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Determination of Some Physical and Mechanical Properties of Pea (*Pisum sativum* L.) Seeds

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Abstract: In the present study some physical properties of pea seeds at different moisture content (4.47 to 61.23%) were estimated. The results revealed that mean values of seed length, width, thickness, geometric mean diameter, sphericity, seed weight and volume were 9.42, 6.71, 7.42, 8.43 mm, 85.0%, 0.32 g and 0.20 cm^3, respectively. As moisture content increased from 4.47 to 61.23%, true density, porosity, projected area and terminal velocity were raised from 1480 to 1990 kg m^{-3}, 62.0 to 75.0%, 52.34 to 91.46 mm^2 and 7.67 to 9.75 m sec^{-1}, respectively. Furthermore, bulk density was decreased from 600 to 490 kg m^{-3} for the same moisture content range.

Key words: Pea seed, moisture contents, physical properties, mechanical properties

INTRODUCTION

Pea is a vegetable that is widely cultivated in Turkey. The seed is regarded as an important source of protein, carbohydrate and vitamins[1]. Pea plays an important role in human diet. Nutritionally, 100 g of pea contains 5.36 g protein, 12.5 g carbohydrate, 0.5 g fat, 85 kcal energy, 597 IU vitamin A, 0.259 mg B_1 (Thiamin), 0.149 mg B_2 (Riboflavin), 14.2 mg ascorbic acid (Vit-C), 2.021 mg niacin, 27 mg Ca, 117 mg P, 1.54 mg Fe[1].

According to the Turkish Government Statistical data of 2003, vegetable production area was 1 010 204 ha representing 2.12% of total agricultural land and forest area. The vegetable production obtained from this area is 25 671 517 tons. Total pea production is almost 54 000 tons representing 7.62% of total leguminous vegetable production[2]. Pea is manually or machine harvested. Machine threshing is usually carried out on hard floor with homemade threshing machine. In order to optimize various factors like threshing efficiency, pneumatic conveying, storage pertaining to pea seed, the physical properties must be known.

Ige[3] studied the relationship between the size and rupture strength of seeds in five cow pea varieties and determined relationship between rupture strength and the moisture content of the seeds. In results, the rupture strength slightly decreased as the moisture content increased. Deshpande *et al.*[4] found a linear decrease in kernel density, bulk density and porosity of soybean with increase of the moisture content in the range of 8.7 to 25% d.b. Various physical properties of chickpea seeds including bulk density, porosity, projected area, terminal velocity and coefficient of static and dynamic friction were evaluated by Konak *et al.*[5].

In order to design equipment and facilities for the handling, separation, conveying, driying, aeration, processing and storing of pea seed, it is necessary to determine their physical properties as a function of moisture content. However, detailed measurements of the principal dimensions of pea seed and variations in physical properties with seed of moisture content have not been investigated. The objective of this study was to investigate some physical properties depend on moisture content, namely linear dimensions, seed weight and volume, sphericity, densities, porosity, projected area, terminal velocity and rupture force of pea seed.

MATERIALS AND METHODS

Dried pea (*Pisum sativum* L. cv. Ronda) seeds were used for all the experiments in this study. Ronda pea variety widely grown in Turkey. The seeds were cleaned in an air screen cleaner to remove all foreign matter like dust, dirt, stones, chaff, immature and broken seeds. The initial moisture content of seeds was determined by following a standard method[6].

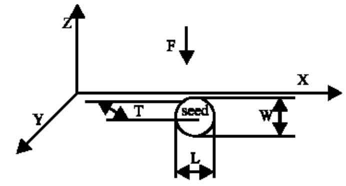

Fig. 1: Axis and three major perpendicular dimensions of pea seed

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The densities, porosity, projected area, terminal velocity and rupture force of the seed were assessed at moisture levels of 4.47, 16.17, 23.93, 42.23 and 61.23% (d.b.). with three replications at each level.

To determine the average size of the seed, a sample of one hundred seeds was randomly selected. Dimensions along three perpendicular mutually axes of the seed were measured with a micrometer to an accuracy of 0.01 mm.

The geometric mean diameter, D_p of the seed was calculated by using the following relationship[7]:

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

Where, L is the length, W is the width and T is the thickness in mm (Fig. 1).

The sphericity Φ was calculated using the following formula[7]:

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

The bulk density was determined with a weight per hectoliter tester which was calibrated in kg m^{-3}[4]. To obtain the mass, each seed was weighed by a chemical balance reading to 0.001 g.

The seeds volume was determined using the liquid displacement method. Toluene (C_7H_8) was used rather than water because it is not absorbed by seeds and it a low surface tension, so it fills even shallow dips in seeds and its dissolution power is low[8,9].

The porosity, ϵ of bulk seed was computed using the relationship given by Mohsenin[7] as follows:

$$\varepsilon = \frac{\rho_k - \rho_b}{\rho_k} 100 \quad (3)$$

Where, ρ_b is the bulk density and ρ_k is the kernel density.

The projected area of a seed was measured by a scanner connected to a computer. For this purpose, a special computer program was used[10].

The terminal velocities of seed was measured using an air column. The air velocity near the location of the fruit suspension was measured by an electronic anemometer having an accuracy of 0.1 m s^{-1}[11]. Three replications were made for each seed sample.

To determine the rupture force of seeds, biological material test device developed by Aydin and Ögüt[12] was used. It has three main components which are stable up and motion bottom platform, a driving unit and the data acquisition system. The seed was placed on the stable up platform and pressed with motion platform. The rupture force of seed was measured by the data acquisition system.

All data were analysed using a computerised statistical programme called 'Minitab'.

RESULTS AND DISCUSSION

Dimensions and size distribution of pea seed: Table 1 shows the dimension, volume and seed weight of the pea seeds at 4.47% moisture content. The frequency distribution tables (Table 2) for the mean values of the dimensions indicate that about 80% of the seeds have a length ranging from 8.74 to 10.10 mm, 80% of them have a width ranging from 5.90 to 7.52 mm, while 80% of the needs have a thickness ranging from 6.72 to 8.11 mm. The estimated mass and volume of a single pea seed were similar to chickpea seeds[5].

Bulk density: The bulk density of pea seed at different moisture levels decreased non-linearly from 600 to 490 kg m^{-3} as the seed moisture content increased (Table 3). The variation in bulk density ρ_b in kg m^{-3} with moisture content of pea seed can be represented by following equation:

$$\rho_b = 686.09 M_c^{-0.0934} \quad (4)$$

with a value for the coefficient of determination R^2 of 0.8669.

Similar results were obtained for terebinth and chickpea by Aydin and Özcan[11] and Konak *et al.*[5], respectively.

Seed density: The seed density of pea at different moisture levels varied from 1480 to 1990 kg m^{-3} (Table 3). It is clear that by increasing the moisture content of seeds, the seed density increased.

The relationship between seed density and moisture content M_c in % d.b. can be represented by the following equation:

$$\rho_b = 10.398 M_c + 1408.2 \quad (5)$$

with a value for R^2 of 0.6798.

Aydin and Özcan[11] observed linear increase in seed density of terebinth with increase seed moisture content.

Porosity: The porosity was found to increase with increasing moisture content (Table 3). The porosity of pea seed was found to bear for the following relationship with moisture content:

$$\varepsilon = -0.0056 M_c^2 + 0.6688 M_c + 55.931 \quad (6)$$

with a value for R^2 of 0.6557.

Konak *et al.*[5] observed similar to increase in seed porosity of chickpea with increase seed moisture content.

Table 1: Mean±SE of pea seed dimensions at 4.47% moisture content (d.b.)

Measurement	Mean±SE
Length (mm)	9.42±0.53
Thickness (mm)	7.42±0.54
Width (mm)	6.71±0.63
Geo. Mean diameter (mm)	8.43±0.87
Sphericity (%)	85.0±0.41
Seed weight (g)	0.32±0.01
Volume (cm^3)	0.20±0.01

Table 2: Frequency distribution table of seed dimensions at 4.47% moisture content (d.b.)

Clarification	Width	Length	Thickness
4-4.5	3	-	-
5-5.5	5	-	-
6-6.5	29	-	30
7-7.5	51	3	43
8-8.5	12	14	22
9-9.5	-	31	5
10-10.5	-	52	-

Table 3: Effect of moisture contents on some physical properties

	Moisture content % (d.b.)				
Properties	4.47	16.17	23.93	42.23	61.23
Bulk density (kg m^3)	600.00	538.00	500.00	460.00	490.00
Seed density (kg m^3)	1480.00	1350.00	1870.00	1890.00	1990.00
Porosity (%)	62.00	57.00	73.00	76.00	75.00
Projected area (cm^2)	5.47	5.93	6.74	7.95	9.99
Thousand seed weight (g)	316.00	356.00	377.00	435.00	495.00
Terminal velocity (m sec^{-1})	7.67	9.19	9.40	10.16	9.99
Rupture force (N)	240.00	159.00	44.00	15.00	10.00

Projected area of seed: The projected area of pea seed (Table 3) increased by about 82.77%, as the moisture content increased from 4.47 to 61.23%. The variation in projected area of seed P_a in cm^2 with moisture content of pea seed can be represented by following equation:

$$P_a=0.0803M_c+4.8387 \qquad (7)$$

with a value for R^2 of 0.9809.

Similar trends have been reported for other seeds[4,7,8]. It was found significant positive relationship between projected area and moisture content of pea seeds, whereby the higher the moisture content, superiority of the projected area. Projected area increased as the seed moisture content increased.

Thousand seed weight: The thousand seed weight of pea seed (Table 3) increased by about 56.64%, as the moisture content of pea seed increased from 4.47 to 61.23%. The relationship between thousand seed weight and moisture content M_c in% d.b. can be represented by the following equation:

$$Wt = 6.7038M_c+258.47 \qquad (8)$$

with a value for R^2 of 0.9635.

Similar trends have been reported for different other seeds[7,8,10] . It was found significant positive relationship between thousand seed weight and moisture content of pea seeds, whereby the higher the moisture content, superiority of the thousand seed weight.

Terminal velocity: The results reveal that as moisture content increased, the terminal velocity increased linearly. The increase of terminal velocity of pea seeds was about 27.12%, when the moisture content of seeds increased from 4.47 to 61.23% (Table 3). The relationship between terminal velocity of pea seed and moisture content M_c in% d.b. can be represented by the following equation:

$$Vt=-0.0014M_c^2+0.1292M_c+7.2161 \qquad (9)$$

with a value for R^2 of 0.9775.

These results are similar to those reported by Konak *et al.*[5]. The increase in terminal velocity with increase in moisture content could be attributed to the increase in the mass of individual seed as the moisture content increases.

Rupture force: The results of rupture force (Table 3) show that the rupture force along any of the two major axis is highly affected by seed moisture content. For all the seed curves investigation, higher forces were necessary to rupture the seeds at lower than higher moisture contents. The small rupturing forces at higher moisture content might have resulted from the fact that the seed tended to be very soft at high moisture content. The relationship between rupture force of pea seed and moisture content M_c in % d.b. can be represented by the following equation:

$$Pr = 283.37e^{-0.0601Mc} \qquad (10)$$

with a value for R^2 of 0.9211.

Similar trends have been reported by Konak *et al.*[5] for chick pea. The rupture force was decreased by moisture content increases.

It may be concluded from this study that the average of length, width, thickness and geometric mean diameter of pea seeds at 4.47% moisture content were 9.42 mm, 6.71 mm, 7.42 mm and 8.43 mm respectively. The average unit seed weight and volume were 0.32 g and 0.20 cm^3, respectively.

The bulk density of pea seed at different moisture levels varied from 600 to 490 kg m^{-3} , while the porosity increased from 62 to 75% as the moisture content increased from 4.47 to 61.23% d.b.

The seed density of pea at different moisture levels varied from 1480 to 1990 kg m^{-3}.

The terminal velocity increased from 7.67 to 9.96 m sec^{-1} as the moisture content increased from 4.47 to 61.23%.

The rupture force was highly dependent on moisture content. The highest rupture force was obtained as 290 N on loaded along the Z axis at a moisture content of 4.47%.

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