Determination of Some Physical and Mechanical Properties of Pofaki Variety of Pea

M. Azadbakht, E. Ghajarjazi, E. Amiri, F. Abdigaol

***Abstract*—**In this research the effect of moisture at three levels (47, 57, and 67 w.b.%) on the physical properties of the Pofaki pea variety including, dimensions, geometric mean diameter, volume, sphericity index and the surface area was determined. The influence of different moisture levels (47, 57 and 67 w.b.%), in two loading orientation (longitudinal and transverse) and three loading speed (4,6 and 8 mm min^{-1}) on the mechanical properties of pea such as maximum deformation, rupture force, rupture energy, toughness and the power to break the pea was investigated. It was observed in the physical properties that moisture changes were affective at 1% on, dimensions, geometric mean diameter, volume, sphericity index and the surface area. It was observed in the mechanical properties that moisture changes were effective at 1% on, maximum deformation, rupture force, rupture energy, toughness and the power to break. Loading speed was effective on maximum deformation, rupture force, rupture energy at 1% and it was effective on toughness at 5%. Loading orientation was effective on maximum deformation, rupture force, rupture energy, toughness at 1% and it was effective on power at 5%. The mutual effect of speed and orientation were effective on rupture energy at 1% and were effective on toughness at 5% probability. The mutual effect of moisture and speed were effective on rupture force and rupture energy at 1% and were effective on toughness 5% probability. The mutual effect of orientation and moisture on rupture energy and toughness were effective at 1%.

***Keywords*—**Mechanical properties, Pea, Physical properties.

I. Introduction

PEAS with the scientific name *Pisum sativum* its annual herbaceous plant from *Legumynus* family, chilling resistance, with long branches and ascending are grown for green beans. Cultivation and average worldwide yield is one million hectare as 8.5 tons per hectare. Cultivation in the Golestan province, Iran is 1222 ha with the yield of 6, 7 tons per hectare. The farmers of Golestan province in order to comply with the principles of rotation, especially in the wheat and the area affected by the economic argument the cultivation of this crop held [1]. Access to scientific information on the physical characteristics of seed for the design of the equipment storage, transportation, cleaning, processing and packaging seems necessary. Shape, size, volume, surface area, density, porosity, color and physical appearance of the characteristic that in many issues related to machine designs, processing or analysis of product design issues are important in the transmission. Grain shape and physical dimensions are important for measuring, sorting, screening and separation processes [2]. Hence few studies done on this subject will be addressed:

Researchers have looked at the physical properties of a bean named Christmas Lima bean at different moisture. They found that with increasing humidity, length, width and thickness, geometric mean diameter, volume, sphericity, mass, mass of 100 grains, the body image and output speed increased. With increased moisture, a decline was observed for bulk density and true density [3]. In the study about the physical properties of hazelnut and its seed it was observed that with increasing moisture, dimensions, weight, volume and surface area increased and sphericity decreased [3]. In a study the physical properties of 3 varieties of chickpea at 3 levels of moisture was investigated. It was observed that the effect of moisture on physical properties such as volume and geometric diameter were significant [4]. Researchers investigated the effect of moisture on physical properties of wax bean. They observed that the effect of moisture on physical properties was Significant [5]. Understanding the mechanical properties of agricultural products and food had always been interested in agriculture and food industry professionals. This is especially the case with agricultural machinery and it is important about impacts on different parts of machine during harvesting, transportation, storage and processing of the product [6]. Mechanical damage in fruits and vegetables is an unwanted phenomenon which is associated with increased product quality and reduced level of corruption [7]. Mechanical properties of agricultural products to design and improve harvesting equipment and then transmitting devices, separating, washing, processing, packaging and storage is necessary, which has been reported and researched by numerous scholars for products [8]-[11]. The results of static and quasi-static tests can be a criterion for designing machines used in agriculture and food processing [12], [13]. Energy required for knocking bean pods, with two of the pendulum and the force of friction and pressure were measured. Dried beans (15.3% to 13.3% moisture) are fully opened and then it was observed that the shells were broken. After the release of seed, pods with 17.3% moisture slowly open and never break [14]. Researchers continue to investigate the mechanical properties of a bean named Christmas Lima bean observed that static and dynamic friction coefficient increased with increasing moisture. The average breaking force, deformation and rupture energy rupture pressure were checked and they found that the rate of deformation, deformation, rupture and rupture energy generally increases with the increase of

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moisture ratio [3]. Researchers investigated two loading orientation and three chickpea varieties under the influence of quasi-static forces and found that power and energy required breaking the grain, in three levels of moisture (7%, 12%, and 16%), the moisture, and the loading orientation on the power and energy leading to seed breakage was significant [4]. Given that one of the major problems in the pea harvest, is mechanical damage to it [16], [17]. In this study, to reduce mechanical damage, researches have been performed on physical and mechanical properties of pea harvested and processed in order to equip machines.

II. Materials and Methods

A. Sample Preparation

In this study, the green peas of Pofaki were produced in number 1 field samples in Gorgan University of Agricultural Sciences and Natural Resources, Iran.

To obtain initial moisture content 100 g of seed pods were selected and were placed for 24 hours at 72°C in the oven and in accordance with ASAE Standard, moisture was measured on the basis of wetness was measured according to (1) [18]:

$$W = \frac{(m_1 - m_2)}{m_1} \times 100 \tag{1}$$

m_1 initial seed weight, m_2 grain weight after drying in an oven, W is weight percentage of seeds moisture on wet basis.

B. Physical Properties

The physical properties of the pea at three moisture levels (47, 57, and 67%) were investigated. The grain size was measured by a caliper with accuracy of 0.02 mm. Because the shape of the grains and other agricultural products are irregular granular, grain size is expressed by geometrical diameter. Geometric grain diameter was calculated according to (2) [13]:

$$d_g = (TWL)^{1/3} \tag{2}$$

In (2), T, W and L are the thickness, width and length of the seed.

According to (3) and (4), surface area and volume of seeds, were determined [2].

$$S = \pi \times d_g^2 \tag{3}$$

$$V_s = \frac{\pi d_g^3}{6} \tag{4}$$

Sphericity coefficient was calculated according to (5) [2]:

$$\phi = \frac{d_g}{L} \tag{5}$$

C. Mechanical Properties

In order to study the mechanical properties of peas, whole seeds at three moisture levels (47, 57 and 67%), three loading speed (4, 6 and 8 mm min-1) and two to loading orientations (longitudinal and transverse) were placed between two flat steel plates under Quasi-static loading.

Since the rupture point is on the force – deformation curve, with very little increase in deformation, power at that point highly decreases, and rupture force was calculated [19]. And with respect to the corresponding point of rupture force on the deformation axis in the graph of force - deformation, Deformation at the point of rupture was calculated. To calculate the rupture power, the area under the load – deformation from the starting point of loading to the point of rupture was calculated [20]. Toughness is equal to the amount of work done by point of rupture on the volume of the object and also considering that the amount of work done is the area under the curve, thus, by dividing the area under the curve from the sample size of rapeseed, toughness will be obtained [2]. The necessary power to break the peas was calculated according to (6) in [15]:

$$P = \frac{E \times S}{60000 \times \Delta x} \tag{6}$$

III. Results and Discussion

A. Physical Properties

Analysis of variance parameters and physical properties of Pofaki peas are shown in Table I. Studying Table I shows that moisture factor at 1% on the length, width, thickness, geometric diameter, mean volume and surface area, had a significant effect and it had no significant effect on grain sphericity.

TABLE I
Analysis of Variance of the Effect of Moisture on the Physical Properties of the Pea

Source of variation	Physical Properties	Degrees of freedom	Sum of squares	Mean square	F
Moisture	Length	2	128.03	64.01	172.20**
	Width	2	95.63	47.81	124.05**
	Thickness	2	94.65	47.32	137.94**
	Geometric Diameter	2	105.66	52.83	238.99**
	Mean Volume	2	239067.53	1195335.76	232.72**
	Sphericity	2	0.002	0.001	1.47ns
	Surface Area	2	394660.72	197330.36	242.38**

** Significant difference at 1% level (p <0.01), ns not significant

As can be seen in Figs. 1-3 with decreasing moisture from 67% to 47% the length, width and thickness were significantly decreased. These observations were equal with the results obtained in [6] and [3]. This increase due to the High moisture can be related to cellular Inflation and water permeability of seeds [21].

As shown in Figs. 4-6, the geometric diameter, volume and the surface area increased with increasing moisture. This was due to the increase in grain size. Reason of the increasing size because of rising grain moisture, is water absorption by the grain. These observations were similar to the results obtained in determining the physical properties of beans and in determination of physical and mechanical properties of chickpea [3], [5].

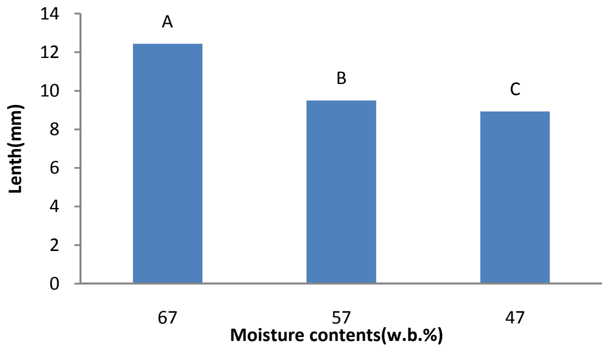

Fig. 1 Pea in different moisture contents

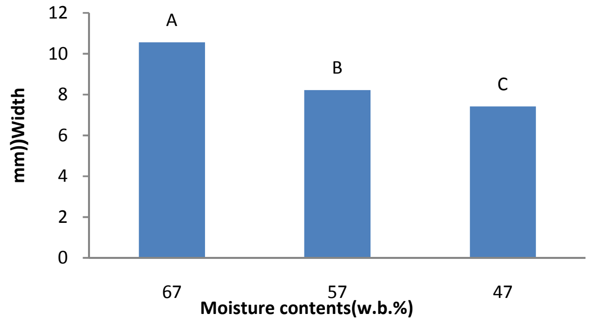

Fig. 2 Width of pea seeds in different moisture contents

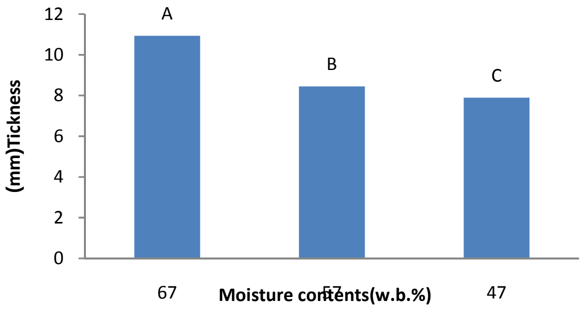

Fig. 3 The thickness of the pea in different moisture content

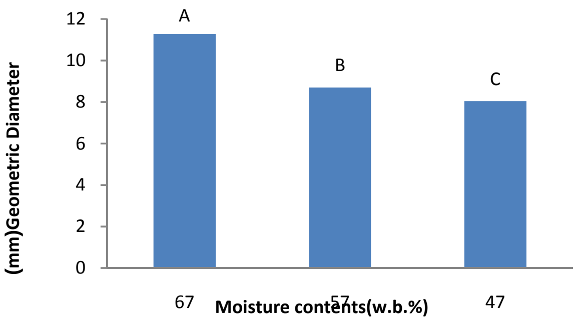

Fig. 4 Diagram of geometric diameter of pea in different moisture

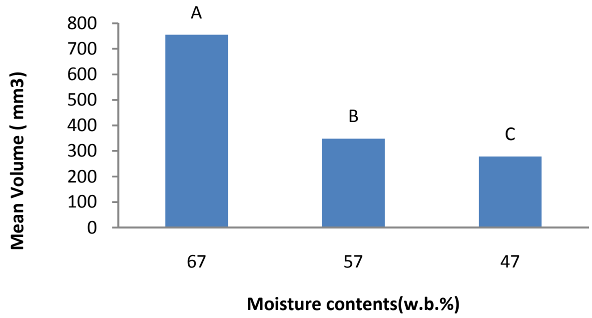

Fig. 5 Diagram of Medium Sized pea in different moisture

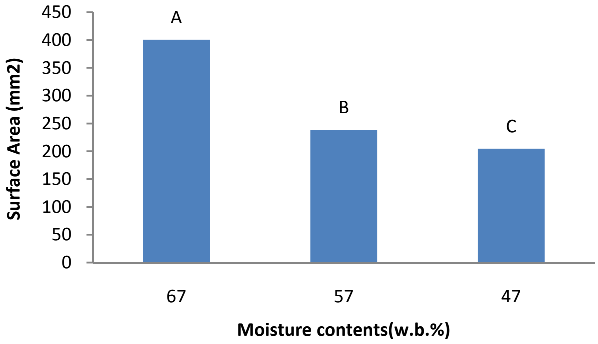

Fig. 6 Diagram of pea surface area in different moisture

B. Mechanical Properties

In this section, the effect of different levels of moisture, loading orientation and maximum loading speed on deformation, rupture force, rupture energy, toughness and power to defeat the pea seeds were investigated.

Effects of moisture, loading orientation and loading rate on maximum deformation of pea are shown in Table II. As can be seen in Table II, moisture content, loading orientation and speed at 1% on the maximum deformation had a significant effect and their mutual effect had no significant effect on deformation.

TABLE II
RESULTS OF VARIANCE ANALYSIS OF THE EFFECT OF MOISTURE, LOADING ORIENTATION, SPEED OF LOADING, ON THE MAXIMUM DEFORMATION OF PEAS

Source of variation	Degrees of freedom	Sum of squares	Mean square	F
Moisture	2	4.63	2.31	35.23^{**}
Load orientation	1	0.68	0.68	10.41^{**}
speed	2	6.59	0.29	50.15^{**}
Orientation × Speed	2	0.24	0.12	1.85^{ns}
Moisture × Speed	4	0.58	0.14	2.22^{ns}
Moisture × Orientation	2	0.42	0.21	3.23^{ns}

** Significant difference at the 1% level ($p < 0.01$), ns not significant, CV=6/79

According to Fig. 7 it is shown with decreasing moisture the deformation decreases. This result was the same as the one obtained in [4]. It was observed that with increasing moisture, the deformation increases because of the increased moisture and softening of the skin, the amount of the deformation increases.

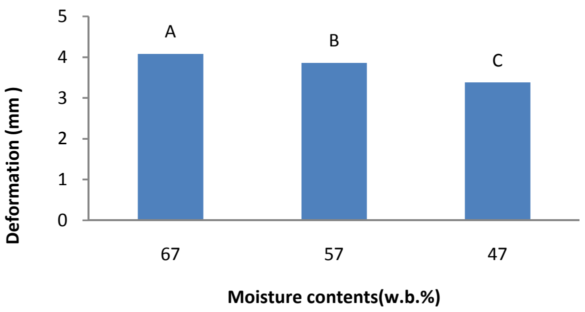

Fig. 7 The variation of pea maximum deformation diagram under Loading in different moistures

According to Fig. 8, the deformation in the longitudinal orientation is greater than the deformation in the orientation of the width of the grain.

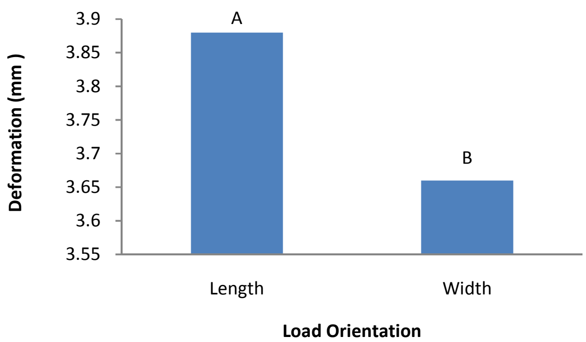

Fig. 8 The variation of pea maximum deformation diagram under Loading in different orientation

As shown in Fig. 9, with increasing loading speed, the deformation decreases. The result was similar to observations done in the mechanical properties of the 3 Varieties of Pistachio. These results are due to an appropriate opportunity for stress reduction [19].

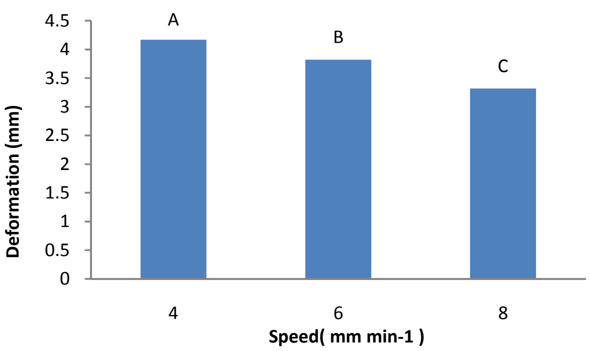

Fig. 9 The variation of pea maximum deformation diagram under Loading in different speeds

In Table III the results of analysis of variance of effects of moisture, loading orientation, and loading speed rupture force of peas are presented. According to Table III, the effect of moisture, loading orientation, and loading speed and also the mutual effect of moisture and loading speed on rupture force were significant at the 1% level. So a LSD test to compare the mean was used and the results are shown in Table IV.

TABLE III
RESULTS OF VARIANCE ANALYSIS RELATED TO THE EFFECT OF MOISTURE, LOADING ORIENTATION, AND LOADING SPEED ON RUPTURE FORCE OF POFAKI PEA

Source of variation	Degrees of freedom	Sum of squares	Mean square	F
Moisture	2	11420.94	5710.47	295.36^{**}
Load Orientation	1	485.28	485.28	25.10^{**}
Speed	2	17876.11	8938.05	462.29^{**}
Speed × Orientation	2	19.07	9.53	0.49^{ns}
Moisture × Speed	4	3289.69	822.42	42.54^{**}
Moisture × Orientation	2	86.37	43.18	2.23^{ns}

** Significant difference at the 1% level ($p < 0.01$), ns no significant difference, CV= 6.88

As shown in Table IV, the maximum and minimum rupture force equivalent to 103.89 N and 35.39 N, respectively, 47% and 67% moisture level, at a speed of 4 (min mm^{-1}) and 8 (min mm^{-1}).

TABLE IV
MUTUAL EFFECT OF MOISTURE AND LOADING SPEED ON RUPTURE FORCE

Speed (mm min^{-1})	Moisture (w.b.%)		
	47%	57%	67%
4 (mm/min)	103.89^{aA}	95.96^{aA}	56.04^{bA}
6 (mm/min)	88.62^{aB}	65.55^{bB}	42.26^{cB}
8 (mm/min)	46.49^{aC}	40.58^{abC}	35.39^{bB}

Lowercase letters in each row, uppercase letters in each column represent no significant difference

According to Fig. 10, moisture reduction of 67% to 47% increases rupture force. This result was the same as [4], [19]. Increase in grain moisture causes weak hydrogen bonds of cellulose and also reduce the ties between proteins, starch and other compounds which ultimately reduces the mechanical strength of the grain [15]. And also with accelerating the loading speed rupture force decreased. The result was similar to observations done in some physical and mechanical properties of two varieties of almond [22].

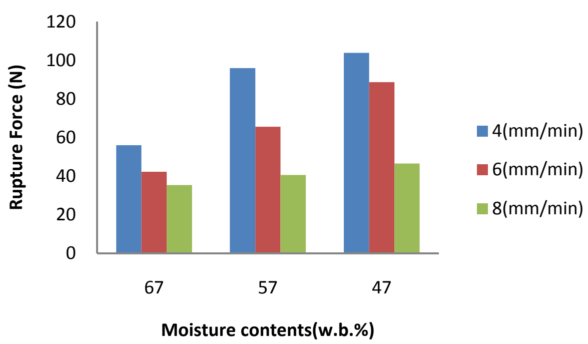

Fig. 10 Effects of moisture and loading speed on rupture force

Referring to Fig. 11 rupture force in the orientation of width is more than length. This result is similar to observations in investigating the mechanical properties of grain and Reviewing Mechanical rupture under quasi-static loading [5], [23].

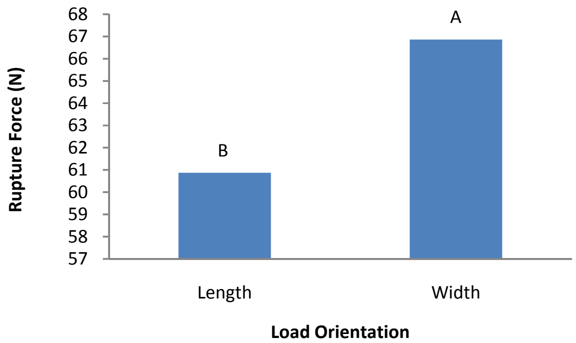

Fig. 11 The variation of pea rupture force diagram under loading in different orientation

In Table V variance analysis results for the effects of moisture, loading orientation and loading speed on rupture energy of Pofaki peas are provided. According to Table V, the effect of moisture, loading orientation, and loading speed and their mutual effect on rupture energy were significant at the 1% level. So mean comparison was conducted by LSD test and the results are shown in Tables VI-VIII.

TABLE V
ANALYSIS OF VARIANCE RESULTS OF THE EFFECTS OF MOISTURE, LOADING ORIENTATION AND LOADING SPEED ON RUPTURE ENERGY OF POFAKI PEA

Source of variation	Degrees of freedom	Sum of squares	Mean square	F
Moisture	2	55189.43	27594.71	268.19**
Load Orientation	1	5011.26	5011.26	48.70**
Speed	2	4753.73	2376.86	23.10**
Speed × Orientation	2	1733.20	866.60	8.42**
Moisture × Speed	4	3246.06	811.51	7.89**
Moisture × Orientation	2	2214.68	1107.34	10.76**

** Significant difference at the 1% level ($p < 0.01$), ns not significant, CV=10.49

As shown in Table VI, the highest and lowest rupture energy is respectively 164 mJ and 61.17 mJ, in moisture level of 47% and 67%, at a speed of 4 (min mm^{-1}) and 8 (min mm^{-1}).

TABLE VI
THE MUTUAL EFFECT OF MOISTURE AND LOADING SPEED ON RUPTURE ENERGY

Speed (mm min-1)	**Moisture (w.b.%)**		
	47%	57%	67%
4 (mm/min)	164.41 ^{aA}	84.27 ^{bA}	68.67 ^{bA}
6 (mm/min)	116.59 ^{aB}	75.13 ^{bA}	61.72 ^{cB}
8 (mm/min)	130.66 ^{aAB}	71.1 ^{bA}	61.178 ^{bB}

Lowercase letters in each row, uppercase letters in each column represent no significant difference

Referring to Fig. 12 with the moisture content decreased from 67% to 47% rupture energy increased. For brittle materials such as dried beans and seeds, with increasing moisture content the energy required to break increases, but for fava beans with increased moisture, energy rupture reduced which the results is consistent with [5]. This contradiction is defined as rupture criterion due to high levels of moisture and texture. In [19] was observed similar results. And also with increasing speed energy rupture decreased. The same result as [22].

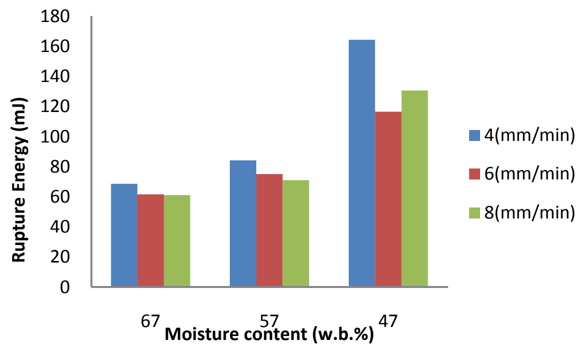

Fig. 12 Effect of moisture and the speed of loading on rupture energy

As shown in Table VII, the highest and lowest energy rupture are respectively 122.95 mJ and 79.43 mJ at the loading speed of 4 (min mm^{-1}) and 8 (min mm^{-1}) in the transverse and longitudinal loading.

TABLE VII
MUTUAL EFFECT OF LOADING SPEED AND LOADING ORIENTATION ON RUPTURE ENERGY

Load Orientation	**Speed (mm min^{-1})**		
	4 (mm/min)	6 (mm/min)	8 (mm/min)
Length	88.61 ^{aA}	80.98 ^{aA}	79.43 ^{aA}
Width	122.95 ^{aA}	87.99 ^{aA}	95.87 ^{aA}

Lowercase letters in each row, uppercase letters in each column represent no significant difference

As can be seen in Fig. 13, the transverse rupture energy is greater than the longitudinal orientation. Rupture energy is under the influence of force and deformations, but because it forces a greater impact on energy, the energy of the transverse load is higher.

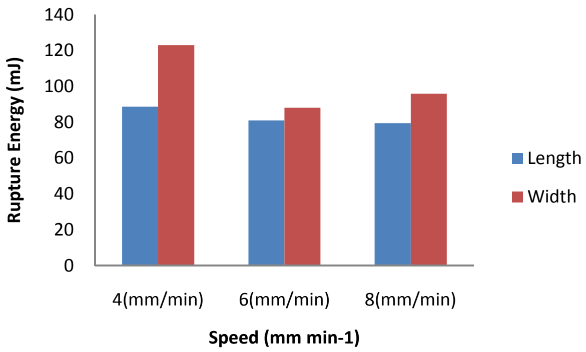

Fig. 13 Effect of speed and orientation of loading on rupture energy

As shown in Table VIII, the highest and lowest energy rupture are respectively 153.67 mJ and 62.79 mJ in the moisture content of 47% and 67%, in the transverse and longitudinal loading.

TABLE VIII
MUTUAL EFFECT OF MOISTURE CONTENT AND LOADING ORIENTATION ON RUPTURE ENERGY

Load Orientation	Moisture (w.b.%)		
	47%	57%	67%
Length	120.77 aA	65.44 bB	62.79 bA
Width	153.67 aA	88.23 bA	64.92 bA

Lowercase letters in each row, uppercase letters in each column represent no significant difference

As shown in Fig. 14, with decreasing moisture and in transverse orientation, the rupture energy increases.

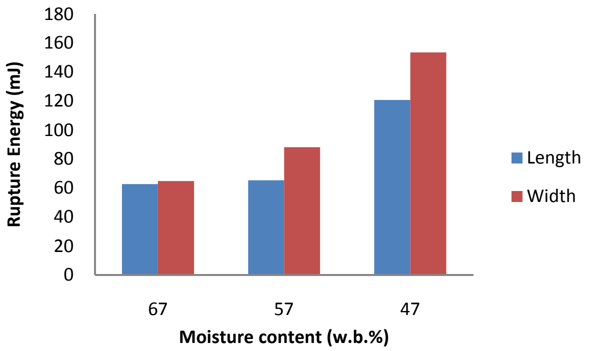

Fig. 14 Effect of moisture and loading orientation on rupture energy

In Table IX, Variance analysis results of effects of moisture, loading orientation and loading speed on toughness (seed stiffness) of Pofaki peas are stated. According to Table IX, the effects of moisture, loading orientation and mutual effect of moisture and orientation on the toughness were significant at the 1% level. Loading speed, mutual effect of speed and orientation and mutual effect of speed and moisture were significant at the 5% level. So mean comparison was conducted by LSD test and the results are shown in Tables X-XII.

TABLE IX
ANALYSIS OF VARIANCE RESULTS OF THE EFFECTS OF MOISTURE, LOADING ORIENTATION AND LOADING SPEED ON TOUGHNESS (SEED STIFFNESS) OF POFAKI PEA

Source of variation	Degrees of freedom	Sum of squares	Mean square	F
Moisture	2	1.83	0.91	234.06**
Load Orientation	1	0.14	0.14	38**
Speed	2	0.03	0.01	4.71*
Speed × Orientation	2	0.03	0.01	4.05*
Moisture × Speed	4	0.05	0.01	3.34*
Moisture × Orientation	2	0.18	0.09	23.40**

** Significant difference at the 1% level ($p < 0.01$), * Significant difference at the 5% level ($p < 0.05$), ns not significant, CV= 22/41

According to Table X, the highest and lowest values of toughness are 0.59 (mJ mm^{-3}) and 0.0822 (mJ mm^{-3}), respectively in the moisture level of 47% and 67%, and the speed of 6 (min mm^{-1}).

TABLE X
THE MUTUAL EFFECT OF MOISTURE AND LOADING SPEED ON TOUGHNESS

Speed (mm min-1)	Moisture (w.b.%)		
	47%	57%	67%
4 (mm/min)	0.54 aA	0.24 bA	0.093 bA
6 (mm/min)	0.43 aA	0.21 bA	0.0824 cA
8 (mm/min)	0.59 aA	0.22 bA	0.0822 bA

Lowercase letters in each row, uppercase letters in each column represent no significant difference

Referring to Fig. 15 with increasing moisture from 47% to 67% toughness was decreased. Reference [19] shows that with decreasing moisture, toughness increased. This increase is because in low moisture rupture force Increased and Pistachio volume declined. Also was observed that with increasing speed the toughness first decreased and then increased.

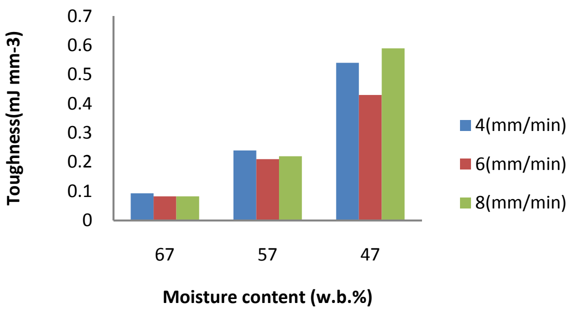

Fig. 15 Effects of moisture and loading speed on the toughness

According to Table XI, the highest and lowest values of toughness are 0.37 (mJ mm^{-3}) and 0.21 (mJ mm^{-3}), respectively in the in the transverse and longitudinal loading and speed of 4 (min mm^{-1}).

TABLE XI
THE MUTUAL EFFECT OF LOADING SPEED AND ORIENTATION ON TOUGHNESS

Load Orientation	Speed (mm min-1)		
	4 (mm/min)	6 (mm/min)	8 (mm/min)
Length	0.21 aA	0.22 aA	0. 23 aA
Width	0.37 aA	0.26 aA	0.36 aA

Lowercase letters in each row, uppercase letters in each column represent no significant difference

As shown in Fig. 16 toughness in transverse loading orientation is more than longitudinal and also was observed that with increasing speed the toughness first decreased and then increased.

According to Table XII, the highest and lowest values of toughness are 0.66 (mJ mm^{-3}) and 0.084 (mJ mm^{-3}), respectively in the moisture level of 47% and 67%, in the transverse and longitudinal loading.

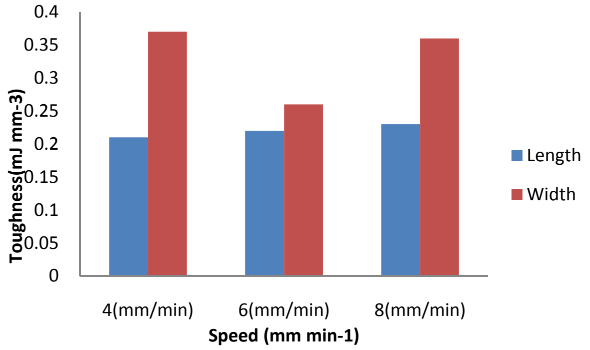

Fig. 16 Effect of loading speed and orientation on toughness

TABLE XII
THE MUTUAL EFFECT OF MOISTURE AND LOADING ORIENTATION ON TOUGHNESS

Load Orientation	Moisture (w.b.%)		
	47%	57%	67%
Length	0.39 ^{aB}	0.2 ^{bA}	0.084 ^{cA}
Width	0.66 ^{aA}	0.24 ^{bA}	0.087 ^{cA}

Lowercase letters in each row, uppercase letters in each column represent no significant difference

Referring to Fig. 17 with decreasing moisture toughness increased because of with decreasing moisture rupture force increases. Also it was observed toughness in transverse loading orientation is more than the longitudinal orientation.

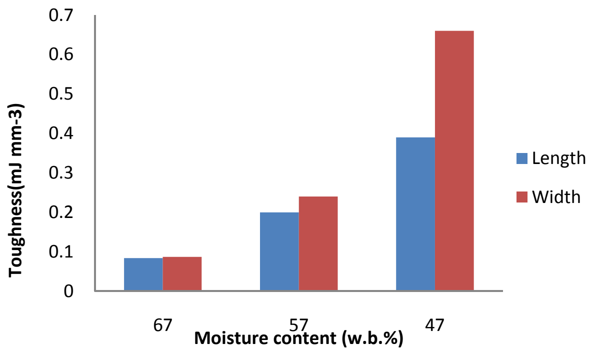

Fig. 17 Effect of moisture and loading orientation on toughness

According to Table XIII the effect of moisture on the power to seed rupture was significant at the 1% level and the effect of loading orientation was significant at the 5% level.

Power necessary for the rupture is directly related to two factors: Loading speed and rupture energy and that power is inversely relative to the amount of [22]. According to Fig. 18 with increased moisture the power necessary to break peas reduced. This is due to the firmness of the grain when the moisture is less.

Fig. 19 also shows necessary power to break pea seeds in both longitudinal and transverse orientations. The necessary power to breakage in the longitudinal orientation is less than the transverse. That this result for the rupture force and rupture energy and toughness is also the case. This must be considered in manufacturing harvest machines and pea seed processing.

TABLE XIII
RESULTS OF VARIANCE ANALYSIS OF THE EFFECT OF MOISTURE, LOADING ORIENTATION AND THE LOADING SPEED ON THE POWER REQUIRED TO BREAK POFAKI PEA

Source of variation	Degrees of freedom	Sum of squares	Mean square	F
Moisture	2	0.00006	0.00003	36.78**
Load Orientation	1	0.000004	0.00004	5.37*
Speed	2	0.000001	0.0000008	0.96^{ns}
Speed × Orientation	2	0.000001	0.0000008	0.93^{ns}
Moisture × Speed	4	0.0000007	0.0000001	0.20^{ns}
Moisture × Orientation	2	0.000001	0.0000006	0.73^{ns}

** Significant difference at the 1% level (p <0.01), * significant difference at the 5% level (p <0.05), ns not significant, CV=36/53

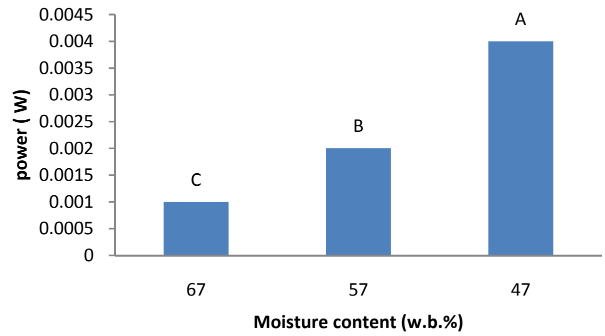

Fig. 18 Effect of different moisture contents on power to break pea

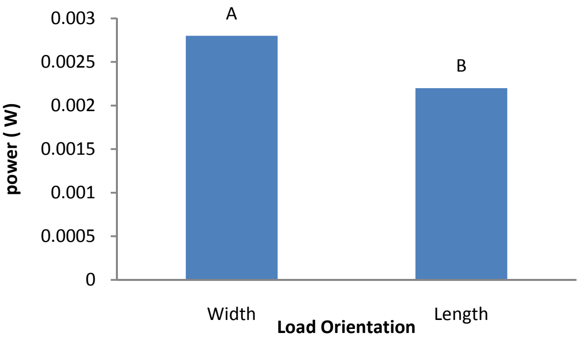

Fig. 19 Effect of different loading orientation on power to break peas

IV. CONCLUSION

With increasing moisture content the grain size, geometric diameter, volume and surface area increased. With increasing moisture, reducing the loading speed and loading deformation in the longitudinal orientation was at its highest value, So these conditions is suitable for transportation, because deformation takes longer to break down. With moisture reduction, reducing the loading speed and loading in the transverse orientation, rupture force, and rupture energy increased. Grain with these conditions has maximum resistance to mechanical damage and has the best conditions for shipping. With regard to the effect of loading speed on toughness, it was observed that with increasing speed the toughness first decreased and then increased. Actually the minimum toughness was observed at the speed of 6 (min mm^{-1}). Moisture reduction and loading in the transverse orientation, increases the power, for carrying out the seed processing operations with high moisture and loading in longitudinal orientation has the best situation because of its minimal power consumption

REFERENCES

[1] H. Mokhtar Poor, R. Bahram, S. Ziadloo and A. Karimian, 'The agriculture in Golestan province". Fekr- e- no Publication, 2004.
[2] N. N. Mohsenin. 'Physical Properties of Plant and Animal Materials", Gordon and Breach science publishers, New York, 1986.
[3] M. Aghkhani, S. Ashtiani, J. B. Motie and M. Abbaspour-Fard, 'Physical properties of Christmas Lima bean at different moisture content", International Agrophysics 26,P 341-346, 2012.
[4] A. M. Kermani, 'Some Physical and Mechanical Properties of Hazelnut". The 5th National Conference on Agricultural Machinery Engineering and Mechanization, Ferdowsi University, Mashhad, Iran, 2008.
[5] H. Zaki Dizaji and S. Minai. 'Determination of some physical and mechanical properties of chickpea seed", Journal of Food Science 4, P 57-65, 2007.
[6] M. Sadeghi, M. Abbasi and A. A Masoomi,'Effect of moisture on physical and aerodynamical properties of Wax bean" Iranian journal of Bio system Engineering 2, P145-152, 2010.
[7] H. Por Azarang, 'Unit Operation in Agricultural Material Processing. 1st edn. Ferdowsi University of Mashhad Publication, Mashhad, Iran, 2002.
[8] A. Afkari Siah, M. Ismailian, S. Minaie and A. Pirayesh, 'The effect of mechanical load on the damages to apple after the storage phase". Journal of Food Science 3, P 37- 44, 2007.
[9] A. Tabatabaeefar and A. Rajabipour 'Modeling the Mass of Apples by Geometrical attributes," Scientia Horticulturae 105, P373–382, 2005.
[10] O. Kabas, A. Ozemerzi and I. Akinci, "Physical properties of cactus pear grown wild in Turkey," Journal of food Engineering 73, P198–202, 2006.
[11] L. Zhiguo, L. Pingpingi and L. Jizhan, "Physical and mechanical properties of tomato fruits as related to robot's harvesting," Journal of Food Engineering 103, P170–178, 2011.
[12] C. B. Pravee and J. Irudayaraj, "Mechanical strength and rheological behavior of barely kernels", International Journal of Food Science and Technology 30, P606-623, 1995.
[13] R. K. Gopta and S. Das, "Physical properties of sunflower seeds". Journal of Agricultural Engineering Research 66, P1-8, 1996.
[14] M. E. De Simone, A. I. Salta, A. Salta, C. López and R. R. Filgueira, "Mechanical Threshing of Dry Beans Pods (*Phaseolus vulgaris* L.)." Written for Presentation at the 2000 ASAE Annual International Meeting Sponsored by ASAE.
[15] J. Khazaei, A. Rajabi Pour, S. Mohtasebi and M. Behroozi lar, "Required Force and Energy For Chickpea Grain Fracture under Compressive Quasi-Static Loading," Iranian Journal Of Agricultural Sciences 35, P765-776, 2004.
[16] H. Haciseferogullari, I. Gezer, M. M. Ozcan and B. Muratasma, "Postharvest chemical and physical–mechanical properties of some apricot varieties cultivated in Turkey," Journal of Food Engineering 79, P364–373, 2007.
[17] K. Tanigaki, T. Fujiura, A. Akase and J. Imagawa, "Cherry harvesting tomato," Computers and Electronics in Agriculture 63, P65–72, 2008.
[18] ASAE, "Moisture Measurement - unground grain and seeds," American Society of Agricultural Engineers, 1999, S 352.2.
[19] A. Golmohammadi, P. Sabouri and T. Mesri Gundoshmian, "The effect of moisture content on some mechanical properties of three varieties of pistachio nuts," Journal of Food Research 23, P211-221, 2013.
[20] M. Gholami Parashkouhi, B. Gooshki, A. M. Kermani, S. H. Mohseni and M. Salimi Beni, "Determination of Mechanical Properties of Pistachio nut and its kernel (Ahmad Aghaei variety)," Journal of Food Technology and Nutrition 10, P23-30, 2013.
[21] A. Imanmehr, B. Ghobadian, S. Minaei and J.Faradmal, "Determination of Some Physical Properties of Canola Seed (Licord Variety)", Journal of Agricultural Engineering Research 7, P119-128, 2007.
[22] V. Bodagh, M. Rasekh, A. H. Afkari-Sayyah, B. Yaghoubian and A. Golmohammadi, "Some physical and mechanical properties of two varieties of Almond", Journal of food science & Technology 8, P49-57, 2011
[23] H. Sadrnia, A. Rajabipour, A. Jafari, A. Javadi, Y. Mostofi and T. Bagherpour, "Mechanical Failure of Two Varieties of Watermelon Under Quasi Static Load," Iranian Journal Biosystems Enginneering 40, P169-174, 2009.