Journal of Applied Sciences

ISSN 1812-5654

Journal of Applied Sciences 6 (6): 1373-1379, 2006
ISSN 1812-5654

Some Physical and Mechanical Properties of Sainfoin (*Onobrychis sativa* Lam.), Grasspea (*Lathyrus sativus* L.) and Bitter Vetch (*Vicia ervilia* (L.) Willd.) Seeds

[1]Ebubekir Altuntas and [2]Yasar Karadag
[1]Department of Agricultural Machinery, Faculty of Agriculture,
University of Gaziosmanpasa, 60240 Tasliciftlik, Tokat-Turkey
[2]Department of Field Crops, Faculty of Agriculture,
University of Gaziosmanpasa, 60240 Tasliciftlik,
Tokat-Turkey

Abstract: Some physical properties of some forage plants namely sainfoin (*Onobrychis sativa* Lam.), grasspea (*Lathyrus sativus* L.) and bitter vetch (*Vicia ervilia* (L.) Willd.) seeds were determined at moisture content of 9.55, 15.40 and 10.00% d.b. (dry basis), respectively. The mean values of length, width, thickness and geometric mean diameter were 5.86, 4.27, 2.84, 4.07 mm for sainfoin seed; 5.29, 4.83, 4.29, 5.28 mm for grasspea seed and 4.12, 3.78, 3.80, 3.89 mm for bitter vetch seed respectively. The mean 1000 seed mass, sphericity, angle of repose, bulk and true density, single seed volume, surface area, porosity values were obtained as 23.92 g, 69.77%, 13.50°, 340.86 kg m^{-3}, 674.53 kg m^{-3}, 0.036 cm^3, 0.54 cm^2 and 48.91% for sainfoin seed; 88.50 g, 88.67%, 15.61°, 736.58 kg m^{-3}, 1273.31 kg m^{-3}, 0.069 cm^3, 1.37 cm^2 and 42.03% for grasspea seed and 45.39 g, 94.54%, 10.85°, 800.02 kg m^{-3}, 1543, 32 kg m^{-3}, 0.030 cm^3, 0.48 cm^2 and 47.45% for bitter vetch seed respectively. The mean values of coefficient of dynamic friction against galvanized steel, chipboard, mild steel, plywood and rubber surfaces were 0.24, 0.28, 0.30, 0.34 and 0.61 for sainfoin seed 0.18, 0.18, 0.15, 0.18 and 0.48 for grasspea seed and 0.26, 0.25, 0.28, 0.35 and 0.48 for bitter vetch seed, respectively; while the values of coefficient of static friction were 0.35, 0.39, 0.40, 0.40 and 0.70 for sainfoin seed; 0.31, 0.23, 0.27, 0.24 and 0.64 for grasspea seed and 0.32, 0.34, 0.35, 0.43 and 0.63, respectively for bitter vetch seed. The rubber surface offered the maximum static and dynamic friction followed by plywood, mild metal, chipboard and galvanized steel. The mechanic properties of sainfoin, grasspea, bitter vetch seeds were determined in terms of average rupture force, specific deformation and rupture energy along X-, Y- and Z- axes. The mean values of rupture force, specific deformation and rupture energy for sainfoin seed were 7.40, 9.72 and 4.56 N; 8.94, 11.71 and 9.97% and 1.97, 2.46 and 0.71 N mm for along X, Y and Z axis, respectively. The mean values of rupture force, specific deformation and rupture energy for grasspea seed were 254.40, 242.60 and 100.80 N; 27.53, 21.29 and 14.03% and 187.20, 129.25 and 38.77 N mm for along X, Y and Z axis, respectively. The mean values of rupture force, specific deformation and rupture energy for bitter vetch seed were 57.60, 145.00, 87.00 N; 7.60, 11.62, 11.93%; 10.14, 34.42, 21.86 N mm for along X, Y and Z axis, respectively.

Key words: Forage plants seeds (sainfoin, grasspea and bitter vetch), physical and mechanical properties

INTRODUCTION

The family Leguminosae comprises of about 690 genera and more than 17.000 species (Hutchinson, 1964). Sainfoin (*Onobrychis sativa* Lam.), grasspea (*Lathyrus sativus* L.) and bitter vetch (*Vicia ervilia* (L.) Willd.), three of the legumes, belongs to the tribe *Vicieae* of the sub-family Papilionaceae (Davis, 1970). The genus *Vicia* has 180-200 species which are mostly temperature annual end perennial, auto and allogamous erect or climbing plants (Kupicha, 1976).

The legume species *Vicia ervilia* (L.) Willd. is an ancient crop and is still cultivated in Turkey, Spain, Greece, Cyprus (Enneking *et al*., 1995). Bitter vetch is an important legume crop cultivated for forage and seed yield in the Mediterranean, West Asia and North Africa regions, where it is traditionally grown for ruminant feed. The grain is crushed before feeding. It is used for cows to encourage and sustain milk production (2-4 kg/head/day), for calves (0.25-0.5 kg/head/day; 3-4 months of age). The grain is also used to feed bovine draught animals (1-2 kg/head/day). *Vicia ervilia* grain is considered to aid

Corresponding Author: Dr. Ebubekir Altuntas, Department of Agricultural Machinery, Faculty of Agriculture, University of Gaziosmanpasa, 60240 Tasliciftlik, Tokat-Turkey
Tel: 90 356 252 1616 Fax: 90 356 252 1488

the recovery of ruminant animals which are in poor condition. Larger seeds are preferred for the purpose of animal feeding (Enneking *et al*., 1995). Bitter vetch is known for its high nutritional value, capacity of nitrogen fixation and ability to grow in poor soils (Lopeze Bellido, 1994). Its seeds contain about 28.5 crude protein content. (Farran *et al*., 2001 a, b).

Lathyrus has 120-170 species, distributed through temperate Northern Hemisphere and South America, with herbaceous, climbing, annual and perennial, auto and allogamous plants (Jackson and Yunus, 1984). In Turkey, this genus includes 58 species (Davis, 1970). *Lathyrus sativus* is a popular drought tolerant crop and important grain legume in drought areas of Africa and Asia (Wang *et al*. 2000). Grasspea is widely grown as a food or forage legume throughout the Meditterranean, Middle East and Indian sub-continent regions. The crop is produced with a minimum amount of care and can be successfully grown in a variety of climates (Wang *et al*., 2000). It has potential as a multipurpose legume-for grazing, hay, green manure or grain (Karadag *et al*., 2004). Lathyrus grain is a safe and nutritious pig and ruminant stockfeed. This plant is resistant to drought and low quality of soil. They are rich in protein, about 20-32% (Castell *et al*., 1994, Grela and Günther, 1995).

Sainfoin (*Onobrychis sativa* Lam.) is an important perennial forage legume for Turkey. It is native, widely grown perennial legume well adapted to highland farming system under dryland conditions of Central and Eastern Anatolia (Karadag, 2003). There is no other forage legume that can be replace it. Sainfoin is grown for green herbage, hay and seed production and can be used successfully in ruminant feeds and feed rations. Sainfoin is a cool-season perennial forage legume that does not cause bloat in ruminants (Alrich, 1984).

The physical properties of sainfoin, grasspea and bitter vetch seeds are to be known; for design and improve of relevant machines and facilities for harvesting, storing, handling, granding and processing. The size and shape are important in designing of separating, harvesting, sizing and granding machines. Bulk density and porosity affect the structural loads, the angle of repose is important in designing of storage and transporting structures. The coefficient of friction of the grain against the various surface is also necessary in designing of conveying, transporting and storing structures.

In recent years, physical properties have been studied for various crops such as cotton seed (Ozarslan, 2002); hemp seed (Sacilik *et al*., 2003); lentil seed (Amin *et al*., 2004); sesame seed (Tunde-Akindute and Akindute, 2004); Hungarian and common vetch seeds (Taser *et al*., 2005) and fenugreek seed (Altuntas *et al*., 2005).

The objective of this study was to investigate some physical properties of sainfoin, grasspea and bitter vetch seeds, namely, size dimension, sphericity, thousand grain mass, bulk density, angle of repose, volume, true density, porosity, surface area and the static and dynamic coefficients of friction on various surfaces. In addition, the rupture force, specific deformation and rupture energy of forage plant seeds were determined as regards mechanical properties of seeds in this study.

MATERIALS AND METHODS

Sainfoin (*Onobrychis sativa* Lam.), grasspea (*Lathyrus sativus* L.) and bitter vetch (*Vicia ervilia* (L.) Willd.) seeds used in the study were obtained from a local market in Tokat, Turkey. The samples were cleaned manually to remove all foreign matter, dust, dirt, broken and immature grains. The moisture content of the samples was determined by oven drying at 105±1°C for 24 h (Suthar and Das, 1996). Each of the samples was replicated three times and the mean moisture content of sainfoin, grasspea and bitter vetch seed was found as 9.55, 15.40 and 10.00% d.b. (dry basis), respectively.

To determine the seed size; one hundred seeds were randomly selected and length, width and thickness were measured using a dial-micrometer to an accuracy of 0.01 mm. The geometric mean diameter D_g and sphericity Φ of faba bean grains was calculated by using the following relationships (Mohsenin, 1970):

$$D_g = (LWT)^{1/3} \quad (1)$$

$$\Phi = \{(LWT)^{1/3} / L\} \times 100 \quad (2)$$

where, L is the length, W is the width and T is the thickness in mm.

To obtain the thousand seed mass were measured by an electronic balance to an accuracy of 0.001 g. To evaluate thousand grain mass, 100 randomly selected grains from the bulk were averaged. The true density of a seed is defined as the ratio of the mass of a sample of a grain to the solid volume occupied by the sample (Deshpande *et al*., 1993). The seed volume and its kernel density were determined using the liquid displacement method. Toluen (C_7H_8) was used rather than water because it is absorbed by seeds to a lesser extent. Also, its surface tension is low, so that it fills even shallow dips in a seed and its dissolution power is low (Sitkei, 1976; Mohsenin, 1970). The bulk density is the ratio of the mass of a sample of a grain to its total volume and it was determined with a weight per hectolitre tester which was calibrated in kg m^{-3} (Deshpande *et al*., 1993; Suthar and Das, 1996). The porosity (p) was determined by the following equation:

$$p = \{ 1-(\rho_b / \rho_t) \} 100 \quad (3)$$

where ρ_b and ρ_t the bulk density and the true density, respectively (Mohsenin, 1970).

The surface area of sainfoin, grasspea and bitter vetch seeds was found by analogy with a sphere of same geometric mean diameter, using experisson cited by Olajide and Ade-Omowaye (1999) and Sacilik *et al*. (2003):

$$S = \Pi D_g^{\ 2} \quad (4)$$

where, S is the surface area in mm^2 and D_g is the geometric mean diameter in mm.

In order to determine the angle of repose; topless and bottomless cylinder with 300 mm diameter and 500 mm height was used. The cylinder was placed at the center of a raised circular plate and was filled with seed. The cylinder was raised slowly until it formed a cone on a circular plate. The angle of repose was calculated from the measurement of the height of the cone and the diameter of cone (Kaleemullah and Gunasekar, 2002).

The coefficient of friction of forage plants seeds was measured using a friction device. The device consists of metal box, friction surface and electronic units which covers mechanical force unit, electronic variater, load cell, electronic ADC card and PC. The load cell is connected to the metal box is sized 30×30×30 cm^3. For the measuring of friction force, friction surface (plywood, mild metal, chipboard and galvanized steel and rubber) is moved horizontally by the stationary velocity of 0.02 m sec^{-1} velocity. Friction force values are measured by load cell, converted by ADC card and converted data is recorded in computer (Kara *et al*., 1997). The mean value was used to calculate the coefficient of dynamic friction and maximum obtained value was used to calculate the coefficient of static friction for each experiment.

To determine the mechanical properties of some forage plants seeds namely sainfoin, grasspea and bitter vetch, a biological material test device was used (Fig. 1). This device has three main component, which are moving platform, a driving unit and a data acquisition (load cell, PC card and software) system as shown in Fig. 1. This device is Zwick/Roell (Instruction Manual for Materials Testing Machines/BDO-FB 0.5 TS). The forage plants seeds were placed on the moving platform considering the variation of moisture content and loading position at the 0.5 mm sec^{-1} speed and pressed with a plate fixed on the load cell until the sainfoin, grasspea and bitter vetch seeds ruptured. Force-deformation curves were recorded. The mechanical behaviour of forage plants seeds were expressed in terms of rupture force, specific deformation and rupture energy required for initial rupture. Three replication were made each test and ten samples in each test were used. The three compression axes (X, Y, Z) for forage plants seeds were used to determine the specific deformation, rupture force and rupture energy. The X-axis (force F_x) is the longitudinal axis through the hilum (length), while the Y-axis (force F_y) is transverse axis containing the minor dimension (width) at right angles to the X-axis and the Z-axis (force F_z) is the transverse axis containing the minimum dimension (thickness). From the compressed speed and time, sainfoin, grasspea and bitter vetch seeds deformation was computed and force-deformation were measured directly from the plotted force-deformation curve. The specific deformation was obtained from the following Equation:

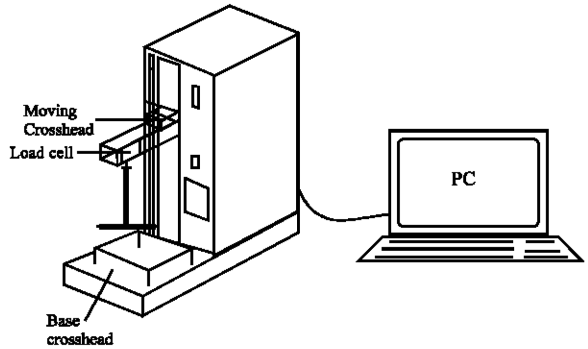

Fig.1: Biological material test device

$$\in = \{1- (L_f / L_u)\} 100 \quad (6)$$

where, $\in$ is the specific deformation in%; L_u is the undeformed forage plants seed dimension on the direction of the compression axis in mm; and L_f is the deformed forage plants seed dimension on the direction of the compression axis in mm (Braga *et al*., 1999). Energy absorbed (E_a) by the sample at rupture was determined by calculating the area under the force-deformation curve from the following equation

$$E_a = \{1/2 (FD)\} \quad (7)$$

where, F is the rupture force and D is the deformation at rupture point (Braga *et al*., 1999).

RESULTS AND DISCUSSION

The length, width and thickness of sainfoin seeds ranged from 4.14 to 7.21, 2.87 to 5.74 and 1.27 to 3.61 mm,

Table 1: Some physical and mechanical properties of sainfoin (*Onobrychis sativa* Lam.) seeds at a moisture content of 9.55% d.b.

	Values			
Physical properties	Mean	Maximum	Minimum	SD
Length, L (mm)	5.86	7.21	4.14	0.69
Width, W (mm)	4.27	5.74	2.87	0.54
Thickness, T (mm)	2.84	3.61	1.27	0.41
Geometric mean diameter, D_g(mm)	4.07	5.07	2.71	0.42
Sphericity, Φ (%)	69.77	84.47	56.70	5.22
1000 seed mass (g)	23.92	12.70	36.30	11.80
Bulk density ρ_b (kg m^{-3})	340.86	348.45	337.71	3.36
True density ρ_t (kg m^{-3})	674.53	782.36	597.47	80.73
Angle of repose (°)	13.50	15.12	11.89	1.62
Porosity p (%)	48.91	56.43	42.95	5.86
Surface area, S (cm^2)	0.54	0.83	0.23	0.11
Single seed volume (cm^3)	0.036	0.040	0.031	0.004
Coefficient of friction on				
Plywood	0.34	0.40	0.26	0.026
Galvanize steel	0.24	0.35	0.19	0.029
Mild steel	0.30	0.40	0.19	0.034
Chipboard	0.28	0.39	0.22	0.042
Rubber	0.61	0.70	0.51	0.040
Mechanical properties				
Rupture force (N)				
X-axis	7.40	10.00	4.00	2.79
Y axis	9.72	14.00	6.00	2.91
Z-axis	4.56	7.00	2.50	0.07
Specific deformation (%)				
X-axis	8.94	10.64	6.93	1.65
Y axis	11.71	20.41	6.61	5.20
Z-axis	9.97	14.24	6.21	2.98
Rupture energy (N mm)				
X-axis	1.97	3.00	0.80	0.95
Y axis	2.46	5.60	0.75	1.84
Z-axis	0.71	1.12	0.25	0.31

Table 2: Some physical and mechanical properties of grasspea (*Lathyrus sativus* L.) 15.40% d.b.

	Values			
Physical properties	Mean	Maximum	Minimum	SD
Length, L (mm)	5.29	7.45	3.93	0.51
Width, W (mm)	4.83	7.08	3.47	0.50
Thickness, T (mm)	4.29	6.97	3.02	0.55
Geometric mean diameter, D_g (mm)	5.28	5.69	4.58	0.60
Sphericity, Φ (%)	88.67	99.49	80.98	9.64
1000 seed mass (g)	88.50	90.70	82.50	4.24
Bulk density ρ_b (kg m^{-3})	736.58	740.67	733.00	2.76
True density ρ_t (kg m^{-3})	1273.31	1325.04	1191.40	71.75
Angle of repose (°)	15.61	17.48	14.74	0.97
Porosity p (%)	42.03	44.41	38.18	3.36
Surface area, S (cm^2)	1.37	1.49	1.25	0.12
Single seed volume (cm^3)	0.069	0.073	0.067	0.003
Coefficient of friction on				
Plywood	0.18	0.24	0.11	0.03
Galvanize steel	0.18	0.31	0.13	0.04
Mild steel	0.15	0.27	0.09	0.04
Chipboard	0.18	0.23	0.15	0.02
Rubber	0.48	0.64	0.37	0.05
Mechanical properties				
Rupture force (N)				
X-axis	254.40	363.00	195.00	65.83
Y axis	242.60	310.00	183.00	45.59
Z-axis	100.80	123.00	50.00	29.06
Specific deformation (%)				
X-axis	27.53	38.28	19.55	7.65
Y axis	21.29	25.17	14.13	4.58
Z-axis	14.03	18.00	8.65	3.58
Rupture energy (N mm)				
X-axis	187.20	290.40	126.75	63.33
Y axis	129.25	178.25	59.48	43.92
Z-axis	38.77	55.35	11.25	16.84

respectively (Table 1). The length, width and thickness of grasspea seeds ranged from 3.93 to 7.45, 3.47 to 7.08 mm and 3.02 to 6.97 mm, respectively (Table 2). The length, width and thickness of bitter vetch seeds ranged from 3.51 to 4.80, 3.02 to 4.29 mm, 3.07 to 4.19 mm, respectively (Table 3). The length, width and thickness values are important in development of sizing and grading machines. The geometric diameter was 4.07, 5.28 and 3.89 mm for sainfoin, grasspea and bitter vetch seeds, respectively.

The sphericity values of sainfoin, grasspea and bitter vetch seeds were found 56.70 to 84.47%, 80.98 to 99.49% and 87.96 to 99.82%, respectively. The mean 1000 seed mass of sainfoin, grasspea and bitter vetch seed were found to be 23.92, 88.50 and 45.39 g, respectively. The bulk density were changed between 337.71 to 348.45 kg m^{-3}, 733.00 to 740.67 kg m^{-3} and 787.35 to 807.54 kg m^{-3} for sainfoin, grasspea and bitter vetch seeds, respectively. The true density were ranged from 597.47 to 782.36 kg m^{-3}, 1191.40 to 1325.04 kg m^{-3} and 1324.00 to 1762.43 kg m^{-3} for sainfoin, grasspea and bitter vetch seeds, respectively (Table 1-3). The mean angles of repose of sainfoin, grasspea and bitter vetch seeds were 13.50, 15.61 and 10.85°, respectively. These values are considerably lower than those reported for sesame seed as 32° by Tunde-Akindute and Akindute (2004), for locust bean seed as 20.32° by Ogunjimi *et al.* (2002). Similar results have been reported for Hungarian and common vetch seeds as 13.64° and 12.95° by Taser *et al.* (2005) and wheat, bulgur and yarma seeds as 13.04, 14.44 and 16.17° by Ozgoz *et al.* (2005), respectively.

The single volume of sainfoin, grasspea and bitter vetch seed were 0.036, 0.069 and 0.030 cm^3. The porosity were ranged from 42.95 to 56.43%, 38.18 to 44. 41% and 39.58 to 54.61% for sainfoin, grasspea and bitter vetch seeds, respectively. The surface area were changed from 0.23 to 0.83, 1.25 to 1.49and 0.40 to 0.52 cm^2 for sainfoin, grasspea and bitter vetch seeds, respectively.

The values of dynamic and static coefficients of friction against the various test surfaces, namely, plywood, mild steel and galvanised metal, chipboard and rubber were are given in Table 1. The mean values of coefficient of dynamic friction against galvanized steel, chipboard, mild steel, plywood and rubber surfaces were

Table 3: Some physical and mechanical properties of bitter vetch (*Vicia ervilia* (L.) Willd.) seeds at a moisture content of 10.00% d.b.

	Values			
Physical properties	Mean	Maximum	Minimum	SD
Length, L (mm)	4.12	4.80	3.51	0.28
Width, W (mm)	3.78	4.29	3.02	0.24
Thickness, T (mm)	3.80	4.19	3.07	0.20
Geometric mean diameter, D_g (mm)	3.89	4.38	3.46	0.21
Sphericity, Φ (%)	94.54	99.82	87.96	8.87
1000 seed mass (g)	45.39	72.30	30.17	23.37
Bulk density ρ_b (kg m^{-3})	800.02	807.54	787.35	11.03
True density ρ_t (kg m^{-3})	1543.32	1762.43	1324.00	219.68
Angle of repose (°)	10.85	12.68	9.77	1.014
Porosity p (%)	47.45	54.61	39.58	7.54
Surface area, S (cm^2)	0.48	0.52	0.40	0.07
Single seed volume (cm^3)	0.030	0.034	0.026	0.004
Coefficient of friction on				
Plywood	0.35	0.43	0.29	0.046
Galvanize steel	0.26	0.32	0.20	0.026
Mild steel	0.28	0.35	0.23	0.030
Chipboard	0.25	0.34	0.20	0.008
Rubber	0.48	0.63	0.34	0.083
Mechanical properties				
Rupture force (N)				
X-axis	57.60	95.00	43.00	21.70
Y axis	145.00	175.00	123.00	19.38
Z-axis	87.00	120.00	44.00	27.77
Specific deformation (%)				
X-axis	7.60	11.68	5.94	2.39
Y axis	11.62	13.19	8.74	1.54
Z-axis	11.93	16.75	6.59	4.58
Rupture energy (N mm)				
X-axis	10.14	23.75	5.85	7.66
Y axis	34.42	43.75	27.68	6.50
Z-axis	21.86	39.00	5.94	12.41

0.24, 0.28, 0.30, 0.34 and 0.61 for sainfoin seed 0.18, 0.18, 0.15, 0.18 and 0.48 for grasspea seed and 0.26, 0.25, 0.28, 0.35 and 0.48 for bitter vetch seed respectively; while the values of coefficient of static friction were 0.35, 0.39, 0.40, 0.40 and 0.70 for sainfoin seed; 0.31, 0.23, 0.27, 0.24 and 0.64 for grasspea seed and 0.32, 0.34, 0.35, 0.43 and 0.63 for bitter vetch seed respectively. From these results, static coefficients of friction is higher than dynamic coefficients of friction. The rubber surface offered the maximum static and dynamic friction followed by plywood, mild metal, chipboard and galvanized steel. The lowest values were found in the galvanized steel surface. This may be due to smoother and more polished surface of galvanised metal than other test surfaces. Similar results were found by other researchers (Çarman, 1996 for lentil seed; Gupta and Das, 1997 for sunflower grain; Ogut, 1998 for white lupin; Baryeh, 2002 for millet; Taser *et al*., 2005 for Hungarian and common vetch).

The mechanic properties of sainfoin, grasspea, bitter vetch seeds were determined in terms of average rupture force, specific deformation and rupture energy along X-, Y- and Z- axes. The mean values of rupture force, specific deformation and rupture energy for sainfoin seed were 7.40, 9.72 and 4.56 N; 8.94, 11.71 and 9.97% and 1.97, 2.46 and 0.71 N mm for along X, Y and Z axis, respectively. The mean values of rupture force, specific deformation and rupture energy for grasspea seed were 254.40, 242.60 and 100.80 N; 27.53, 21.29 and 14.03% and 187.20, 129.25 and 38.77 N mm for along X, Y and Z axis, respectively. The mean values of rupture force, specific deformation and rupture energy for bitter vetch seed were 57.60, 145.00 and 87.00 N; 7.60, 11.62 and 11.93%; 10.14, 34.42 and 21.86 N mm for along X, Y and Z axis, respectively.

The highest rupture force was obtained for sainfoin seed loaded along the Y- axis (F_y), while those loadded along the Z- axis (F_z) required the least force to rupture. The highest force was obtained for grasspea seed loaded along the X- axis (F_x), while those loadded along the Z- axis (F_z) required the least force to rupture. The highest force was obtained for bitter vetch seed loaded along the Y- axis (F_y), while those loadded along the X- axis (F_x) required the least force to rupture. Among the forage plants seeds, the highest rupture force was obtained grasspea seed loaded along X, Y and Z axis, while the lowest rupture force was obtained for sainfoin seed.

The highest specific deformation was obtained for sainfoin seed loadded along the Y- axis (F_y), while those loadded along the X- axis (F_x) required the least specific deformation. The highest specific deformation was obtained for grasspea seed loaded along the X- axis (F_x), while those loadded along the Z- axis (F_z) required the least specific deformation. The highest specific deformation was obtained for bitter vetch seed loaded along the Y- axis (F_y), while those loadded along the X- axis (F_x) required the least specific deformation. Among the forage plants seeds, the highest specific deformation was obtained grasspea loaded along X, Y and Z axis, while the lowest rupture force was obtained for sainfoin seed .

The highest specific deformation was obtained for sainfoin seed loadded along the Y- axis (F_y), while those loadded along the X- axis (F_x) required the least specific deformation. The highest specific deformation was obtained for grasspea seed loaded along the X- axis (F_x), while those loadded along the Z- axis (F_z) required the least specific deformation. The highest specific deformation was obtained for bitter vetch seed loaded along the Y- axis (F_y), while those loadded along the X- axis (F_x) required the least specific deformation. Among the forage plants seeds, the highest specific deformation was obtained grasspea loaded along X, Y and Z axis, while the lowest rupture force was obtained for sainfoin seed.

The highest rupture energy was obtained for sainfoin seed loadded along the Y- axis (F_y), while those loadded along the Z- axis (F_z) required the least rupture energy. The highest rupture energy was obtained for grasspea seed loaded along the X- axis (F_x), while those loadded along the Z- axis (F_z) required the least rupture energy. The highest rupture energy was obtained for bitter vetch seed loaded along the Y- axis (F_y), while those loadded along the X- axis (F_x) required the least rupture energy. Among the forage plants seeds, the highest rupture energy was obtained grasspea loaded along X, Y and Z axis, while the lowest rupture force was obtained for sainfoin seed.

CONCLUSIONS

The following conclusions are drawn from the investigation on physical and mechanical properties of some physical properties of sainfoin (*Onobrychis sativa* Lam.), grasspea (*Lathyrus sativus* L.) and bitter vetch (*Vicia ervilia* (L.) Willd.) seeds at moisture content of 9.55, 15.40 and 10.00% d.b., respectively.

The mean values of length, width, thickness and geometric mean diameter were 5.86, 4.27, 2.84 and 4.07 mm for sainfoin seed; 5.29, 4.83, 4.29 and 5.28 mm for grasspea seed and 4.12, 3.78, 3.80 and 3.89 mm for bitter vetch seed respectively.

The mean 1000 seed mass, sphericity, angle of repose, bulk and true density, single seed volume, surface area, porosity values were obtained as 23.92 g, 69.77%, 13.50°, 340.86 kg m^{-3}, 674.53 kg m^{-3}, 0.036 cm^3, 0.54 cm^2 and 48.91% for sainfoin seed; 88.50 g, 88.67%, 15.61°, 736.58 kg m^{-3}, 1273.31 kg m^{-3}, 0.069 cm^3, 1.37 cm^2 and 42.03% for grasspea seed and 45.39 g, 94.54%, 10.85°, 800.02 kg m^{-3}, 1543, 32 kg m^{-3}, 0.030 cm^3, 0.48 cm^2 and 47.45% for bitter vetch seed respectively.

The mean values of coefficient of dynamic friction against galvanized steel, chipboard, mild steel, plywood and rubber surfaces were 0.24, 0.28, 0.30, 0.34 and 0.61 for sainfoin seed 0.18, 0.18, 0.15, 0.18 and 0.48 for grasspea seed and 0.26, 0.25, 0.28, 0.35 and 0.48 for bitter vetch seed respectively. The mean values of coefficient of static friction were 0.35, 0.39, 0.40, 0.40 and 0.70 for sainfoin seed; 0.31, 0.23, 0.27, 0.24 and 0.64 for grasspea seed and 0.32, 0.34, 0.35, 0.43 and 0.63 for bitter vetch seed respectively. The rubber surface offered the maximum static and dynamic friction followed by plywood, mild metal, chipboard and galvanized steel.

The mechanic properties of sainfoin, grasspea, bitter vetch seeds were determined in terms of average rupture force, specific deformation and rupture energy along X-, Y- and Z- axes. The mean values of rupture force, specific deformation and rupture energy for sainfoin seed were 7.40, 9.72 and 4.56 N; 8.94, 11.71 and 9.97% and 1.97, 2.46 and 0.71 N mm for along X, Y and Z axis, respectively. The mean values of rupture force, specific deformation and rupture energy for grasspea seed were 254.40, 242.60 and 100.80 N; 27.53, 21.29 and 14.03% and 187.20, 129.25 and 38.77 N mm for along X, Y and Z axis, respectively. The mean values of rupture force, specific deformation and rupture energy for bitter vetch seed were 57.60, 145.00, 87.00 N; 7.60, 11.62, 11.93%; 10.14, 34.42, 21.86 N mm for along X, Y and Z axis, respectively.

REFERENCES

Alrich, D.T.A., 1984. Lucerne, red clover and sainfoin-herbage production. In: D.J. Thomson (Ed.). Forage legumes. Occ. Syp. No: 16, British Grassland Soc. Publ.

Altuntas, E., E. Ozgoz and O.F. Taser, 2005. Some physical properties of fenugreek (*Trigonella foenum-graceum* L.) seeds. J. Food Eng., 71: 37-43.

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

Baryeh, E.A., 2002. Physical properties of millet. J. Food Eng., 51: 39-46.

Braga, G.C., S.M. Couto, T. Hara and J.T.P.A. Neto, 1999. Mechanical behaviour of macadamia nut under compression loading. J. Agric. Eng. Res., 72: 239-245.

Carman, K., 1996. Some physical properties of lentil grains. J. Agric. Eng. Res., 63: 87-92.

Castell, A.G., R.L. Cliplef, C.J. Briggs, C.G. Cambell and J.E. Bruni, 1994. Evaluation of lathyrus (*Lathyrus sativus* L.) as an ingredient in pig starter and grower diets. Can. J. Anim. Sci., 74: 529-539.

Davis, P.H., 1970. Flora of Turkey and East-Aegean Islands. Edinburgh Univ., Press, 3: 78.

Deshpande, S.D., S. Bal and T.P. Ojha, 1993. Physical properties of soybean grains. J. Agric. Eng. Res., 56: 89-92.

Enneking, D., A. Lahlou, A. Noutfia and M. Bounejmate, 1995. A note on *Vicia ervilia* cultivation, utilization and toxicity in Morocco. Al Awamia, 89: 141-148.

Farran, M.T., G.W. Barbour, M.G. Uwayjan, and V.M. Ashkarian, 2001a. Metabolizable energy values and amino acid availability of Vetch (*Vicia sativa*) and Ervil (*Vicia ervilia*) seeds soaked in water and acetic acid. Poult. Sci., 80: 931-936.

Farran, M.T., P.B. Dakessian, A.H. Darwish, M.G. Uwayjan, H.K. Dbouk, F.T. Seliman and V.M. Ashkarian, 2001b. Performance of broilers and production and egg quality parameters of laying hens fed 60% raw and treated common vetch (*Vicia ervilia*) seeds. Poult. Sci., 80: 203-208.

Grela, E.R. and K.D. Günther, 1995. Fatty acid composition and tocopherol content of some legume seeds. Anim. Feed. Sci. Technol., 52: 325-331.

Gupta, R.K. and S.K. Das, 1997. Physical properties of sunflower grains. J.Agrc. Eng. Res., 66: 1-8.

Hutchionson, J., 1964. The Genera of Flowering Plants, Dicotyledons. Vol. F. Clarendon Pres, Oxford.

Jackson, M.T. and A.G. Yunus, 1984. Variation in the grasspea (*Lathyrus sativus* L.) and wild species. Euphytica, 37: 69-75.

Kaleemullah, S. and J.J. Gunasekar, 2002. Moisture-dependet physical properties of arecanut trues. Biosys. Eng., 82: 331-338.

Kara, M., N. Turgut, Y. Erkmen and İ.E. Güler, 1997. Determination of coefficient of friction of some granules. 17 National Symposium on Mechanization in Agriculture (In Turkish) (pp: 609-614). Tokat. Turkey.

Karadağ, Y., 2003. Some characteristics of sainfoin (*Onobrychis sativa* Lam.) grown in Tokat natural rangeland vegetations. J. Agric. Faculty of Gaziosmanpasa Univ., 20: 131-134 (in Turkish).

Karadağ, Y., S. İptaş and M. Yavuz, 2004. Agronomic potential of grasspea *(Lathyrus sativus* l.) under rainfed condition in semi-arid regions of Turkey, Asian J. Plant Sci., 3: 151-155.

Kupicha, F.K., 1976. The infrageneric structure of *Vicia*. Notes from the Royal Botanical Garden Edinburgh, 34: 287-326.

Lopeze Bellido, L., 1994. Grain Legumes for Animal Feeds. In: Hernando Bermejo J.E. and J. Leon (Eds.). Neglected Crops: 1492 from a Different Perspective. Plant Production and Protection Series No. 26. FAO, Rome, Italy, pp: 273-288.

Mohsenin, N.N., 1970. Physical Properties of Plant and Animal Materials. Gordon and Breach Sci. Publishers, New York.

Ogunjimi, L.A.O., N.A. Aviara and O.A. Aregbesola, 2002. Some engineering properties of locust bean seed. J. Food Eng., 55: 273-277.

Ogut, H., 1998. Some physical propetrites of white lupin. J. Agric. Eng. Res., 69: 273-277.

Olajide, J.D. and B.I.O. Ade-Omowaye, 1999. Some physical properties of locust bean seed. J. Agric. Eng. Res., 74: 213-215.

Ozarslan, C., 2002. Some physical properties of cotton grain. Biosys. Eng., 83: 169-174.

Ozgoz, E., O.F. Taser and E. Altuntas, 2005. Some physical properties of Yarma Bulgur. J. Applied Sci., 5: 838-840.

Sacilik, K., R. Öztürk and R. Keskin, 2003. Some physical properties of hemp grain. Biosys. Eng., 86: 213-215.

Sitkei, G., 1976. Mechanic of Agric. Materials. Akademia Kiado, Budapest.

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

Taser, O.F., E. Altuntas and E. Ozgoz, 2005. Physical properties of Hungarian and common vetch seeds. J. Applied Sci., 5: 323-326.

Tunde-Akindute, T.Y. and B.O. Akindute, 2004. Some physical properties of sesame seed. Biosys. Eng., 88: 127-129.

Wang, F., X. Chen, Q. Chen, X. Qin and Z. Li, 2000. Determination of neurotoxin 3-N-oxalyl-2,3-diaminopropionic acid and non-protein amino acids in *Lathyrus sativus* by precolumn derivatization with 1-fluoro-2, 4-dinitrobenzene. J. Chromatogr. A, 883: 113-118.