



## The Effect of Batch Drying at Different Temperatures on Seed Germination, Physical, and Seedling Properties of Paddy (*Oryza sativa* L.)\*\*

Hilal ERDOĞAN<sup>1</sup>, Eşref İŞİK<sup>1\*</sup>

<sup>1</sup>Uludağ University, Faculty of Agriculture, Department of Biosystems Engineering, Bursa, Turkey  
e-posta: dresref@uludag.edu.tr

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**Abstract:** The aim of the present study was to determine some physical properties, drying time, energy consumption, the effects of batch drying at different temperatures on seed germination, and seedling characteristics of paddy cultivar Osmancik-97, which is grown extensively in Turkey. Paddy seeds, which were dried at different temperature values (50, 60, 70 and 80 °C), were dried to 14%, with initial moisture content 25% (w.b.). The average length, width, and thickness measurements of rice seeds decreased with the decrease in moisture content. Width, height, thickness decreased by 14-1.78-1.42%, respectively. Surface area, arithmetic and geometric mean diameters, static friction coefficients on aluminium, stainless steel, galvanized iron, and rubber reduced with reducing moisture content. The highest static coefficient of friction for harvesting and storage moisture content was determined on the rubber surface and the lowest surface was determined as aluminium. Drying time, germination percentage, radicle and seedling weights, radicle and seedling lengths of Osmancik-97 paddy seeds dried in 4 different (50, 60, 70, 80 degrees) hot weather conditions were determined. Drying times were 691, 593, 495, and 478 minutes, respectively, with germination percentages of 96.0, 90.0, 87.3, and 68.7. The radicle and seedling weights of paddy seeds were found as 1.19-1.69, 1.09-1.65, 1.05-1.48, and 0.69-0.95 g respectively, and the radicle and seedling lengths were found as 106.8-81.8, 98.6-81.6, 92.8-78.7, and 75.7-70.9 mm respectively. Besides, we found that the dry seedling weight of paddy was 0.18, 0.17, 0.16, and 0.09 g at air of 50, 60, 70, and 80 °C, respectively. In the current study, the drying at 80 °C was reduced seed viability and seedling vigour but found to be the least energy consumption; consequently, the drying at 50 °C was determined to be the highest for energy consumption.

**Keywords:** Drying; Germination; Paddy; Physical properties; Radicle; Seedling.

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# Farklı Sıcaklıklarda Kurutma İşleminin Çeltik (*Oryza sativa* L.) Tohumunun Çimlenme, Fiziksel ve Fide Özellikleri Üzerine Etkisi

**Öz:** Bu çalışmanın amacı, Türkiye’de yaygın olarak yetiştirilen Osmancık-97 çeltik çeşidini, farklı sıcaklıklarda kurutarak, tohumun bazı fiziksel, çimlenme ve fide özelliklerine etkisini incelemek ve buna bağlı olarak kuruma süresi ve enerji tüketimini belirlemektir. Başlangıç nemi %25 olan çeltik tohumları dört farklı sıcaklıkta (50, 60, 70 ve 80 °C) nem değeri %14 olana kadar kurutulmuştur. Tohumların bazı fiziksel özellikleri olan en, boy, kalınlık ölçümlerinin nem içeriğinin azalmasına bağlı olarak azaldığı görülmüştür. En, boy, kalınlık için sırasıyla %14, 1.78, 1.42’lik oranda azalma tespit edilmiştir. Aynı zamanda tohumların yüzey alanı, aritmetik ortalama ve geometrik ortalama çap değerleri ile farklı yüzeylerdeki (alüminyum, paslanmaz çelik, galvaniz sac ve kauçuk) statik sürtünme katsayısı değerleri de nem içeriğinin azalmasına istinaden azalmıştır. Hasat ve depolama nem değerinde yapılan ölçümler sonucu en yüksek statik sürtünme katsayısı kauçuk yüzeyde en düşük ise alüminyum yüzeyde bulunmuştur. Farklı sıcaklık değerlerinde kurutulan Osmancık-97 çeltik çeşidi tohumların kuruma süresi, çimlenme oranı, kök ve fide ağırlığı, kök ve fide uzunluğu incelenmiştir. 50, 60, 70 ve 80 derece için kurutma süreleri sırasıyla 691, 593, 495 ve 478 dakika olarak belirlenmiştir. Çimlenme oranları sırasıyla % 96.0, 90.0, 87.3 ve 68.7 olarak tespit edilmiştir. Kök ve fide ağırlıkları 50 derece için sırasıyla 1.19-1.69, 60 derece için sırasıyla 1.09-1.65, 70 derece için sırasıyla 1.05-1.48 ve 80 derece için 0.69-0.95 gram olarak ölçülmüştür. Kök ve fide uzunlukları ise sırasıyla 106.8-81.8, 98.6-81.6, 92.8-78.7 ve 75.7-70.9 mm bulunmuştur. Ayrıca çeltik tohumunun kuru fide ağırlıkları da tespit edilmiştir. Kuru fide ağırlıkları farklı sırasıyla 0.18, 0.17, 0.16 ve 0.09 gram olarak ölçülmüştür. Mevcut çalışmada 80 °C’de en düşük enerji tüketimine karşın en düşük de çimlenme oranı, 50 °C’de ise en yüksek çimlenme oranına karşın en yüksek enerji tüketimi tespit edilmiştir.

**Anahtar Kelimeler:** Çeltik; Çimlenme; Fide; Fiziksel özellikler; Kök; Kurutma.

## Introduction

An Asian plant, paddy (also known as *Oryza sativa* L.) is among the basic nutrients used for various purposes worldwide. Although paddy contains less protein composition, it is the most widely used products in human nutrition after wheat. Paddy is rich in terms of amino acids (Catak, 2008). Paddy is the world's most important food source and is the second largest producer of grain in the world (Anbumalarmathi and Mehta, 2013; Khanali *et al.*, 2016). Paddy, which can be a product in many different areas used for various purposes worldwide, is an indispensable food item for millions of consumers (Dounghorn *et al.*, 2012). Which is about 1.5 billion hectares of agricultural land in the world, about 700 million hectares of grains are planted. Paddy meets about %22 of the world cereal cultivation and gets a share of %28 of the production. About %91 of world's paddy is done in Asia. China ranks first in the world in terms of paddy production, while others were India, Indonesia and Bangladesh, respectively. Paddy production in Turkey is a constantly increase in the last decade. Production growth is due to increase mainly in yield per unit area and in cultivation area. The Marmara region in Turkey is the most important cultivation and manufacturing region. After the Marmara Region comes to the Black Sea region. The total paddy production of these two regions constitutes more than 90% of Turkey's production. Thrace region, especially Edirne province provides about %40 of the paddy production and cultivation (Taylı, 2008).

The physical characteristics of agricultural products are crucial parameters in the design of systems such as storage, carrying, classification and processing systems. The mass, volume, and surface area are most important ones of these physical parameters for the classification systems. Also the other important parameters are the length, width, and thickness (Alibas and Koksal, 2015a; Jaliliantabar *et al.*, 2013; Giczewska and Borowska, 2003). Studies in recent years, many researchers have reported physical properties of various types of seeds. These include soybean, dry bean, and bitter gourd seeds (Alibas and Koksal, 2015b; Kibar, 2015; Unal *et al.*, 2013, respectively).

After the rice is harvested, it must first be dried in order to prevent the decomposition of respiration and microorganisms in order to be processed (Dounporn *et al.*, 2012; Doymaz, 2013). The simplest definition of the dryer is to remove the moisture from the product. In other words, it is a protection method that is used to lower the humidity to low levels and to protect the lives of the living things in order to prevent the deterioration activities of the biological material. (Izli and Isik, 2010; Doymaz, 2017). Drying can also be defined as providing control against internal and external factors such as harmful bacteria, viruses, fungi (Yari *et al.*, 2012; Nakagawa and Yamaguchi, 1989) and to break seed dormancy. The dry-heat method was significantly better than the other treatment (Zhang, 1990; Izadifar and Mowla, 2003). Hot air is better than other drying methods, but the optimum temperature value must be well defined. Otherwise, seed germination rate and seedling vigour abilities are reduced. However, when optimum conditions are determined, it contributes to germination and seedling (Yari *et al.*, 2012). Paddy is usually harvested at moisture contents (20-25%, w.b.) (Khanali *et al.*, 2016) higher than that needed for safe storage (12-14%, w.b.) (Zare *et al.*, 2015; Pan *et al.*, 2008). After harvesting, fresh rice should be dried to reduce the moisture content. Conventional hot air drying is used, but it is a very slow system when the temperatures are low. (Zare *et al.*, 2006; Zare *et al.*, 2012). Harvested paddy has to be dried in the twelve hours (Tayli *et al.*, 2009). Tayli *et al.*, (2009) reported that Osmancık-97 and Halilbey paddy seeds were exposed to hot air drying, sun drying, and shade drying. In Osmancık-97 and Halilbey paddy seeds, drying treatment at sun and shade resulted in increased vigour. Farooq *et al.*, (2004) have also dried their paddy of Japonica and Indica with hot air. They found germination and seedling at low temperatures while high temperatures had negative effects on the seeds exposed to drying for 72 hours at 40 degrees and for 24 hours at 60 degrees. With this study, it is possible to determine the parameters required to store the products for a long time without losing the properties of the products where the products are harvested, depending on the energy consumption and the drying rate, and to make the producers and the industry benefit from these parameters. Furthermore, to dry at four different temperature values, the physiological properties of paddy such as germination rates, radicle weight, seedling weight, dry seedling weight, radicle length, seedling length were determined and the statistical differences were investigated.

## Materials and Methods

The Osmancık-97 paddy seeds, which are the hybrid of ROCCA X EUROPA, used in the study were obtained from fields of Gönen, Balıkesir, Turkey. Properties of Osmancık-97 are given in Table 1. When the paddy was procured, storage moisture %14 wet basis. Paddy was thoroughly mixed and moistened with water spray and kept in the refrigerator at

+4 °C (Steffe *et al.*, 1978; Hacıhafızoglu, 1995). With this method paddy seeds at storage moisture were increased to harvesting moisture of 25%. The initial moisture content of the seeds was determined by digital moisture meter (Pfeuffer HE 50, Germany).

**Table 1.** Properties of paddy seed of Osmançık-97

Properties	Osmançık-97
1000 kernel weight (g)	33-34
Ripening time (day)	130-135
Plant height (mm)	950-1000
Kernel appearance	Yellow and lengthy
Morphological properties	Strong stem and lodging resistance
Parents	ROCCA x EUROPA
Year of registration	1997

To determine the average size of the paddy seed, 100 grains were randomly picked and their three principal dimensions, namely length  $L$  (mm), width  $W$  (mm), and thickness  $T$  (mm) were measured using a digital calliper (Mitutoyo, Japan) with a sensitivity of 0.001 mm. The geometric mean diameter ( $D_g$ ), sphericity ( $\emptyset$ ), surface area ( $A_s$ ), volume of seeds ( $V$ ), and aspect ratio ( $R$ ) were calculated at the different moisture contents according to Alibas and Koksall, (2015a), Unal *et al.*, (2013), and Mohsenin, (1986).

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

$$\emptyset = (LWT)^{1/3}/L \quad (2)$$

$$A_s = \pi D_g^2 \quad (3)$$

$$V = \pi/6 * (LWT) \quad (4)$$

$$R = W/L * 100 \quad (5)$$

The mass of thousand seeds was determined by using an electronic balance (RADWAG PS4500/C/2, Poland) weighing to an accuracy of 0.01 g. The static coefficient of friction was obtained from the following relationship:

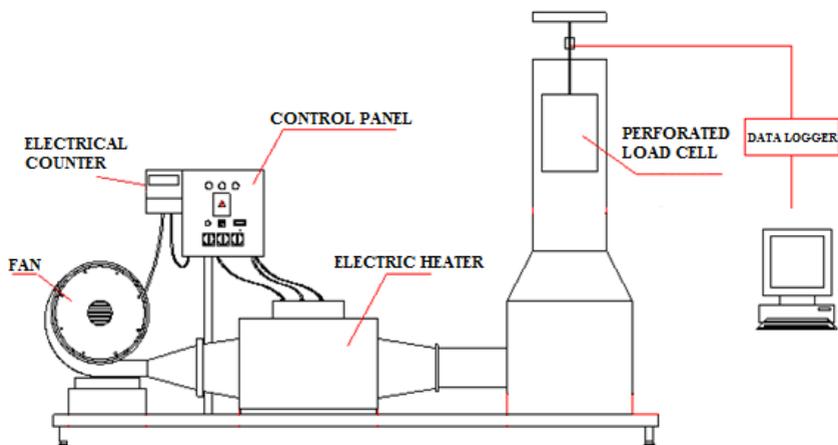
$$\theta = \tan \alpha \quad (6)$$

where;  $\theta$  is the static coefficient of friction,  $\alpha$  is static friction angle (°).

Four different surfaces (aluminium, stainless steel, galvanized iron, and rubber) were exercised for determined of static fraction angles of seeds (Izli *et al.*, 2009; Alibas and Koksall, 2015b; Unal *et al.*, 2013).

The paddies were dried in a laboratory-type cabinet dryer. Main parts of cabin dryer; radial fan, electric heaters, and control panel with speed and temperature adjustment. The air temperature has set the desired temperature from the control panel. All drying operations were carried out at an air velocity of 1 ms<sup>-1</sup> and measurements were made with a digital anemometer (Thies Clima, Germany). The air was dragged into the area where the residents were located by means of the fan, and thereafter, the heated air was dragged into the area of the seeds due to the increase of the moisture holding capacity. Drying of paddy was finalized when the moisture content decreased to 14% from the initial value of 25%

wet basis. In the drying system, there are 3 resistances with 10 kW power and a radial fan which has a 1.5 kW electric motor. An electricity meter was used to determine energy consumption during the drying process. (Makel Type T410.2216, Turkey). A schematic representation of the dryer is shown in Figure 1.



**Figure 1.** Schematic representation of the pilot scale batch dryer

In view of the results of the literature searches, the drying tests were carried out at a temperature range of 40-80 degrees. During drying, the energy measurements were taken every 15 minutes and the weight measurements were taken every 1 minute and transferred to the computer. Weight measurements were automatically saved to the computer with software attached to the system. Germination rate, radicle weight, seedling weight, radicle length, and seedling length was determined. For germination measurements, one hundred fifty seeds were randomly selected from batch with different dry temperature. Fifty seeds from each treatment and control were placed germination box containing two layers of moistened blotters with distilled water. Seeds were placed in growth chamber (25 °C) under normal light. Germination was recorded daily according to the ISTA (2006). Treatments were arranged in the laboratory according to a completely randomized plot design with three replications. Dry seedling weight was recorded after oven drying at 70 °C for 48 hours in drying oven. The data were subjected to analyses of variance using JUMP program. LSD test was used to group the means per dry temperature when the F-test was significant.

## Result and Discussion

The average values of the three major dimensions of paddy seed such as length, width, and thickness determined in this study at different moisture contents are presented in Table 2. The length, width and thickness of the paddy seeds at the initial (harvest) moisture level are decreased by 1.67%, 16.27% and 16.67%, respectively, relative to the moisture content. Similar results were found for Tarom and Fajr paddy kernels (Gharekhani *et al.*, 2013), lentil seeds (Carman, 1996), and bitter melon seeds (Unal *et al.*, 2013). The geometric and

arithmetic mean diameters of paddy kernels at the initial moisture level decreased by 11.44%, and 1.68%, respectively, according to the moisture content. The geometric mean diameters were highly decreased with decrease in moisture content, while arithmetic mean diameters decreased very gently (Table 2). The similar relationship of geometric mean diameter with moisture content was also observed by other research workers for paddy kernels (Gharekhani et al., 2013), soybean seeds (Alibas and Koksals, 2015a), and millet (Baryeh, 2002).

**Table 2.** Relationship between some physical properties and moisture content obtained of paddy as a function of moisture content

	Moisture Content, % w.b.±(Stdev)	
Seed Properties	25.0 (harvest moisture)	14.0 (storage moisture)
Length, (mm)	9.10±(0.04) <sup>ns</sup>	8.95±(0.04) <sup>ns</sup>
Width, (mm)	3.50±(0.02) <sup>a*</sup>	3.01±(0.02) <sup>b*</sup>
Thickness, (mm)	2.31±(0.01) <sup>a**</sup>	1.98±(0.01) <sup>b**</sup>
Arithmetic mean diameter,(mm)	4.97±(0.02) <sup>a**</sup>	4.64±(0.02) <sup>b**</sup>
Geometric mean diameter,(mm)	4.19±(0.02) <sup>a**</sup>	3.76±(0.01) <sup>b**</sup>
Sphericity, (%)	0.421±(0.002) <sup>b*</sup>	0.461±(0.002) <sup>a*</sup>
Aspect Ratio, (%)	0.336±(0.003) <sup>ns</sup>	0.386±(0.003) <sup>ns</sup>
Surface Area, (mm <sup>2</sup> )	55.04±(0.39) <sup>**</sup>	44.43±(3.37) <sup>**</sup>
L/W	2.60±(0.02) <sup>ns</sup>	2.98±(0.02) <sup>ns</sup>
L/T	3.95±(0.03) <sup>b**</sup>	4.52±(0.03) <sup>a**</sup>
L/D <sub>g</sub>	2.17±(0.01) <sup>b*</sup>	2.38±(0.01) <sup>a*</sup>
Mass of 1000 seeds, (g)	35.28±(0.46) <sup>a**</sup>	31.68±(0.38) <sup>b**</sup>
Volume, (mm <sup>3</sup> )	38.40±(0.40) <sup>a**</sup>	27.85±(0.33) <sup>b**</sup>

\*, 5% statistically significant, \*\*, 1% statistically significant, ns, statistically non-significant

With decreased moisture content of the paddy kernels, the value of aspect ratio and sphericity increased. When moisture content was decreased from 25% to 14%, it was stated that sphericity and aspect ratio increased at the rate of 8.68% and 12.95%, respectively. The averages of results are given in Table 2. Alibas and Koksals (2015a), and Gharekhani et al., (2013) stated that sphericity and aspect ratio of soybean and paddy seeds increase as the moisture content.

In the present study, it was determined that as the moisture content decreases, the surface area decreases. Surface area decreases at the rate of 23.88% (Table 2). This situation has been determined by many researches (Izli *et al.*, 2009; Alibas and Koksals, 2015a; Unal *et al.*, 2013). The thousand seed mass of paddy kernels decreased from 31.68 to 35.28 g according to moisture content decreased from 25 to 14% (Table 2). The thousand seed mass has also been obtained for paddy kernels (Gharekhani et al., 2013), barbungia bean (Cetin, 2007). Volume of paddy seeds is influenced positively by decreasing moisture content. As shown in the Table 2, an decrease of 37.88 % was detected due to the decrease in humidity. Similar results have been determined by Unal *et al.* (2013) for bitter gourd

seeds, Alibas and Koksai, (2015a) for soybean, and Gharekhani *et al.* (2013) for paddy kernels.

The friction characteristics of paddy seed used in the study were investigated depending on the harvesting and storage moisture content. These results are presented in Table 3 together with their statistical analysis. Four different surfaces were also used in the table. These are rubber, stainless steel, galvanized iron and aluminium, respectively. The surface with the highest coefficient of friction for the harvesting moisture is identified as rubber. This is followed by stainless steel, galvanized iron and aluminium surfaces respectively. The same results apply in the harvesting moisture content but it has been observed that there is no difference in the 1% probability level between the galvanized surface and the aluminium surface and it is observed that it is in the same group. As the moisture content decreases, the coefficient of friction of the seeds decreases clearly on all surfaces. Similar results have been found by some researchers such as Unal *et al.* (2008), Alibas and Koksai, (2015b), Barnwal *et al.* (2012).

**Table 3.** Coefficient of static friction of paddy kernels

Moisture content (%)	Coefficient of static friction				Significance level
	Rubber	Stainless Steel	Galvanized Iron	Aluminium	
14.0	0.550±(0.004) <sup>B,a</sup>	0.518±(0.006) <sup>B,b</sup>	0.496±(0.006) <sup>B,c</sup>	0.455±(0.003) <sup>B,d</sup>	**
25.0	0.717±(0.015) <sup>A,a</sup>	0.600±(0.009) <sup>A,b</sup>	0.550±(0.008) <sup>A,c</sup>	0.525±(0.008) <sup>A,c</sup>	**
<b>Significance level</b>	**	**	**	**	

Means followed by the same letter between rows (a, b, c) and between columns (A, B, C) within each surface are significant. Standard error is given in parenthesis. All data were obtained in 10 replicate results. \*\*, Significance levels at  $p < 0.01$ .

Paddy grains with a moisture content of 25% (harvesting moisture) were dried to a storage value of 14%, which is the appropriate moisture value for storage. The total drying times at 50, 60, 70, and 80 degrees were determined as 691, 593, 495, and 478 minutes, respectively. Total energy consumption and drying time are given in Table 4. The results are similar to those reported by Tayli *et al.* (2009) for rice, Izli and Isik (2010) for maize and Siddique and Wright (2003) for pea.

The energy consumption values of the paddy dried at 4 different temperatures are as follows; 43.306 at 50, 38.889 at 60, 37.707 at 70, and 33.627 kWh at 80. The results are similar to those reported by Yildiz *et al.* (1989) for maize seeds. According to the results obtained, drying at 80 degree, the shortest drying period and the lowest energy consumption occurred (Table 4).

**Table 4.** Results depending on time, total energy consumption

Temperature (°C)	Time (min)	Total energy consumption (kWh)
50	691	43.306
60	593	38.889
70	495	37.707
80	478	33.627

The germination percentages of paddy seeds dried at 4 different temperature values (50, 60, 70, and 80 degree) were determined as 96.0, 90.0, 87.3, and 68.70%, respectively. Similar results of germination vigour have been reported for maize (Govender *et al.* 2008), *Catharanthus roseus* (Jaleel *et al.* 2007), corn (Branco *et al.* 2002) and sunflower (Ducournau *et al.* 2004), wheat (Toklu *et al.* 2008). Statistical analysis results depending on germination percentage, radicle weight, seedling weight, dry seedling weight, radicle length and seedling length are given Table 5.

**Table 5.** Effect of dry temperature treatments on some germination traits of paddy and the result of F testing and statistical grouping dry temperature

Temperature (°C)	Germination percentage (%)	Radicle weight (g)	Seedling weight (g)	Dry seedling weight (g)	Radicle length (mm)	Seedling length (mm)
Control	98.0 a	1.21 a	1.99 a	0.21 a	107.9 a	84.1
50	96.0 a	1.19 a	1.69 b	0.18ab	106.8 a	81.8
60	90.0 b	1.09 a	1.65 b	0.17 b	98.6 ab	81.6
70	87.3 b	1.05 a	1.48 b	0.16 b	92.8 b	78.7
80	68.7 c	0.69 b	0.95 c	0.09 c	75.7 c	70.9
Significance	**	*	**	**	**	ns

\*\* 1% substantial, \* 5% substantial, ns unsubstantial

Note: Means followed by the same letter are not significantly different at the P=0.05 level using LSD test

Radicle weight values for paddy dried by four different hot air drying are: at air 50, 60, 70 and 80 °C – 1.19; 1.09; 1.05 and 0.69 g, respectively. Seedling weight values for paddy dried by four different hot air drying are: at air 50, 60, 70 and 80°C – 1.69; 1.65; 1.48 and 0.95 g, respectively.

Dry seedling weight values for paddy dried by four different hot air drying are: at air 50, 60, 70 and 80°C – 0.18; 0.17; 0.16 and 0.09 g, respectively.

Radicle length values for paddy dried by four different hot air drying are: at air 50, 60, 70 and 80 °C – 106.8; 98.6 ; 92.8 and 75.7 mm, respectively. Seedling length values for paddy dried by four different hot air drying are: at air 50, 60, 70 and 80 °C – 81.8; 81.6 ; 78.7 and 70.9 mm, respectively. No studies similar to the radicle weight, seedling weight, dry seedling weight, radicle length, and seedling length of the paddy seeds obtained due to different drying temperatures were found.

## Conclusions

According to the results of the research, it has been seen that some physical properties of paddy seed increase due to increase of moisture and decrease in some physical properties. The physical characteristics that are observed to increase are: width, length, thickness, geometric mean diameter, surface area, thousand grain weight, and volume. The physical properties that appear to diminish are sphericity and aspect ratio.

The coefficient of friction on 4 different surfaces was determined as the highest coefficient of rubber surface between the other surfaces depending on the increase of the humidity according to the study results.

When looking at energy consumption and drying time, it is determined that the longest drying time is 50 degrees and the shortest drying time is 80 degrees, but energy consumption is the opposite.

When the effects of drying results at 4 different temperatures on seed germination properties (radicle weight, seedling weight, dry seedling weight, radicle length, and seedling length) were examined, it was determined that all properties were high at 50 degrees.

According to all the outcomes, the interpretation is as follows; although the minimum energy consumption and drying time are 80 degrees, the results of all germination properties are the lowest. The highest germination characteristics at 50 degrees while the longest drying time and energy consumption.

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