jatropha seed (Jatropha curcas L.). *Industrial Crops and Products,* 27(1): 123-129.

Gupta, R. K., and S. K. Das. 1997. Physical properties of sunflower seeds. *Journal of Agricultural Engineering Research,* 66(1):1-8.

Gupta, R. K., and S. Prakash. 1990. Effect of moisture content on some engineering properties of pulses. Paper presented at XXVI Annual convention of Indian society of Agricultural Engineers, Hissar, February, 7-9.

Işik, E., and H. Ủnal. 2007. Moisture-dependent physical properties of white speckled red kidney bean grains. *Journal of Food Engineering,* 82(2): 209-216.

Jalilian Tabar, F. and A. Lorestani. 2012. *Physical properties and effect of loading orientation on the mechanical properties of black chickpea. Agricultural Engineering International: CIGR Journal.*, 14(3): 230-235.

Kashaninejad, M., A. Mortazavi, A. Safekordi, and L. G. Tabil. 2006. Some physical properties of pistachino (pistacia verb L.) nut and its kernel. *Journal of Food Engineering,* 72(1): 30-38.

Kulkelko, D. A., D. S. Jayas, N. D. G. White, and M. G. Britton. 1988. Physical properties of canola (rapeseed) meal. *Canadian Agricultural Engineering,* 30(1): 61-64.

Mohsenin, N. N. 1980. *Physical properties of plant and animal material*. New York: Gorden and Breach.

Nimkar, P. M., and P. K. Chattopadyay. 2001. Some physical properties of green gram. *Journal of Agricultural Engineering Research*, 80(2): 183-189.

Nimkar, P. M., S. M. Dipali, and M. D. Renu. 2005. Physical properties of moth gram. *Biosystem Engineering,* 91(2):183-189.

Reddy, B. S., and A. Chakravertty. 2004. Physical properties of raw and parboiled paddy. *Biosystems Engineering,* 88(4): 461-466.

Selvi, K. C., Y. Pinar, and E. Yeşiloğlu. 2006. Some physical properties of linseed. *Biosystems Engineering,* 95(4): 607-612.

Shepherd, H., and R. K. BhardwaJ. 1986. Moisture dependent Physical properties of pigeon pea. *Journal of Agricultural Engineering Research,* 35(4): 227-234.

Singh, K. K., and T. K. Goswami. 1996. Physical properties of cumin seed. *Journal of Agricultural Engineering Research*, 64(2): 93-98.

Tavakkoli Hashtjin, T. 2003. *Agricultural products mechanics (Translate)*. Zanjan University Publications.

Visvanathan, R., P. T. Palanisamy, L. Gothandapani, and V. V. Sreenarayanan. 1996. Physical properties of neem nut. *Journal of Agricultural Engineering Research,* 63(1): 19-26.

www. Pezeshk. Us

Yalçin, L., and C. Özarslan. 2004. Physical properties of vetch seed. *Biosystems Engineering,* 88(4): 407-512.