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Product Quality and Safety

Some physical properties of lentil seeds affected by harvest time

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Abstract: *The physical properties and the hardness of lentil seeds, which can also be affected by harvest times, are very important variables in the designing and adjustment of machineries used during harvest, handling and other processes. The objective of this study is to determine the effects of different harvest times on some physical and mechanical properties of lentil seeds. A field experiment was conducted at six harvest times including the harvesting at physiological maturity (H1) and 5, 10, 15, 20 and 25 days after physiological maturity (H2, H3, H4, H5 and H6, respectively). The variables determined were moisture content, diameter, thickness, sphericity, seed mass, bulk density, true density, porosity and hardness of lentil seeds. It was found that seed moisture content, seed dimensions, seed mass and bulk density decreased with delayed harvest time. However, sphericity, true density, porosity and hardness of lentil seeds increased with increased harvest time.*

Keywords: density, lentil, moisture content, physiological maturity, seed hardness

Introduction

Lentil has an important role in human nutrition as a rich source of starch, calories, certain minerals, and vitamins. It also contains high levels of protein and fiber. The two main market classes of lentil are the green and red types. Green lentil is usually marketed as whole seed, while red lentil is marketed as whole seed or in dehulled and split forms (Vandenberg, 2009). Red lentils account for the majority of world lentil production and trade. Turkey is one of the largest red lentil producers after Canada and India (Yadav et al., 2007).

The physical and mechanical properties of seeds are very important in the design of harvest and handling machineries used in preparation of the processing chain from grain to food (Bagherpour et al., 2010). Therefore, the knowledge of physical and mechanical properties of raw material can be necessary for food processing industry and equipment design. Also, the knowledge as such is important for food science, plant breeders, processors and other scientists (Mohsenin, 1986). The moisture content of lentil seeds is important in crop storability and in maintenance of seed quality (Hasan et al., 2017). Also, moisture content strongly influences the mechanical properties of seed and thus the grinding process (Dziki and Laskowski, 2005). The dimensions and shape properties of seeds are very important in the design of sizing, cleaning and grading machines. The properties such as bulk density, true density, and porosity are major parameters in the designing of drying and aeration (natural and mechanical), store systems (silos and warehouses) and transporting structures (Dursun and Dursun, 2005). The seed hardness of pulse is an important variable affecting pulse millability and the resulting flour (Thakur et al., 2019). Vishwakarma et al. (2018) reported that seed properties such as size, shape, moisture content and hardness are the major factors that affect the dehulling of grain legumes. Also, Tikle and Mishra (2018) stated that fundamental grain properties should be determined to improve the performance and efficiency of milling machines.

The physical and mechanical properties of lentil seeds are mainly affected by genetic properties, environmental factors and agronomic practices (Dobrzański and Stępniewski, 2013). Harvest time is one of the most important factors affecting the physical and mechanical properties of lentil seed. The best time for harvest should be carefully monitored to avoid shattering of pods. While late harvest causes loss of yield due to pod drop and shattering, early harvest results in poor seed quality due to high percentage of immature seeds and high seed moisture content (Yadav et al., 2005).

Several researchers (Tang et al., 1990; Gonçalves et al., 2005; Shaheb et al., 2015) reported that the seed reaches its maximum dry weight at physiological maturity and the physiological changes in seeds retained on mother plant after physiological maturity may lead to formation of hard seeds or off colour seeds in pulse crops. Ansari et al. (2015) stated that lentil harvest takes place 10 to 15 days after physiological

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maturity. Also, they reported that the moisture content and physical properties of seed were significantly affected by harvest time. Tang et al. (1990) suggested that lentil should be harvested at the 14% to 19% wet basis (wb) for undamaged threshing. However, above 14% moisture content can reduce the safe storage for extended period (Barker, 2018). Therefore, it is a very important issue to understand the variations in seed moisture content, and seed physical and mechanical properties according to the harvest times, and the relationships between moisture content and relevant physical properties.

The objective of this study is to investigate the effects of different harvest times on some physical and mechanical properties of red lentil seed, namely, moisture content, diameter, thickness, sphericity, seed mass, bulk density, true density, porosity and hardness.

Material and methods

The red lentil seeds, line BM-559, used in the present study were obtained from the seed production field at Dicle University, Agriculture Faculty experiment area in Diyarbakır, Turkey (37°55'36"N, 40°13'49"E and 670 m asl) in 2019. The soil texture of the seed production area was clay loam. Total rainfall during lentil growing season (January to June) was 476.2 mm, which was 67.2, 77.4, 135.2, 152.6, 42.8 and 14.4 mm in January, February, March, April, May and June, respectively, and monthly average temperature was 5.8, 5.4, 8.2, 11.8, 20.1 and 28.3°C in January, February, March, April, May and June, respectively.

The seedbed preparation included disc harrow tillage at 15-20 cm depth in October, and cultivator at 10-15 cm and planking three days before seeding. The lentil seed was sown on the 25th of November by universal seed drill. Land roller was used after seeding to provide seed-soil contact. The seeding rate was 300 seed m^2 and seeding depth was approximately 5-6 cm. The space between rows was 20 cm.

Six harvest times were tested in a Factorial Randomized Block Design with four replications. Harvest times included the harvest at physiological maturity (H1), 5, 10, 15, 20 and 25 days after physiological maturity (H2, H3, H4, H5 and H6, respectively), harvested on 10th June, 15th June, 20th June, 25th June, 30th June and 05th July, respectively. The harvest at physiological maturity stage (R7) was carried out when leaves started to yellow and 50% of pods were yellow.

Twenty plants randomly selected in each replication of each treatment were harvested by hand at each of the harvest times and seeds were separated from pods by hand. Then, the seeds were taken to the processing lab and evaluated for moisture content, dimension, sphericity, mass, bulk density, true density, porosity and hardness.

The moisture content of seed samples was determined by air oven drying at 103°C for 72 h according to the Approved Method ASABE S352.2 (ASABE Standards, 1998).

The physical dimensions of seeds were determined measuring the diameter and thickness of 20 seeds by a digital caliper (Mitutoyo Corporation, Japan) having least count of 0.01 mm.

The sphericity degree of seeds was calculated by the equation (1) proposed by Mohsenin (1986):

$$\Phi = [(D^2 \times T)^{1/3}/D] \times 100, \% \quad (1)$$

Where, Φ is the seed sphericity, %; D is the seed diameter, mm; T is the seed thickness, mm.

The seed mass was determined by taking 100 seeds randomly and measured by an electronic balance (WL-3002L) to an accuracy of 0.01 g, and then divided by 100 to give the seed mass.

The bulk density of lentil seeds (ρ_b) was determined by measuring the volume of a known mass of seeds into a graduated cylinder of 500 ml (readable to 2 ml) (Amin et al., 2004). The 20 g seeds were dropped into the graduated cylinder from a height of 150 mm and, then, the seed volume of the 20 g seeds was recorded from the graduated scale of the cylinder. The bulk density was calculated by the equation (2):

$$\rho_b = m/v \quad (2)$$

Where, ρ_b is the bulk density, g cm^{-3}; m is the mass, g; v is the volume, cm^{-3}.

The true density of lentil seeds (ρ_t) was determined using water displacement technique (Karababa and Coşkuner, 2007). A hundred milliliter of water was placed in a 500 ml graduated measuring cylinder and 10 g seeds were dropped in that water. The amount of displaced water was recorded from the graduated scale of the cylinder. The true density was calculated as the ratio of the weight of seeds to the volume of displaced water.

Porosity (ε) was calculated from the values of the true and the bulk density by using the Equation (3) (Mohsenin, 1986):

$$\varepsilon = 100 \times [1 - (\rho_b / \rho_t)], \quad (3)$$

Where ε = porosity, %; ρ_b = bulk density of seeds, g cm^{-3}; ρ_t = true density of seeds, g cm^{-3}.

The hardness of lentil seeds affected by harvest times was measured using a hardness tester (GWJ-1, Jiangsu Tongjun Instrument Technology Co. Ltd., Jiangsu, China). The seeds were placed in their natural resting position on the working platform. The rotatable hand-wheel under the working platform was turned to allow a rod attached to the dial gauge to press the seed against the working platform. When the seed was crushed, its hardness value was read as kgf on the dials and then this value was multiplied by 9.81 for expressing as Newton.

The data obtained were subjected to analysis of variance (ANOVA) and the significant differences among means were compared using the least significant difference test at 5% significant level using the JMP statistical software (SAS Institute Inc., 2002). To determine the relationship between the harvest times and the evaluated seed properties, regression analysis was performed using Microsoft Excel 2007 software. The best model was chosen as the one with the highest coefficient of determination.

Results and discussion

Table 1 shows some physical and mechanical properties (moisture content, diameter, thickness, sphericity, mass, bulk density, true density, porosity, hardness) of lentil seeds affected by different harvest times. All properties evaluated were significantly influenced by harvest time at 1% probability level ($p<0.01$). Mean moisture content of lentil seeds was observed to be changed from 27.80% for H1 to 9.49% for H6. The relationship between harvest time and seed moisture content is indicated in Figure 1. The second order polynomial model was selected as a suitable model to predict the moisture content as a function of harvest times. The seed moisture content decreased at an increasing rate until H3, then at a decreasing rate. Similarly, Gnyandev et al. (2019) observed the loss of moisture content of seed with delay of harvest time. Seed moisture content has been used as an index of optimum harvest time because it significantly impacts the physical and mechanical properties of seeds (Tang et al., 1990; Bedance et al., 2006; Berti et al., 2007). It is also a very important factor for the safe storage (Barker, 2018).

Table 1. Significance of analysis of variance (ANOVA) for moisture content (MC), diameter (D), thickness (T), sphericity (Φ), mass (W), bulk density (ρ_b), true density (ρ_t), porosity (ε), hardness (H) of lentil seeds as affected by harvest times

SV	df	Mean squares								
		MC, % (wb)	D, mm	T, mm	Φ, %	W, mg	ρ_b, gcm^{-3}	ρ_t, g cm^{-3}	ε, %	H, N
HT	5	185.83**	0.207**	0.010**	3.080**	349.24**	0.012**	0.151**	648.6**	1390.96**
R	3	7.395^{ns}	0.009^{ns}	0.002^{ns}	0.036^{ns}	6.455^{ns}	0.002^{ns}	0.001^{ns}	20.35^{ns}	12.357^{ns}
E	15	11.122	0.012	0.001	0.142	8.672	0.001	0.006	13.73	69.697
CV, %		19.61	2.12	1.26	1.47	6.20	5.24	5.96	8.85	6.54

*SV, sources of variance; df, degree of freedom; HT, harvest time; R, replication; E, error; CV, change of variation; ^{ns}non-significant; *significant at 5%; ** significant at 1%.

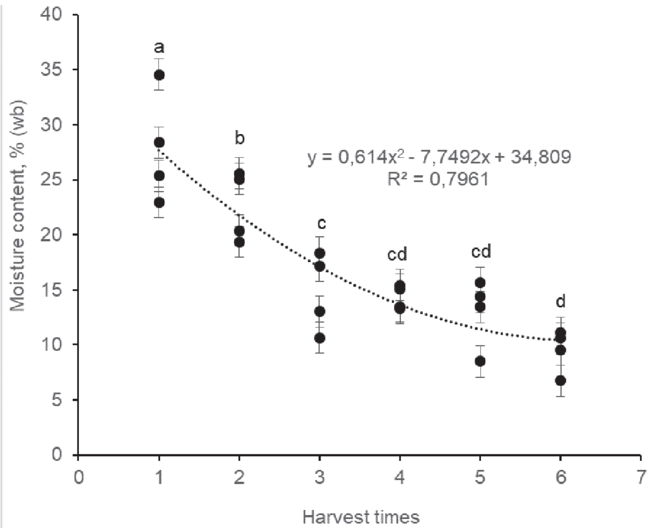
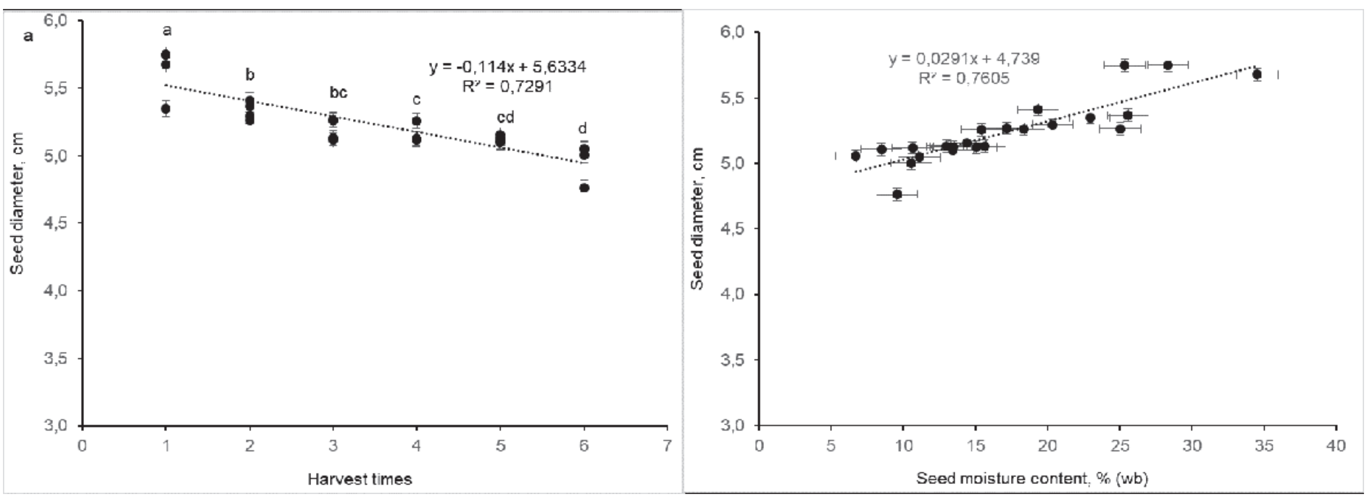


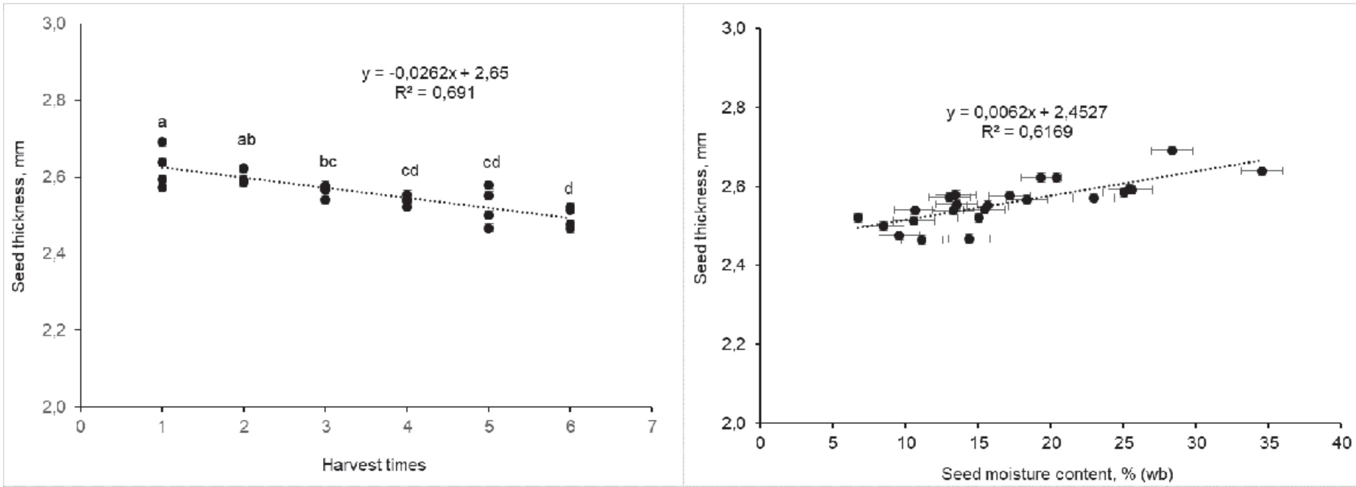
Figure 1. Effect of harvest times on the moisture content of lentil seeds (Means followed by different letters are significantly different according to LSD's multiple range test at significance level of 0.05)

Statistically, significant difference ($p<0.01$) was found among harvesting times for both the diameter and the thickness of lentil seed (Table 1). The regression equation obtained between the seed diameter and the harvest times is shown in Figure 2a. There was a linear decrease in the seed diameter with increasing harvest time. Similarly, seed thickness linearly decreased with delayed harvest time (Figure 3a). The shrinkage of seed due to the decrease of seed moisture content with delaying harvest time might reduce the diameter and thickness of seed. The change in the diameter and thickness of seed related to seed moisture content is seen in Figure 2b and Figure 3b. It was observed that both the diameter and the thickness of lentil seed increased linearly with increasing the moisture content. Similar relationships were reported by several researchers (e.g. Carman, 1996; Mwithiga and Sifuna, 2006; Gharibzahedi et al., 2011) who found that seed dimension increased linearly with increased moisture content. Sologubik et al. (2013) stated that the increase in the seed moisture content could cause the expansion of the seed as a result of moisture absorption in the intracellular spaces inside the seeds.



a) b)

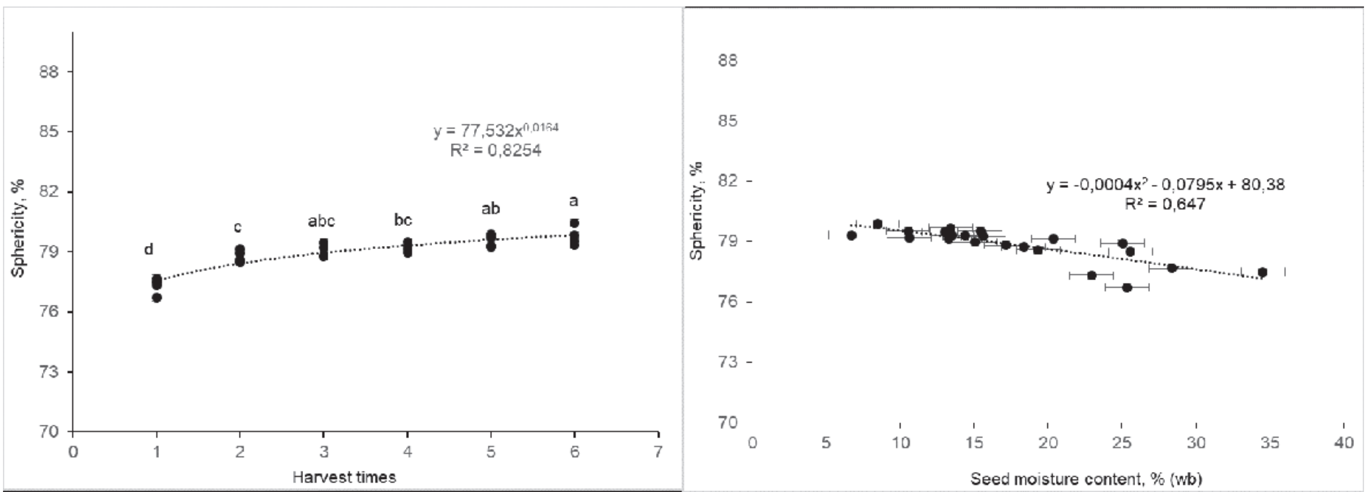
Figure 2. Effect of harvest times (a) and seed moisture content (b) on the diameter of lentil seeds (Means followed by different letters are significantly different according to LSD's multiple range test at significance level of 0.05)



a) b)

Figure 3. Effect of harvest times (a) and seed moisture content (b) on the thickness of lentil seeds (Means followed by different letters are significantly different according to LSD's multiple range test at significance level of 0.05)

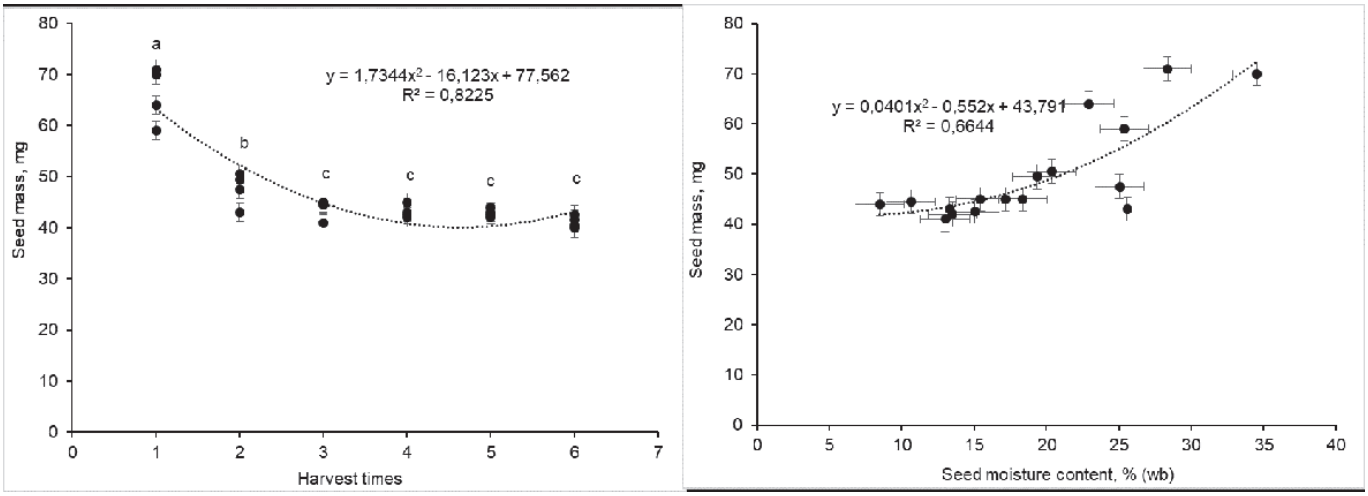
Figure 4 shows how sphericity is affected by harvest time and seed moisture content. The 25 days delay of harvest time after physiological maturity increased the sphericity of seeds by 3.35%. There was a quadratic relationship between harvest time and seed sphericity. The relationship between seed sphericity and seed moisture content affected by harvest times was significant ($p<0.01$) and the second order polynomial models was selected as a suitable model to predict seed sphericity as a function of moisture content. Seed sphericity increased with decreased moisture content. The sphericity of the lentil seed increased from 77.10 to 79.45%, when moisture content decreased from 35 to 10% (w.b.). Similarly, an increase of seed sphericity with decreased moisture content was reported by Irtwange and Igbeka (2002) for African yam bean and Isik (2007) for round red lentil.



a) b)

Figure 4. Effect of harvest times (a) and seed moisture content (b) on the sphericity of lentil seeds (Means followed by different letters are significantly different according to LSD's multiple range test at significance level of 0.05)

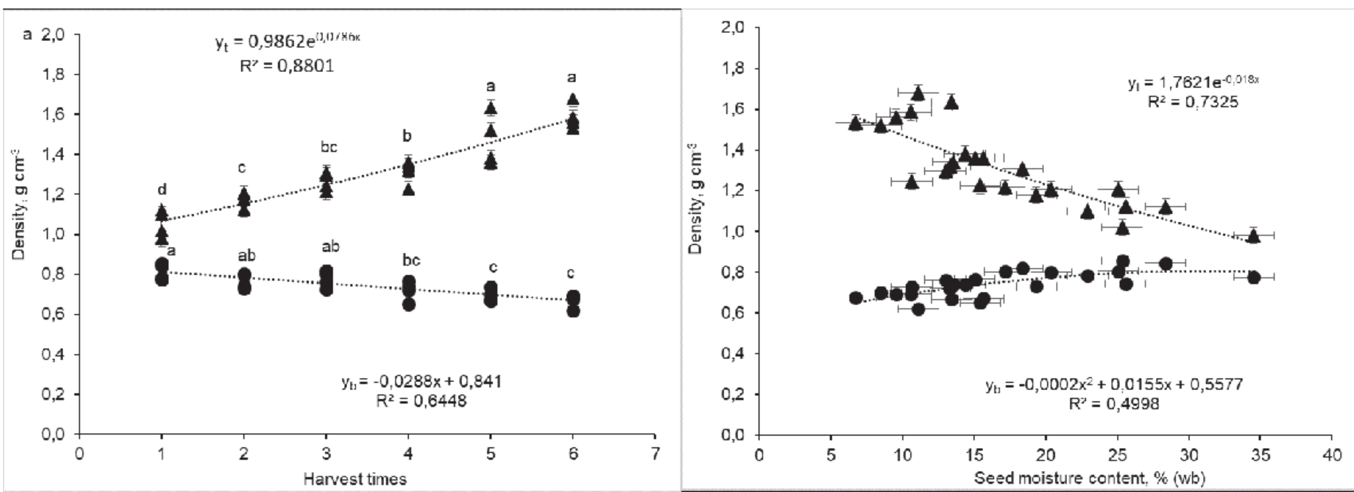
The relationships between the seed mass and the harvest times, and between the seed mass and the moisture content are presented in Figures 5a and 5b. The polynomial model was selected as a suitable model to predict the mass of lentil seeds as a function of harvest time and moisture content. The highest seed mass was found at H1 and decreased at an increasing rate until H2, then at a decreasing rate (Figure 5a). The 25 days delay of harvest time after physiological maturity stage decreased the seed mass by 36%. Similarly, Mehta et al. (1993) and Gaikwad and Bharud (2017) determined that the seed mass significantly decreased with delay of harvest time after physiological maturity. This decrease in the seed mass could be due to the loss of the moisture content in seed or the disruption of vascular connection and utilization in various physiological and metabolic processes like respiration, etc. (Mehta et al., 1993). There was a polynomial relationship between the seed mass and the moisture content, and the seed mass increased with the increase in seed moisture contents (Figure 5b). Other researchers (e.g. Szot et al., 2003; Amin et al., 2004; Isik, 2007) also found a positive but linear relationship between the mass and the moisture content of lentil seed.



a) b)

Figure 5. Effect of harvest times (a) and seed moisture content (b) on the mass of lentil seeds (Means followed by different letters are significantly different according to LSD's multiple range test at significance level of 0.05)

The bulk density of lentil seeds was observed to decrease linearly with delayed harvest time after physiological maturity while the true density increased exponentially with harvest time (Figure 6a). The bulk density of lentil seeds was the highest at physiological maturity and it reduced about 21.55% when lentil seeds were harvested 25 days after physiological maturity. This can be attributed to the change of the seed textural and material structures as the seed matures (Eboibi and Uguru, 2018*)*. Also, the relationship between the bulk density and the moisture content of lentil seeds affected by harvest times are given in Figure 6b. Lentil bulk density (ρ_b) was found to increase as second order polynomial with the increase in moisture content. The bulk density is estimated to be decreased from 0.867 g cm^{-3} to 0.713 g cm^{-3} when the moisture content of lentil seeds decreased from 20% to 10% by delaying harvest time. This decrease in bulk density with decrease of moisture content could result from the higher decrease in seed mass compared to the decrease in bulk seed volume. Also, the variation in the shape and surface characteristics of lentil seeds due to the loss in seed moisture content with delayed harvest time might have affected the bulk density (Nelson, 2002).

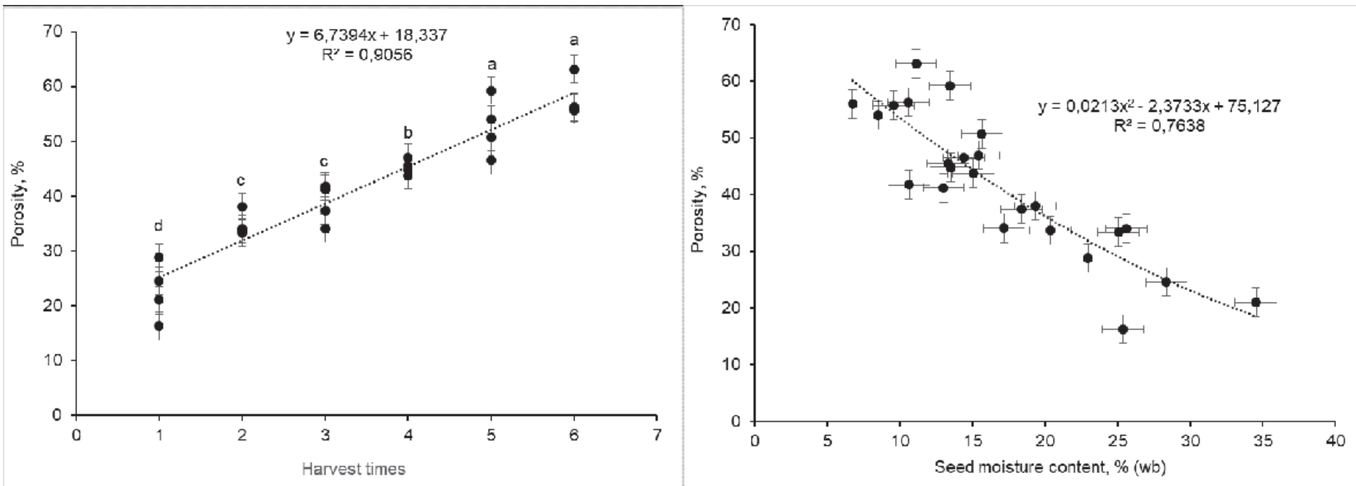


a) b)

Figure 6. Effect of harvest times (a) and seed moisture content (b) on the bulk and the true density of lentil seeds (Means followed by different letters are significantly different according to LSD's multiple range test at significance level of 0.05)

The true density of lentil seeds showed an exponential increase with delayed harvest time after physiological maturity. The 25 days delay of harvest time after physiological maturity increased the true density of seeds by 48% (Figure 6a). The true density increase with the delay of harvest time after physiological maturity could be due to the higher rate of decrease in single seed volume compared to the decrease in the mass of single seed due to moisture content loss. These results are in agreement with those found by Gaikwad and Bharud (2017) for soybean, Eboibi and Uguru (2018) for beans. The relationship between true density and moisture content of lentil seeds affected by harvest time is presented in Figure 6b. True density exponentially decreased by increased moisture content. Gharibzahedi et al. (2011), evaluating the moisture-dependent physical properties of red lentil seeds during a rewetting process, it was observed that true density decreased linearly with increase in moisture contents. Also, negative linear relationship of true density with moisture content was determined for lentil, chickpea, wheat (Tabatabaeefar, 2003; Amin et al., 2004; Nikoobin et al., 2009). However, Işık and Izli (2016) determined that true density of yellow lentils increased linearly as a result of the increased moisture content.

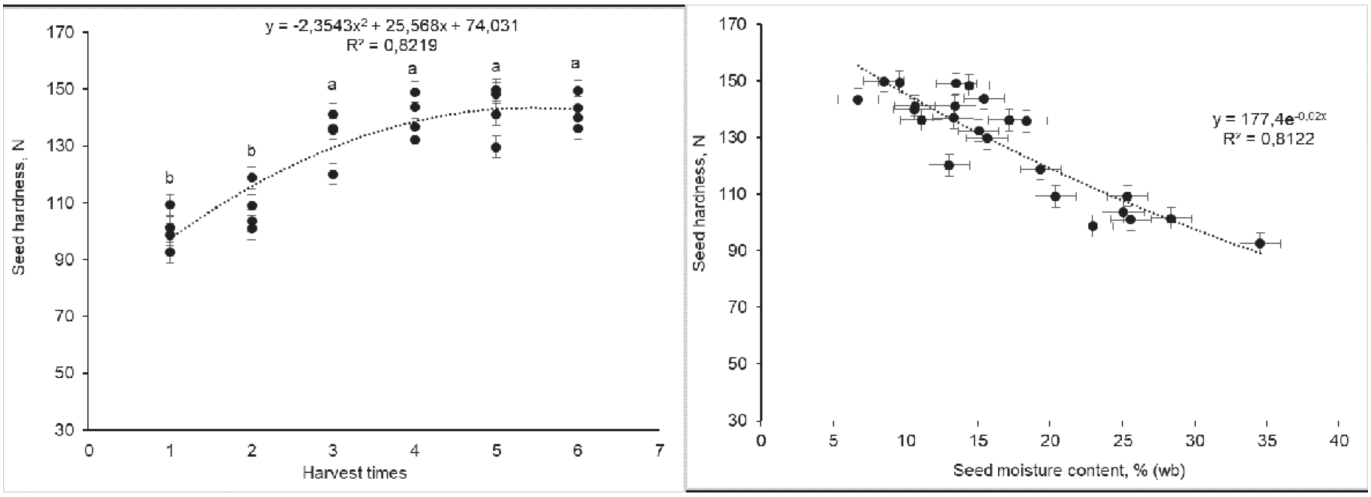
The porosity of lentil seeds increased linearly with delayed harvest time (Figure 7a). The 25 days delay of harvest time increased the porosity of seeds by 57.33%. This increase may be attributed to the change in bulk and true densities with delayed harvest time (Nikoobin et al., 2009). The fact that the delayed harvest time increased the true density and decreased the bulk density resulted in increased porosity of seeds. Also, change in the dimension, shape and surface properties of seeds due to the loss in seed moisture content by delayed harvest time significantly affects the porosity (Karababa and Coşkuner, 2007; Mpotokwane et al., 2008). The relationship between the porosity and the moisture content of lentil seeds affected by harvest time is presented in Figure 7b. Porosity decreased as polynomial by increased moisture content. It can be predicted that porosity will increase from 22.77% to 53.49% if moisture content decreases from 30% to 10%. While Ghasemlou et al. (2010) found a decrease in the porosity of Mungbean seeds with increasing of moisture content, Işık and Izli (2016) reported that the porosity of yellow lentil seeds increased with increased moisture content. Also, Szot et al. (2003), evaluating the porosity of two different lentil varieties, observed that the influence of moisture content on porosity was different for the tested lentil varieties.



a) b)

Figure 7. Effect of harvest times (a) and seed moisture content (b) on the porosity of lentil seeds (Means followed by different letters are significantly different according to LSD's multiple range test at significance level of 0.05)

The change in the hardness of lentil seeds with delaying harvest time after physiological maturity is showed in Figure 8a. The lowest seed hardness was found at H1 and increased at an increasing rate until H2, then at a decreasing rate until H5. Seed hardness was found to be decreased after H5. But, the difference among H3, H4, H5 and H6 harvest times was not statistically significant. Also, there was no significant difference between H1 and H2 harvest times. The loss of the moisture content of seeds during maturity stage might cause an increase in hardness as seeds tend to lose flexibility when they lose water (Gonçalves et al., 2005). Shaheb et al. (2015) stated that physiological changes in seeds retained on mother plant after physiological maturity might lead to formation of hard seeds in pulse crops. The relationship between seed hardness and moisture content of lentil seeds affected by harvest times was presented in Figure 8b. The hardness of lentil seeds exponentially decreased from 149.80 N to 92.55 N with increase in moisture content from 8.48 % to 34.53% (wb). The results of this study showed that the hardness of lentil seeds was highly dependent on the change in moisture content due to delaying harvest time after physiological maturity, which means that greater forces were necessary to rupture the grains with lower moisture level. Similarly, Vishwakarma et al. (2018) stated that for a given pulse genotype, seed hardness decreases with increase in moisture content. Decrease in rupture force with increase in moisture content was also reported by Ghasemlou et al. (2010) for green gram and Gharibzahedi et al. (2014) for lentil.



a) b)

Figure 8. Effect of harvest times (a) and seed moisture content (b) on the hardness of lentil seeds (Means followed by different letters are significantly different according to LSD's multiple range test at significance level of 0.05)

Conclusıon

The results of this study showed that a delay of harvest time after physiological maturity significantly influenced the physical and mechanical properties of lentil seeds which are considered as design parameters for food production and description of product quality due to change in moisture content. The diameter, thickness, mass and bulk density decreased with delayed harvest time while sphericity, porosity, true density and hardness of lentil seeds increased with the delay of harvest time.

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