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Determination of important biotechnical characteristics of some safflower (Carthamus tinctorius L.) cultivars

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Keywords:
Carthamus tinctorius, Sphericity, Coefficient of friction, a, b* color characteristics*

Abstract — The study aimed to determine the biotechnical characteristics (physical properties, color characteristics, angle of repose, and coefficient of friction) of the seeds of safflower cultivars. Moisture contents of Asal, Balcı, and Dinçer cultivars were determined as 8.64%, 9.52%, and 8.57%, respectively. The width (4.04 mm) of the Dinçer cultivar gave higher values than other cultivars. Statistically significant ($p < 0.01$) differences were determined between the width values of safflower cultivars. There was no statistically significant difference in length, sphericity, surface area, and geometric mean diameter values between cultivars, but statistical differences at $p < 0.05$ level were determined between cultivars in thickness values. $L*$ brightness color value was higher (75.31) in Dinçer cultivar than in other cultivars. The rubber surface gave the highest values (0.360-0.384) in terms of coefficient of friction values. In the study, it is thought that the biotechnical characteristics (physical properties, color characteristics, coefficient of friction, and angle of repose values of the safflower seeds will contribute to obtaining important engineering data in the design of machinery, facilities, and systems to be used for sowing, harvesting and threshing mechanization and postharvest technologies.

Subject Classification (2020):

1. Introduction

In Türkiye, 1.5-1.7 million tons of edible oil is consumed annually. The amount obtained from different oil plants grown is approximately 600,000-700,000 tons. Accordingly, only about half of the consumed oil can be produced. The remaining oil needed (about 60% of the oil we consume) is imported in exchange for foreign currency (about 4.5 billion dollars). It can be said that one of the homelands of the safflower plant is Türkiye. It can be grown easily in every region, its root structure is deep and resistant to drought, and it is a plant that can contribute to the country's oil needs [1]. Safflower oil, which contains high oleic acid, seems promising as a diesel fuel that reduces air pollution by reducing CO2 emissions with the biofuel program since the 2000s [2,3].

Safflower (Carthamus tinctorius L.) is an oil plant that can be produced, especially in areas where other products with high economic gain cannot be cultivated. It is observed that safflower seeds can be easily processed in sunflower processing facilities. According to TUIK 2022 data [4], 30,000 tons of safflower were produced from 262,375 decares of land, and the yield was determined as 114 kg da-1. According to FAO 2020 data, 23,070 tons of production was cultivated from 32,612 ha in Africa, 7,074 kg ha-1, in

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Asia 353,221 tons from 473,677 ha, 7,457 kg ha-1, in Europe 17,518,296,739 tons of production was cultivated from the hectare area, and the yield was determined as 5,522 kg ha-1 [5].

In addition to pre-harvest factors, such as soil conditions, climate, and agricultural practices, harvesting methods and postharvest conditions, storage, and postharvest processes also significantly affect the product's quality. Agricultural products have irregular shapes and sizes. Geometric and gravimetric properties of agricultural products are essential biotechnical characteristics for sowing, harvesting, postharvest processing, storage, packaging, and quality control stages [6]. The design and development of special machinery and technology systems to obtain maximum product quality with minimum energy and labor consumption also make it necessary to know the biotechnical properties specific to the product [7]. The physical properties of seeds are a vast amount of data that can be useful in harvesting and storage or drying and other processes. This data is involved in designing machines for harvesting and in every part of the food processing chain. The main purpose of post-harvest biotechnical properties technology is to increase agricultural production through the dissemination of quality seeds of high-yielding varieties. This includes identifying varieties with high seed quality, thereby improving seedling and plant growth, and assessing seed quality using different methods [8].

It is seen that safflower seeds will be in a significant position in the coming years, both in terms of agricultural production, especially in terms of oil need, and as an alternative environmentally friendly biofuel, with the increasing importance of our country in recent years, being suitable for cultivation and developing the usage area. For this reason, it is seen that the comprehensive research of researchers in different fields related to the safflower plant will be important in directing the studies on a sectoral basis in terms of the production and postharvest technology of the safflower plant [9].

Some researchers on safflower have carried out certain studies: [10] seed and oil properties of the safflower plant, [11] physical and chemical properties of safflower genotypes, [12] some physical and mechanical properties of safflower seeds, [13] determined some physical properties of safflower seeds, [14] seed yield and yield components of some safflower cultivars, [15] moisture dependent physical and compression properties of safflower seed. This study aimed to determine critical biotechnical characteristics (physical properties, color characteristics, coefficient of friction, and angle of repose) of three important domestic safflower cultivars.

2. Materials and Methods

In this study, the safflower seeds for Asal, Balcı, and Dinçer cultivars were obtained from Tokat Gaziosmanpaşa University, Faculty of Agriculture, Department of Field Crops. To determine the geometric and volumetric properties of safflower seeds, a digital caliper with an accuracy of 0.01 mm in length (Ln), width (Wd), and thickness (Th) values were used for 100 samples. Samples for Asal, Balcı, and Dinçer cultivars were given Figure 1.

a) Asal b) Balcı c) Dinçer

Figure 1. Samples for Asal, Balcı, and Dinçer cultivars

The moisture content of safflower seeds was determined as dry bases (d.b%) as a result of drying the seed samples in a dry oven at 105±1°C and 24 hours [16]. Moisture contents of Asal, Balcı, and Dinçer cultivars were determined as 8.64%, 9.52%, and 8.57% (d.b), respectively.

To determine the geometric and volumetric properties of safflower seeds, a digital caliper with an accuracy of 0.01 mm in length (L_n), width (W_d), and thickness (T_h) values were used for 100 samples. The sphericity (S_p), geometric mean diameter (G_{md}), and surface area (S_r) values of the seeds were calculated with the equations given below [17].

$$G_{md} = (L_n W_d T_h)^{1/3} \tag{2.1}$$

$$S_p = \frac{(L_n W_d T_h)^{1/3}}{L_n} 100 \tag{2.2}$$

$$S_r = \pi (G_{md})^2 \tag{2.3}$$

The masses (M) of the seeds were determined using an electronic digital balance with an accuracy of 0.001 g. To determine the thousand-grain weight (T_{sm}) of the seeds, the average weights of 100 seed samples with four replications were taken. The bulk density (B_d) of safflower seeds was determined using the hectoliter method. Seed volume (S_v) was calculated using the following equation. The liquid displacement method was used to determine the true density (T_d) values, and the porosity (P_r) was determined using the actual and bulk volume weight values [17].

$$T_y = \frac{\pi}{6 L_n W_d T_h} \tag{2.4}$$

To determine the color characteristics of the seeds, L^*, a^*, and b^* color characteristics were determined with a Minolta brand CR-400 Model Tokyo-Japan colorimeter. In the determination of color characteristics, measurements were taken from a total of 15 samples for seeds. L^*, a^*, and b^* color characteristics, L^* indicates brightness, a^* scale indicates redness, and b^* scale indicates yellowness. Hue angle (α) and chroma (C) color characteristics were determined by the following equations [18]. Chroma indicates the vitality or pastel shade of the seeds. Vivid tones are close to 10, and pastel tones are close to 0 [19].

$$\alpha = \frac{1}{\tan \frac{b}{a}} \tag{2.5}$$

$$C = (a^2 + b^2)^{1/2} \tag{2.6}$$

PVC, laminate, rubber, and plywood surfaces were used to measure the friction coefficients of the seeds. In the measurement of the friction coefficient, the slope (inclination) angle read at the first moment when the seeds started to move in the experimental setup, which can be tilted via the screw arm, was taken as a basis [20] (Figure 2).

In determining the angle of repose, the inclination angle of the cone was taken into account by using a cylinder measuring 300 × 500 mm with an open top and bottom part and raising the seeds into the cylinder until a cone is formed on a flat surface [21](Figure 3). The relevant equation is as follows. The angle of repose is as follows:

$$As = \frac{1}{\tan \frac{H}{R}} \tag{2.7}$$

Here, As, H, and R denote Angle of repose (°), Height of the cone formed (cm), and Base radius of the cone formed (cm), respectively.

Figure 2. Measuring device for the coefficient of the friction

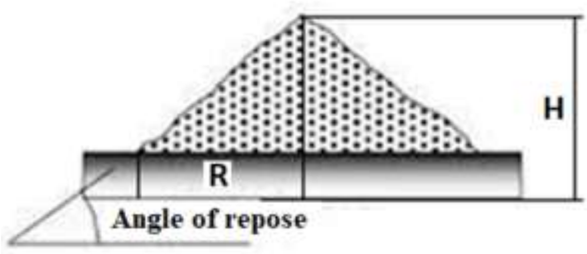

Figure 3. Measurement of the angle of repose

A normality test was performed before the analysis of variance to determine the suitability of the data in the study for statistical analysis. In the study, using a one-way analysis of variance, the effect of cultivars on biotechnical properties was determined by DUNCAN multiple comparison test.

3. Results and Discussions

3.1. Geometric Properties

The geometric properties and variance analysis results of safflower seeds are shown in Table 1. The width (4.04 mm) of the Dinçer cultivar gave higher values than other cultivars. Statistically, differences were observed in the width values of safflower seeds in terms of cultivars ($p < 0.01$). There was no statistical difference between the cultivars in terms of length, sphericity, surface area, and geometric mean diameter (Table 1). The sphericity value varied between 61.52% and 63.38% in safflower cultivars.

Table 1. Some geometrical properties of seeds of safflower cultivars

Cultivars	Length (mm)	Width (mm)	Thickness (mm)	Geometric mean diameter (mm)	Surface area (mm^2)	Sphericity (%)
Asal	7.69 ± 0.24^{ns}	$3.67 \pm 0.10b^{**}$	$3.95 \pm 0.15a^{*}$	4.80 ± 0.11^{ns}	72.60 ± 3.40^{ns}	62.66 ± 1.73^{ns}
Balcı	7.85 ± 0.20^{ns}	$3.59 \pm 0.16b^{**}$	$4.01 \pm 0.14a^{*}$	4.82 ± 0.14^{ns}	73.35 ± 4.36^{ns}	61.52 ± 1.26^{ns}
Dinçer	7.64 ± 0.23^{ns}	$4.04 \pm 0.34a^{**}$	$3.71 \pm 0.42b^{*}$	4.84 ± 0.35^{ns}	74.23 ± 10.83^{ns}	63.38 ± 3.29^{ns}
F value	2.46	11.81	3.72	0.09	0.13	1.72

**: $p < 0,01$, *: $p < 0,05$, ns: non-significant. Differences between similar letters in the same columns are insignificant, $\pm$: standard deviation.

Ghareeb et al. [10] reported the geometric mean diameter values of safflower seeds as 4.98 mm and sphericity values as 65.20% in their study. Kobuk et al. [11] reported that the geometric mean diameter values are in the range of 4.58 - 5.08 mm, sphericity values are in the range of 56.93 - 65.90%, and surface area values are in the range of 65.99 - 81.33 mm^2 for safflower seeds at the moisture content varied between 3.07% and 4.04%, respectively. Aktas et al. [12] reported that the length values varied from 7.27 to 7.81 mm, the width values changed from 3.50 to 3.79 mm, and the thickness varied from 2.80 mm to 3.50 mm; the geometric mean diameter was between 4.46 mm and 4.82 mm, and sphericity values changed from 47.14% to 48.83% at different moisture contents (7.4%, 8.1%, 8.7%, and 9.2%), respectively.

Çalışır et al. [13] reported that the length, width, thickness, and geometric mean diameter were 6.89 mm, 3.76 mm, 2.71 mm, and 4.13 mm at a moisture content of 5.61%, respectively. When the literature results are examined, it is seen that the geometric properties of safflower seeds show values close to the values found in this study.

3.2. Mass and Volumetric Properties

The values of seed mass and volumetric properties of safflower seeds are given in Table 2. The highest values for mass and bulk density were determined as 0.053 g and 557.76 kg m^{-3} in the Dinçer cultivar. Statistically significant differences were determined in bulk density values of safflower cultivars ($p < 0.01$). No statistically significant difference between cultivars in porosity, true density and seed volume was observed.

Table 2. Mass and volumetric properties of seeds of safflower cultivars

Cultivars	Mass (g)	Thousand seed mass (g)	Seed volume (mm^3)	Bulk density (kg m^{-3})	True density (kg m^{-3})	Porosity (%)
Asal	0.047±0.003b*	40.19±0.22b*	58.89±4.17 ^{ns}	468.71±18.27b**	1155.1±373.9 ^{ns}	54.21±18.14 ^{ns}
Balcı	0.049±0.004b*	40.31±0.37b*	59.75±5.36 ^{ns}	468.75±13.05b**	1182.3±285.3 ^{ns}	58.02±10.71 ^{ns}
Dinçer	0.053±0.005a*	50.02±0.11a*	61.31±13.51^{ns}	557.76±13.14a**	1102.3±271.2 ^{ns}	45.95±15.39 ^{ns}
F value	5.32	9.16	0.20	175.69	0.25	2.52

**: $p < 0,01$, *: $p < 0,05$, ^{ns}: non-significant. Differences between similar letters in the same columns are insignificant, ±: standard deviation.

Ghareeb et al. [10] reported that the thousand seed mass of safflower seeds was 42.49 g, the seed volume was 0.048 ml, and the true density value was 103.97 g l^{-1} in their study. Kobuk et al. [11] reported that the bulk density values of safflower seeds were 537.07 g l^{-1} - 602.37 g l^{-1}, and the thousand-grain weight values were 31.15 g - 49.10 g.

Aktas et al. [12] determined the true density values of safflower seeds in the range of 0.78 g cm^{-3} - 0.73 g cm^{-3}, and the porosity was 40.7% - 44.2%. Çalışır et al. [13], the seed mass and thousand seed mass values of safflower seeds were in the range of 0.035 g - 0.054 g and 36.1 g - 47.2 g, respectively. Moreover, the true density and porosity varied from 1096.7 to 1187.6 kg m^{-3}, from 52.0 to 56.7%, at moisture contents ranging from 5.61% to 23.32%, respectively. The results of the study were observed to differ from the literature. This difference is thought to be due to the genetic differences between the safflower seeds used in the studies and the climate and growing conditions.

3.3. Color Characteristics

The results of the variance analysis of the color characteristics of safflower seeds are given in Table 3. The highest L^* value was 75.31 in the Dinçer cultivar, and statistically, $p < 0.01$ level differences were observed between cultivars in terms of L^* value. The study determined that the difference between cultivars was statistically insignificant in terms of hue angle, chroma, a^*, and b^*color values.

Table 3. Color characteristics of seeds of safflower cultivars

Cultivars	*L**	*a**	*b**	*C*	*α (°)*
Asal	70.84±2.71b**	2.39±0.35 *ns*	11.67±1.27 *ns*	11.92±1.27 *ns*	78.36±1.75 *ns*
Balcı	69.93±2.97b**	2.39±0.26 *ns*	12.67±1.45 *ns*	12.89±1.45 *ns*	79.22±1.33 *ns*
Dinçer	75.31±2.31a**	2.65±0.43 *ns*	12.41±1.44 *ns*	12.69±1.46 *ns*	77.92±1.79 *ns*
F value	17.37	2.52	2.06	2.05	2.46

**: $p < 0{,}01$, *: $p < 0{,}05$, ns: non-significant. Differences between similar letters in the same columns are insignificant, ±: standard deviation.

Kobuk et al. [11] reported that $L^*$and a^*color values of safflower seeds varied from 63.65 to 67.81 and from 3.41 to 3.97, respectively. Moreover, chroma and hue angle changed from 9.88 to 12.28, from 67.15 to 71.24°, respectively. Significant differences were observed in the results in terms of color characteristics. It is thought that this difference is due to the cultivar of safflower seeds used in the studies and the cultivation and climatic conditions.

3.4. The Angle of Repose and the Coefficient of Static Friction

The static coefficient of friction and angle of repose of safflower seeds were determined, and the results are given in Table 4. In terms of static friction coefficient values, statistically, $p < 0.05$ differences were observed between the cultivars on the rubber surface, while no statistically significant difference was observed between the cultivars on PVC and laminate surfaces. Statistically significant differences were determined in the natural aggregation angle values between safflower cultivars ($p < 0.01$).

Table 4. Static coefficient of friction and angle of repose of seeds of safflower cultivars

Cultivars	Angle of Repose (°)	Friction surfaces			
		Plywood	Rubber	PVC	Laminate
Asal	8.65±1.09a**	0.368±0.016a**	0.384±0.025a*	0.302±0.022 *ns*	0.302±0.029 *ns*
Balcı	8.43±0.98a**	0.323±0.014b**	0.360±0.016b*	0.306±0.027 *ns*	0.300±0.013 *ns*
Dinçer	7.27±0.77b**	0.327±0.019b**	0.374±0.010ab*	0.285±0.019 *ns*	0.289±0.014 *ns*
F value	9.03	22.67	4.44	2.41	1.28

**: $p < 0{,}01$, *: $p < 0{,}05$, ns: non-significant. Differences between similar letters in the same columns are insignificant, ±: standard deviation.

Kobuk et al. [11] reported that the static coefficient of friction values ranged between 0.33 and 0.44, and the angle of repose values ranged from 23.17° - 26.23°. The angle of repose was found to be lower than in the literature. The difference is thought to be due to the difference in the ecological conditions and soil characteristics in which the seeds are grown, as well as the cultivar used.

4. Conclusion

In the study, width values were higher in the Dinçer cultivar than in other cultivars. The highest value for mass and bulk density was determined in the Dinçer cultivar. L* value was higher in the Dinçer cultivar than in the other two cultivars. The highest static coefficient of friction value was found on the rubber surface. In agricultural applications, especially in sowing, harvesting, postharvest classification, storage, and transportation processes, important biotechnical properties of seeds should be considered.

Author Contributions

All the authors equally contributed to this work. They all read and approved the final version of the paper.

Conflicts of Interest

All the authors declare no conflict of interest.

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