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Research Article

Some Bio-Technical Properties of Flax Seeds, Fennel Seeds and Harmal Seed Capsules

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ABSTRACT

Some bio-technical properties of flax seeds, fennel seeds, and harmal seed capsules were determined. The size dimensions (length, width, and thickness) of flax seeds and fennel seeds were as 4.31 mm, 2.28 mm, 0.87 mm; 6.93 mm, 2.13 mm, 1.75 mm, respectively. The diameter and length for harmal seed capsules were 9.07 mm and 6.65 mm, respectively. The true density (ρ_t) was determined using the liquid displacement method, and the bulk density (ρ_b) was determined using the hectolitre tester. The bulk density for flax seeds, fennel seeds, and harmal seed capsules were determined as 384.3 kg m^{-3}, 270.5 kg m^{-3} and 201.5 kg m^{-3}, while, true density was found as 1256.5 kg m^{-3}, 664.6 kg m^{-3}, 936.2 kg m^{-3} for flax seeds, fennel seeds, and harmal seed capsules, respectively. The sphericity of for flax seeds, fennel seeds and harmal seed capsules were obtained as 0.47, 0.43, 0.72, respectively. The angle of repose was obtained as 13.84°, 17.35°, 29.94° for flax seeds, fennel seeds, and harmal seed capsules, respectively. The rubber friction surface has given the highest static friction coefficient for flax seeds, fennel seeds, and harmal seed capsules.

RESEARCH ARTICLE

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Keywords :

- Flax seed,
- Fennel seed,
- Harmal seed capsule,
- Size dimension,
- Bulk density,
- Angle repose

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INTRODUCTION

Today, traditional food, feed and fiber crops are a basic plant in agriculture and trade, they are also considered as the main natural inputs in perfumery and chemical industries with aromatic and therapeutic properties in the World (Ahmadi et al., 2009).

Flax seed (*Linum usitatissimum* L.) is a member of the Linaceae family. It is origin to Western Asian and Mediterranean origin. Flaxseed was used by the Egyptians to wrap their mummies, while the Greeks used their seeds for therapeutic purposes (Oomah, 2001). Flax seed is a leading source of phenolic compounds (knows lignans) and Omega-3 fatty acids. Flax seed is one of the most important oil plants in the world economically. It is rich in oil, protein and dietary fiber. The main components such as fat, dietary fiber, and protein are 41%, 28%, and 21%, respectively. Flax seed sizes range from approximately 3.0-6.4 mm in length, 1.8-3.4 mm in width and 0.5-1.6 mm in thickness (Freeman, 1995). Flax seeds have a storage life of more than twelve months for 9-10% moisture content. Flax seeds (*Linum usitatissimum* L.) are used in the food industry due to their functional properties. (Coskuner and Karababa, 2007). Flaxseed is one of the most important oil plants in the world economically. It is rich in oil, protein and dietary fiber (Amer Eissa, 2011).

Flaxseed is an important raw material for functional foods, it has an important economic potential in the food and chemical industries, thus, its biotechnical properties must be known (Oomah and Mazza, 1998). These properties features are; design and developing equipment for processing, handling, drying, storage and other operations. In the process of removing flaxseed oil and its derivatives, the seeds undergo a series of treatments. Therefore, it is necessary to know the biotechnical properties for the design of the harvest and post-harvest machinery and facilities (Sahay *et al.,* 1996; Oomah and Mazza, 1998). Cleaning, classification and grading of flax seeds are important steps after harvesting to produce high quality crops (Amer Eissa, 2011).

Fennel (*Foeniculum vulgare* L.) is a plant belonging to the Apiaceae (Umbelliferae) family. The fennel plant is native to the Mediterranean. Fennel seeds are cultivated in many different geographies in India, China, Middle-East, Turkey, Europe, China, Iran, Vietnam and South America. Bitter fennels are grown in north Bulgaria and Hungary. The fennel seeds have anethole (more than 85%), and essential oil content (2.7%). Anethole gives the plant a particularly sweet taste (Pukkaherbs, 2016). Fennel seeds are used as culinary and medicinal. And also, the essential oils of the seeds are used to making soaps, perfumes, cosmetics, and pharmaceutics (The Herb Society of America, 2016). Its ground is used in many foods (soups, sauces, pickles, etc). (Lucinewton *et al.,* 2005). Fennel seeds have sweet (anise similar) and aromatic. They are baked into biscuits, bread, and they are added to sauerkraut, and sweet pickles. Fennel seeds compliment cucumber asparagus, and tomato (The Herb Society of America, 2016). Fennel seeds have diuretic, analgesic and antipyretic activity (Lucinewton *et al.,* 2005). Fennel oils have antimicrobial, antioxidant, stimulating, and gastrointestinal motility antispasmodic properties. Fennel seeds have a high level of flavonoids, and twelve 12 main phenolic compounds (Shafiee *et al.,* 2010). It is necessary to determine the biotechnical properties of the seeds for the design and development of the equipment necessary for the cleaning, classification, drying, ventilation, storage and processing of fennel seeds after harvest technologies.

Harmal (*Peganum harmala* L.), family Zygophyllaceae, is a perennial herb. It is native to the eastern Mediterranean region. The growing area is semi-arid conditions, steppe areas and sandy soils. It is one of the natural plants of Turkey. *Peganum harmala* widely grown in Turkey. It is mostly referred to as 'Üzerlik'. *Peganum harmala* L. is a shrub, it has 0.3-0.8 m tall with short creeping roots and white flowers and round seed capsules carrying more than 50 seeds. It contains many active substances such as alkaloids, flavonoids, anthraquinones, and fatty oil. Harmal seeds are used in both traditional and modern phytotherapy. Pharmacologically active compounds are harmine, harmalin, harmane and harmalole. In traditional medicine applications, harmal seeds are used as anthelmintic, menstrual flow, anesthetic, diaphoretic and sedative. The peganum harmala is widely used as a medicinal plant in Central Asia, North Africa and Middle East (Küsmenoğlu, 1996; Moloudizargari *et al.,* 2013; Kırıcı *et al.,* 2018).

Fei *et al.* (2017) have developed, alternative fuel as biodiesel production to diesel engines from two kinds of new nonedible herbaceous vegetable oils, including *Leonurus artemisia* L. and *Peganum harmala* L. According to the *Peganum harmala* L. (PHL) biodiesel test results, PHL exhibited better oxidative stability. Also, Fei *et al.* (2017) reported it has great potential to be employed as promising feedstocks for biodiesel production. Therefore, it is necessary to determine the biotechnical properties of the Peganum harmala seeds for the equipment necessary for the handling and processing for post-harvest technologies.

The information on bio-technical properties of the flax seeds, fennel seeds, and harmal seed capsules are needed to design and adjustment of the equipments and systems used during harvesting, handling, cleaning, separating, and storing of the flax seeds, fennel seeds, and harmal seed capsules and to convert them into food, feed and fodder (Tavakoli *et al.,* 2014). The determination of bio-technical properties of flax seeds, fennel seeds, and harmal seed capsules is very important in the design of the post-harvest technologies.

The bio-technical properties of different seeds such as cumin seed, millet, hemp seed, fenugreek, sponge gourd seeds, knotweed seeds, bitter melon seeds, quinoa seeds, allspice seeds have been determined by other researchers such as Singh and Goswami, 1996; Baryeh, 2002; Sacilik *et al.,* 2003; Altuntas *et al.,* 2005; Ogunsima *et al.,* 2010; Önen *et al.,* 2014; Gölükcü *et al.,* 2014; Altuntaş ve Naneli, 2017; Altuntaş ve Erdoğan, 2017; respectively. The objective of this study was to investigate some bio-technical of flax seeds, fennel seeds, and harmal seed capsules.

Statistical analysis such as mean standard deviation and standard error of mean were determined with Microsoft Excel.

MATERIALS and METHODS

Flax seeds and fennel seeds materials used in this study were obtained from Department of Field Crops, Faculty of Agriculture, Tokat Gaziosmanpasa University; and the harmal seed capsule materials were obtained from a local market in Tokat-Turkey. In this study, flaxseed (*Linum usitatissimum* L.) used 'Atalanta' variety and its color is brown. 1000 seed mass varies between 5.5-7.0 g. Seeds of this variety are used in different ways in the food industry. The oil content of the seeds varies between 32-37%. This variety has a high Omega-3 content. At the same time, the fennel seeds (*Foeniculum vulgare* var. dulce) used in this study belong to a local population of Balıkesir origin. It is an annual plant that grows in the summer. 1000 seed mass ranges between 4.0-5.0 g. The essential oil rate ranges from 1.5-2.5%, while the oil rate ranges from 7.0-12.0%. The general view of the studied seeds (flax seeds, fennel seeds and harmal seed capsule was presented in Figure 1. All these seed materials were cleaned manually to remove from all dust, foreign matter, broken, and dirt. The moisture contents of the seed materials for flax seeds, fennel seeds, harmal seed capsules were determined at 105±1°C for 24 h by oven drying reported by Suthar and Das (1996). The seed materials were replicated three times, and the mean moisture contents of flax seeds, fennel seeds, and harmal seed capsules were found as 8.20%, 9.46%, and 9.98% d.b. (dry basis) (Altuntas and Demirtola, 2007).

a) b) c)

Figure 1. Flax seeds (a), fennel seeds (b), harmal seed capsules (c)

To determine of size dimensions such as length, width and thickness of the flax seeds and fennel seeds, the length (height) and diameter for harmal seed capsules, one hundred seed samples were randomly selected, and size dimensions were measured at an accuracy of 0.01 mm using a dial-micrometer. Some physical properties flax seeds, fennel seeds, and harmal seed capsules such as the arithmetic mean diameter (D_a), sphericity (Φ), geometric mean diameter (D_g), and volume (V) were determined presented by Mohsenin (1986).

$$D_a = (\frac{L+W+T}{3}) \quad (1)$$

$$D_g = (LWT)^{\frac{1}{3}} \quad (2)$$

$$\varphi = \left(\frac{D_g}{L}\right) \quad (3)$$

$$V = [\left(\frac{\pi}{6}\right)(LWT)] \quad (4)$$

Where, D_a is arithmetic mean diameter (mm), V is the volume (mm^3), Φ is sphericity (%), L is the length (mm), W is the width (mm), T is the thickness (mm).
The surface areas of seeds such as the flax seeds, fennel seeds, and harmal seed capsules, were found by analogy with a sphere of same geometric mean diameter, using expression cited by Sacilik *et al.* (2003).

$$S = {D_g}^2\pi \quad (5)$$

Where; S is the surface area (mm^2), D_g is the geometric mean diameter (mm).

The size dimensions for harmal seed capsules are defined as length and diameter. Thus, for geometric and arithmetic mean diameters measurement, length (height) and diameter were used. In the geometric mean diameter, arithmetic mean diameter and seed volume calculation, the diameter dimension was used for the second time instead of the thickness criterion.

$$D_a = (\frac{L+W^2}{3}) \quad (6)$$

$$D_g = (LW^2)^{\frac{1}{3}} \quad (7)$$

$$V = [\left(\frac{\pi}{6}\right)(LW^2)] \quad (8)$$

The seed mass (M) and the thousand seed mass (M_{1000}) were measured by an electronic balance at an accuracy of 0.001 g. To evaluate M_{1000} seed mass, 100 randomly selected seeds from the bulk were averaged (Sacilik *et al.*, 2003). The true density (ρ_t) and the volume (V) of the flax seeds, fennel seeds, and harmal seed capsules were determined using the liquid displacement method. Toluene (C_7H_8) is used as a liquid for this method, because toluene is absorbed by the seeds to a lesser extent. Bulk density (ρ_b) was determined using the hectolitre tester (Gupta and Das, 1993). The bulk density is the ratio of the sample seed mass to its total volume. Bulk density was determined to fill a 500 ml container with the studied seeds from a height of 150 mm at a constant rate and then weighing the content (Özarslan, 2002). The porosity (ε) of flax seeds, fennel seeds, and harmal seed capsules was determined by the following equation:

$$\varepsilon = \left[\frac{\rho_t - \rho_b}{\rho_t}\right] 100 \tag{9}$$

Where, ρ_b and ρ_t are the bulk and the true densities, respectively (Mohsenin, 1986).

The angle of repose is the angle with the horizontal at which the agricultural material stands when piled into a cone. A topless and bottomless cylinder (300 x 500 mm diameter and height) was used in order to determine the angle of repose of flax seeds, fennel seeds, and harmal seed capsules. The topless and bottomless cylinder was placed at the centre of a raised circular plate and was filled with flax seeds, fennel seeds, and harmal seed capsules. The cylinder was raised slowly until the cylinder formed a cone on a circular plate. The angles of repose (θ) for the flax seeds, fennel seeds, and harmal seed capsules were calculated from the measurement of the diameter and height of a cone flax seeds (Kaleemullah and Gunasekar, 2002).

$$\theta = tan^{-1}\left(\frac{h}{r}\right) \tag{10}$$

Where, h and r are the height of the cone and radius of the base of the cone, respectively.

The static and dynamic friction coefficients for flax seeds, fennel seeds, and harmal seed capsules were measured by a friction device (Figure 2). The friction force device is formed by an electronic unit (PC, electronic ADC (analog digital converter) card, electronic variator, mechanical force unit, and loadcell [(ESİT, SP-200 kg (min. 20 g, max. 200 kg), Total error ≤±0.05, Serial 3575, Sakarya-Turkey)], a friction surface, and a metal box (Altuntas and Demirtola, 2007). The force of the friction was measured by the loadcell, converted by the ADC card, and data were recorded on a computer. In order to convert the analog information to digital and process it on the computer, an ADC (analog digital converter card) that can be inserted directly into the computer slot with a capacity of 16 channels was used in this study. To calculate the static and dynamic friction coefficients, the maximum friction force and the average friction force values were used respectively. To determine the coefficient of friction, the sample seeds box continued to slide on the different friction surfaces at 0.02 m s^{-1} velocity. In this friction experiments, rubber, chipboard, mild steel, galvanized metal, and plywood as the surfaces of the friction were used. The sample box was emptied and refilled with flax seeds, fennel seeds, and harmal seed capsules for each experiment (Sacilik *et al.*, 2003).

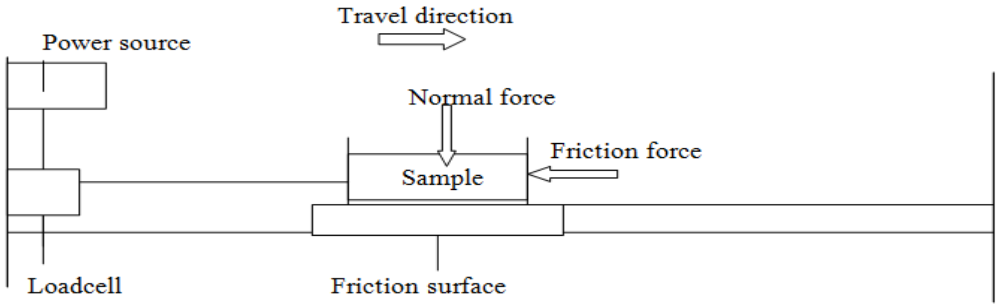

Figure 2. A shematic of the measuring device of friction force

RESULTS and DISCUSSION

Physical properties

The size dimensions (length, width/diameter, thickness), surface area, geometric mean diameter, and sphericity of the flax seeds, fennel seeds, and harmal seed capsules are given in Table 1.

The size dimensions such as length values for fennel seed, flax seeds and harmal seed capsules were found as 6.93 mm, 4.31 mm, and 6.65 mm, respectively. The width values for fennel seeds and flax seeds were found 2.14 mm and 2.28 mm, respectively. The thickness values for fennel seeds and flax seeds were obtained as 1.75 mm and 0.87 mm, respectively. Abalone *et al.* (2004) reported that the length, width, and thickness for Amaranth seeds were as 1.42 mm, 1.29 mm and 0.87 mm, respectively. Coskuner and Karababa (2007) determined the length, width, thickness of flax seeds were found as 4.74 mm, 3.67 mm and 3.39 mm at 7.10% d.b. (dry basis) moisture content, respectively. Ixtaina *et al.* (2008), determined the length, width and thickness for white salvia seeds (*Salvia hispanica* L.) as 2.15 mm, 1.40 mm, and 0.83 mm respectively. According to these results, our results related to the size dimensions or fennel seeds are higher than reported for flaxseed and flax seeds.

Table 1. The size dimensions, geometric and arithmetic mean diameters, surface area and sphericity for flax seeds, fennel seeds, and harmal seed capsules

Seeds	Length L (mm)	Width W (mm)	Thickness T (mm)	Arithmetic mean diameter D_a (mm)	Geometric mean diameter D_g (mm)	Surface area S (mm²)	Sphericity Φ
Fennel seeds	6.93±1.03	2.14±0.38	1.75±0.34	3.61±0.49	2.94±0.44	27.83±8.03	0.43±0.05
Flax seeds	4.31±0.18*	2.28±0.11	0.87±0.09	2.49±0.08	2.03±0.09	12.97±1.12	0.47±0.02
Harmal seed capsules	6.65±0.69	9.07**±0.81	-	8.25±0.65	8.18±0.68	208.5±15.49	0.72±0.32

*: Standard deviation (SD); **: Diameter

The geometric and arithmetic mean diameters were varied as 2.94 and 3.61 mm for fennel seeds, 2.03 mm, and 2.48 mm for flax seeds, 8.18 mm, and 8.25 mm for harmal seed capsules, respectively. The surface area and sphericity of fennel seeds were found as 27.83 mm^2 and 0.43 and, for flax seeds were found as 12.97 mm^2 and 0.47, for harmal seed capsules were found as 208.46 mm^2 and 0.72, respectively. Zewdu (2011) reported that the geometric mean diameter and sphericity Ajwain seeds varied as 1.24 mm and 0.61 for 4.39% w.b. moisture content, respectively. According to these results, our results related to the geometric mean diameter for fennel, flax seeds and harmal seed capsules are higher than reported for Ajwain seeds, while, our results related the sphericity values for fennel seeds and flax seeds.

The thousand seed mass, seed volume, true density, seed mass, and bulk density, and porosity of the flax seeds, fennel seeds, and harmal seed capsules are presented in Table 2. The thousand seed mass, seed volume, and seed mass, and values for fennel seeds were varied as 10.82 g, 0.0166 $mm^{3,}$ and 0.0106 g, while the thousand seed mass, seed volume, and seed mass and for flax seeds were found as 4.972 g, 0.0041 mm^3, and 0.0050 g, respectively. The mass and volume of harmal seed capsules were varied as 0.832 g and 0.152 mm^3, respectively. Selvi *et al.* (2006) reported that the thousand seed mass was found as 6.0 g at 8.25% (d.b.) moisture content. Our results related to the thousand seed mass for fennel seeds and harmal seed capsules are higher than reported lower for flax seeds (Selvi *et al.,* 2006).

Table 2. The thousand seed mass, true density, seed volume, seed mass, porosity, and bulk density for flax seeds, fennel seed, and harmal seed capsules

Seeds	Thousand seed mass M_{1000} (g)	Bulk density, ρ_b (kg m^{-3})	Seed mass, M (g)	Volume V (mm^3)	True density, ρ_t (kg m^{-3})	Porosity ε (%)
Fennel seeds	10.82±0.22*	270.5±3.65	0.011** ±0.003	0.017±0.012	664.6±14.0	59.08±0.54
Flax seeds	4.97±0.09	384.3±0.001	0.005±0.001	0.004±0.001	1256.5±24.4	68.53±6.11
Harmal seed capsules	131.13± 0.89	204.5±3.33	0.832***±0.002	0.152±0.003	936.2±45.7	77.02±2.41

*: Standard deviation (SD); **: Schizocarps mass; *** : Harmal seed capsule mass

Bulk density and porosity for fennel seeds were as 270.5 kg/m3 and 59.08%, for flax seeds were as 384.3 kg m^{-3} and 68.53%, for harmal seed capsule were as 204.5 kg m^{-3} and 77.02%, while, the true density of fennel seeds, flax seeds, and harmal seed capsule was found as 664.6, 1256.5 and 936.2 kg m^{-3} at as 9.46%, 8.20% and 9.98% d.b., respectively. The bulk and true densities for cumin seed have reported as 410 to 502 kg m^{-3}, 1047 to 1134 kg m^{-3}, whereas, the porosity of cumin seed changed from 54% to 64%, respectively, by Singh and Goswami (1996). According to these results, our results related to the bulk density and porosity for fennel, and harmal seed capsules are lower than reported for cumin seeds.

Mechanical properties

The mechanical properties such as coefficient of static friction values of the fennel seed, flax seeds and harmal seed capsules are presented in Table 3. The static friction coefficient for flax seeds, fennel seeds, and harmal seed capsules was determined on the friction surfaces of the plywood, galvanized metal, chipboard, rubber, and mild steel (Table 3). The dynamic and static friction coefficients were the highest for flax seeds, fennel seeds, and harmal seed capsules on the rubber friction surface. The highest and lowest dynamic friction coefficient values of fennel seeds were obtained from rubber and galvanized metal with 0.59 and 0.15 values, while the highest and lowest dynamic coefficient of friction values of flax seeds and harmal seed capsules were obtained from rubber (0.80 and 0.42) and mild steel (0.64 and 0.28), respectively. The static friction coefficient of the fennel seeds was as 0.28, 0.40, 0.72, 0.25 for plywood, chipboard, rubber, galvanized metal and mild steel, respectively. The static friction coefficient of flax seeds and harmal seed capsules was found as 0.33 and 0.28 for plywood, 0.39 and 0.29 for chipboard, 0.66 and 0.56 for rubber, 0.36 and 0.24 for galvanized metal, 0.28 and 0.19 for mild steel, respectively. The static friction coefficient of cumin seed varied on stainless steel from 0.37 to 0.62, aluminum from 0.43 to 0.63, galvanized metal from to 0.48 to 0.65, and mild steel from 0.54 to 0.70 in moisture content from 7 to 22% (d.b.), respectively reported by Singh and Goswami (1996). Ixtaina *et al.* (2008) reported that the static friction coefficient for chia seeds was as 0.31 on mild steel sheet and 0.28 on galvanized sheet.

Altuntaş and Naneli (2017) reported the static friction coefficient were found between 0.47 and 0.51 for chipboard; between 0.34 and 0.43 for galvanized steel, between 0.39 and 0.43 for rubber, between 0.43 and 0.49 for plywood, respectively, for white quinoa seeds; while the static friction coefficient was found between 0.36 and 0.40 for chipboard, between 0.37 and 0.41 for galvanized steel, between 0.40 and 0.44 for plywood, between 0.34 and 0.36 for rubber friction surfaces, respectively for black quinoa seeds. According to these results, our results related to the static friction coefficients on mild steel and galvanized metal for fennel, flax seeds, and harmal seed capsules are lower than reported for cumin seeds, while our results related the static friction coefficients on rubber for fennel, flax seeds, and harmal seed capsules are higher lower than reported for white and black quinoa seeds.

Table 3. The mechanical properties such as static and dynamic coefficient of frictional properties and of the fennel seed, flax seeds and harmal seed capsules

Frictional properties	Seeds	Friction surfaces				
		Plywood	Chipboard	Rubber	Galvanized metal	Mild steel
Static coefficient of friction	Fennel seeds	0.29±0.03*	0.40±0.032	0.73±0.05	0.25±0.04	0.29±0.03
	Flax seeds	0.33±0.02	0.39±0.04	0.66±0.06	0.36±0.04	0.28±0.03
	Harmal seed capsules	0.27±0.02	0.29±0.04	0.56±0.03	0.24±0.07	0.19±0.05
Dynamic coefficient of friction	Fennel seeds	0.21±0.004	0.28±0.01	0.59±0.01	0.15±0.03	0.17±0.01
	Flax seeds	0.46±0.03	0.51±0.02	0.80±0.06	0.45±0.02	0.42±0.03
	Harmal seed capsules	0.37±0.03	0.40±0.08	0.64±0.004	0.33±0.05	0.28±0.03

*:Standard Deviation (SD)

Angle of repose

The mechanical properties such as the angle of repose of fennel seeds, flax seeds, and harmal seed capsules were found as 17.35º, 13.84º, 29.94º, respectively. The angle of repose of fennel seeds, flax seeds, and harmal seed capsules are presented in Figure 3. The angle of repose values for fennel seeds, flax seeds and harmal seed capsules are lower than that of cumin, millet, sesame, reported by Singh and Goswami (1996), Baryeh (2002) Tunde-Akintunde and Akintunde (2004), Altuntas and Naneli (2017) determined the angle of repose values were found between 8.67° and 11.47°, 6.44° and

10.25°, respectively for the white and black quinoa seeds, respectively. Our results related to the angle of repose for fennel, flax seeds, and harmal seed capsules are lower than reported for white and black quinoa seeds.

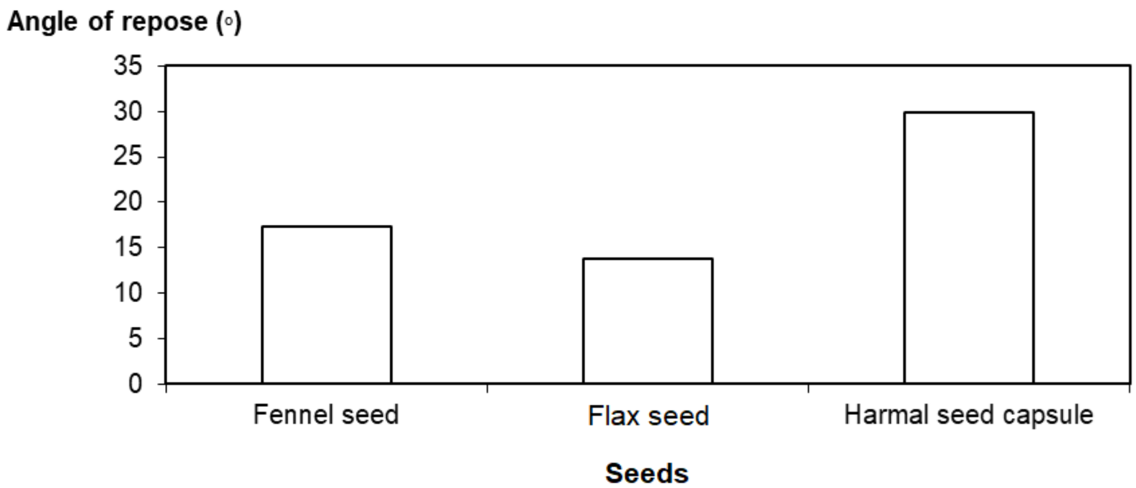

Figure 3. The angle of repose of the flax seeds, fennel seeds and, harmal seed capsule

In this study, the mean moisture contents of flax seeds, fennel seeds, and harmal seed capsules were measurement as 8.20%, 9.46%, and 9.98% d.b. (dry basis). In this study, the higher moisture contented harmal seed capsules give higher angle of repose, whereas flax seed with the lowest moisture content has the lowest angle of repose value (Figure 3).

CONCLUSION

The biotechnical properties of flax seeds, fennel seeds, and harmal seed capsules are required to design the machine and equipment used in postharvest technologies of this agricultural materials. The following conclusions are drawn from the investigation on biotechnical properties such as physical and mechanical properties of flax seeds, fennel seeds, and harmal seed capsules.

The arithmetic and geometric mean diameters for flax seeds, fennel seeds, and harmal seed capsules were found as 2.49 mm and 2.03 mm; 3.61 mm and 2.94 mm; 8.25 mm and 8.18 mm, respectively. The sphericity was found the highest and lowest for harmal seed capsules and fennel seeds, respectively.
The highest and lowest bulk density of seeds were found for flax seeds, harmal seed capsules, whereas, the lowest true density was observed for fennel seeds flax seeds among the studied seeds.

The maximum static and dynamic coefficient of friction were found for rubber friction surface among seeds for fennel seeds, flax seeds and harmal seed capsules, while the lowest angle of repose of seeds was found in flax seeds than the other studied seeds.

DECLARATION OF COMPETING INTEREST

The authors declare that there are no conflict of interest.

CREDIT AUTHORSHIP CONTRIBUTION STATEMENT

The authors declared that the following contributions are correct.
Gungor Yilmaz: Conceptualization, data collation, review and editing of manuscript, investigation.
Ebubekir Altuntas: Methodology, data analysis, validation, Writing of original manuscript draft, design of experiment, formal analysis.

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