Tarım Bilimleri Dergisi
Tar. Bil. Der.
Dergi web sayfası:
www.agri.ankara.edu.tr/dergi

Journal of Agricultural Sciences
Journal homepage:
www.agri.ankara.edu.tr/journal

TARIM BİLİMLERİ DERGİSİ — JOURNAL OF AGRICULTURAL SCIENCES 23 (2017) 42-52

A Study of Some Physical Properties of Lentil and Wild Oat Weed and Parameters Affecting the Separation of Wild Oat Weed from Lentil by a Gravity Table Separator

Mansour RASEKH[a], Hadi BAGHERI[a], Mohammad Hossien KIANMEHR[b], Shahriar KOURAVAND[b]

[a]*University of Mohaghegh Ardabili, Faculty of Agricultural Technology and Natural Resources, Ardabil, IRAN*

[b]*University of Tehran, College of Abouraihan, Department of Agrotechnology, Tehran, IRAN*

ARTICLE INFO
Research Article
Corresponding Author: Mansour RASEKH, E-mail: dr.mara1349@gmail.com, Tel: +90 (453) 315 20 81
Received: 26 May 2015, Received in Revised Form: 01 November 2015, Accepted: 02 November 2015

ABSTRACT

The present study measured physical properties of lentil and wild oat weed; mass of 1000 seeds, true density, porosity and coefficient of static friction. A gravity table separator was used to separate wild oat weeds from lentil seeds. The gravity table separator had five adjustable parameters; longitudinal slope, latitudinal slope, amplitude of oscillation, frequency of oscillation and air velocity. The effect of these parameters was investigated in order to maximize the separation of wild oat weed from lentil. Results of tests indicated that an increase in latitudinal slope of the table from 0.5° to 1° and longitudinal slope from 1.5° to 2° resulted in increased separation of wild oat weed from lentil. At longitudinal slope of 2°, latitudinal slope of 1°, amplitude of oscillation of 5 mm, frequency of oscillation of 400 cycles min^{-1}, and air velocity of 5.7 m s^{-1}, the separation percentage was 37%. Finally, after determination of the most suitable settings for amplitude of oscillation and air velocity; using the information on longitudinal slope, latitudinal slope and frequency of oscillation of the table was used to calculate mathematical relations of separation percentage of wild oat weed from lentil clumps using Datafit Software.

Keywords: Gravity separator; Physical properties; Lentil; Wild oat

Mercimek ve Yabani Yulaf Tohumlarının Kimi Fiziksel Özellikleri ve Gravite Masa Selektörü ile Yabani Yulaf Tohumlarının Mercimek Tohumlarından Ayrılmasını Etkileyen Özellikler Üzerine Bir Araştırma

ESER BİLGİSİ
Araştırma Makalesi
Sorumlu Yazar: Mansour RASEKH, E-posta: dr.mara1349@gmail.com, Tel: +90 (453) 315 20 81
Geliş Tarihi: 26 Mayıs 2015, Düzeltmelerin Gelişi: 01 Kasım 2015, Kabul: 02 Kasım 2015

ÖZET

Bu çalışmada, mercimek ve yabani yulaf tohumlarının 1000 tane ağırlığı, gerçek yoğunluğu, porozitesi ve statik sürtünme katsayıları belirlenmiştir. Yabani yulaf tohumlarının mercimek tohumlarından ayrılmasında gravite masa selektörü kullanılmıştır. Gravite masa selektörü ayarlanabilir boylam açısı, enlem açısı, amplitüd titreşim, titreşim frekansı ve hava hızı olmak üzere 5 özelliğe sahiptir. Yabani yulaf tohumunun mercimek tohumundan ayrılmasını en iyi hale getirmek üzere bu özelliklerin etkisi araştırılmıştır. Çalışmadan elde edilen sonuçlar masaya göre enlem açısının 0.5° ila 1°, boylam açısının ise 1.5° ila 2° artırılmasının yabani yulaf tohumlarının mercimek tohumlarından ayrılmasını artırdığını göstermiştir. Boylam açısının 2°, enlem açısının 1°, amplitüd titreşimin 5 mm, titreşim frekansının 400 titreşim dak^{-1} ve hava hızının 5.7 m s^{-1} olması durumunda ayırma % 37 olmuştur. Sonuç olarak; en uygun amplitüd titreşim ve hava hızı ayarları belirlendikten sonra enlem ve boylam açı bilgileri Datafit programı kullanılarak yabani yulaf tohumlarının mercimek tohumlarından ayrılmasında matematik ilişkiler hesaplanmıştır.

Anahtar Kelimeler: Gravite selektörü; Fiziksel özellikler; Mercimek; Yabani yulaf

1. Introduction

Lentil (*Lens culinaris medic*) is an important and highly nutritious crop belonging to the family of legumes (Kaur et al 2014). Lentil is cultivated worldwide but competition with weeds is a problem affecting production and can reduce performance by more than 80% (Dhuppar et al 2013; Joshi et al 2013). Wild oat (*Avena ludoviciana*) is a major weed in lentil cultivation. Extensive research has been done to increase the purity of seeds and harvested beans. Some such research established physical and aerodynamic properties of crops. For example, Falconer (2003) reports a comparative study on traditional and modern methods of gravity separation for seed purity developed by a gravity separator. The investigation covered advantages, disadvantages, principles and variables of both methods. The study concluded that selection for the most appropriate separator for specific use should be based on empirical experiments, although analysis of parameters is essential for optimization of the separating operation in continuous production (Falconer 2003). In another study, Hollatz & Quick (2003) reported that feeding rates low, aerodynamic separation of grain from straw happening on the screen and at high feed rate of fine particles in the sieve to form a negative factor, loss of separation increases. In another study, Rasekh (2006) was used a gravity separator apparatus for separating of sunn pest-damaged wheat from undamaged wheat. Influence of (longitudinal and latitudinal slopes, oscillation frequency and amplitude and velocity of air) machine table parameters to obtain of maximum separation of sunn pest-damaged wheat from undamaged wheat have been studies. Results showed that increase of latitudinal slope of table from 0.5° to 2° and reduction of longitudinal slope from 5° to 3°, along the frequency of oscillation 450 cycle min^{-1} and air velocity 8 m s^{-1}, increased separation of sun pest-damaged wheat. In another study, Innocentini et al (2009) were experimentally investigated the dehulling process of cracked soybeans. The mean sauter diameter (d_{vs}) of as-received material was 2.70 mm, with an average proportion of 95% meats and 5% hulls for a moisture content of 11.8%. The true densities of hulls and meats were 1090 and 1267 kg m^{-3}, with d_{vs} of 2.11 and 2.74 mm, respectively. Hulls were mostly elutriated around 2.7-4.5 m s^{-1} and meats around 9.1-13.7 m s^{-1}. The overlap of terminal velocity profiles required a combination of pneumatic and sieving operations for optimized separation. The influence of particle concentration on continuous dehulling was investigated for three solid-to-air ratios (W/Q). The procedure that maximized particle separation was a sequence of pneumatic dehulling with v_s= 7.4-9.1 m s^{-1} and W/Q= 1.05 kg_{solids} $m^{-3}{}_{air}$, followed by screening of lifted material with sieve ASTM no. 6 and a final pneumatic separation of small hulls and meats at v_s= 3.9-4.1 m s^{-1}. An industrial scale pneumatic dehuller was built and tested for W= 6973 kg h^{-1}, v_s= 7.6-8.2 m s^{-1} and W/Q= 0.97 kg_{solids} $m^{-3}{}_{air}$. The efficiency of the pneumatic device to remove hulls from the cracked soybean was very high, with the recovery of meats with purity around 99%. Kashi (2009) managed to separate wild oat weed from wheat by a gravity separator. The device had 5 adjustable parameters (the table settings of latitudinal and longitudinal slope, oscillation frequency, oscillation amplitude and air velocity). It was reported that the maximum level of separation was 56.24% based on settings of longitudinal slope 4°, latitudinal slope 1°, frequency of oscillation of 450 cycles min^{-1}, and oscillation amplitude of 7 mm. Results also showed a significant effect of crop type and humidity level on the physical properties of seeds of wheat and wild oat weed. Kashi (2009) maintained that density values of wild oat weed and wheat were 0.902 and 1.327 g cm^{-3}, respectively and that bulk density evaluations were 0.439 and 0.810, respectively (Kashi 2009). In the research of Mollazade et al (2009) some physical and mechanical properties of cumin seed were obtained as moisture content variations from 7.24% to 21.38% d.b. Their results showed that increasing of moisture content was caused to increase the seed length (5.14 to 5.58 mm), width (1.33 to 1.55 mm), thickness (0.97 to 1.05 mm), arithmetic mean diameter (2.48 to 2.73 mm), and coefficient of static friction on the three surfaces: glass (0.48 to 0.77), galvanized iron sheet (0.36 to 0.73), and plywood (0.57-0.69). However, bulk density was found to decrease from 447.66 to 369.88 kg m^{-3}, and rupture force, rupture energy along with seed length and width were found to decrease from 83.74 to 56.17 N, 132.95 to 84.47 N, 50.66 to 27.52 mJ, and 67.8 to 33.36 mJ, respectively. Many studies have also been done to determine physical and aerodynamic properties of agricultural crops including chickpea (Konak et al 2002), lentil (Amin et al 2004), raw and parboiled paddy (Reddy & Chakravertty 2004), sunflower (Gupta et al 2007), flaxseed (Coskuner & Karababa 2007), kokum (Sonawane1 et al 2014) and wild sunflower seeds (Perez et al 2007). The study of physical properties and separation of wild oat weed from lentil by a gravity separator is of extreme importance. Since no study has been done to date, in this work physical and aerodynamic properties of lentil and wild oat weed are investigated. Also, the effects of different parameters of a gravity separator and their influence on the separation of wild oat weed from lentil seeds are evaluated.

2. Material and Methods

In the present research, lentil samples were taken from farms in Ardebil Province (Bileh-Savar cultivar) and transferred to the seed technology laboratory at the University of Tehran. The initial moisture content of the lentil seeds and wild oat weed was determined by oven drying at 103 °C for 72 h (Bagherpour et al 2010). Physical properties of lentil and wild oat weed were calculated as follows. The mass of 1000 seeds and wild oat weed was measured using a digital balance with a measurement accuracy of 0.01 g. The true density of lentil and wild oat weed (P_t) was determined by the fluid displacement method (toluene) by a certain mass of lentil and wild oat weed and using a graduated cylinder, according to Equation 1 (Varnamkhasti et al 2008).

$$P_t = \frac{m_t}{V_t} \tag{1}$$

Where; P_t, true density (g cm^{-3}); m_t, sample mass (g); V_t , volume of the displaced fluid (cm^3).

The bulk density of lentil and wild oat weed (P_b) was determined by measuring the weight obtained from pouring lentil seeds and wild oat weeds from a height of 15 cm into a 500 mL glass beaker, according to Equation 2 (Owolarafe et al 2007).

$$P_b = \frac{m_b}{V_b} \tag{2}$$

Where; P_b, bulk density (g cm^{-3}); m_b, bulk mass (g); V_b, volume of the used cylinder (cm^3).

The porosity percentage of lentil and wild oat weed was calculated using bulk density and true density from Equation 3 (Aydin 2003).

$$\varepsilon = \left[1 - \frac{P_b}{P_t}\right] \text{x}100 \tag{3}$$

Where; ε, porosity.

The coefficient of static friction of lentil and wild oat weed was measured by an inclinometer and through frictional surfaces of galvanized iron sheet and particle board. The crop bulk was poured into a thin can with no lid or bottom end and placed on a surface. The can edge had no contact with the surface of the table and only the seeds inside were in contact with the surface under investigation. Tilt angle of the surface was increased gradually, where the device slope was measured and read with an accuracy of 1° once the slightest slip was observed in the can containing the materials. The coefficient of static friction was calculated by Equation 4 (Mohsenin 1986).

$$\mu_s = \tan\phi \quad (4)$$

Where; μ_s, coefficient of friction; ϕ, angle of tilt in degrees.

Tests were conducted to evaluate seed properties as follows; weight of 1000 seeds, true density, bulk density, porosity, and coefficient of static friction. Tests were done on lentil seeds and wild oat weed seeds based on a completely random design. The bulk of evaluated lentil had a purity of 68%, whereas wild oat weed accounted for 43% of the external materials together with the lentil bulk. A Laboratory Gravity Separator Type LA-K (Westrup A/S Denmark) was used to separate wild oat weed from lentil seeds (Figure 1). In this machine, table settings were as follows; longitudinal slope parameters (0-6° (in x-axis direction in Figure 2)), latitudinal slope (0-3°), air velocity (0-13.3 m s^{-1}), frequency of oscillation (0-500 cycles min^{-1}), and amplitude of oscillation (5, 7, 9, 11 mm), these settings were all adjustable. Similarly, the instrument had 5 boxes whereby, through proper adjustment, the heavier material was transferred toward the right side of the table (box number 5) and lighter material moved toward the left side (box number 1). Through proper adjustment of the main parameters of the instrument, the wild oat weed seeds were separated from the lentil seeds.

Figure 2 shows that materials of different weights were accommodated in different parts. The materials were poured onto the instrument table from inside the tank. The table height was increased in a positive direction of x (longitudinal slope) and positive direction of y (latitudinal slope). Thus, the right-side higher corner of the table (point S) had

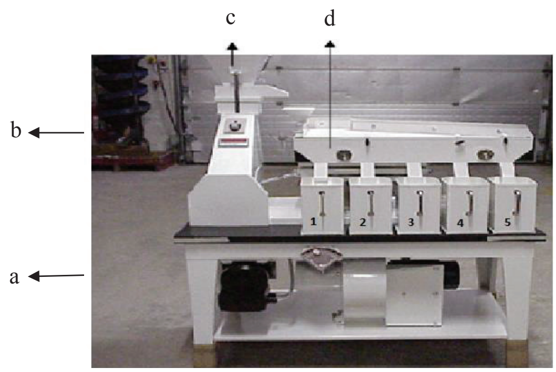

Figure 1- Gravity table separator; a, air velocity; b, frequency of oscillation; c, feeder; d, table surface of gravity separator

Şekil 1- Gravite masa selektörü; a, hava hızı; b, titreşim frekansı; c, besleyici; d, gravite selektörü masa yüzeyi

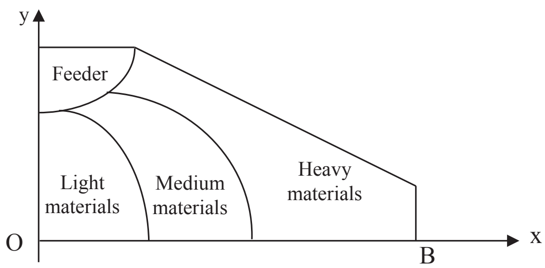

Figure 2- A schematic vertical view of the surface of the table and the approximate range of movement of materials on that surface

Şekil 2- Masa yüzeyinin şematik dikey görünümü ve materyallerin yüzeyde yaklaşık hareket mesafeleri

the maximum height and the left-side lower corner of the table (point O) had the minimum height. The materials were free to leave the table along the OB side. The table had a reciprocating motion along the x-axis and then the underneath airstream hit the materials on the table. In response to table vibration and air force, the lighter materials floated above the heavier materials and were further separated due to longitudinal and latitudinal slopes of the table at the left-side lower corner. The heavier parts remained in contact with the table and were transferred over the longitudinal slope (the right-side lower corner of the table) and were free to leave the table at that point in response to reciprocating motion of the table

In order to determine effects of parameters of table settings longitudinal slope, latitudinal slope and the frequency of oscillation on the separation percentage of wild oat weed from lentil seeds, tests were done according to a fully random, factorial design with the table settings at; latitudinal slope 0.5°, 1°, and 1.5°, longitudinal slope at 1.5°, 1.75°, and 2°, and frequency of oscillation at 380, 400, and 420 cycles min^{-1}. Next, by having the desirable values of the three parameters obtained from this experiment, the instrument was set at the best values of these 3 parameters; longitudinal slope, latitudinal slope, and oscillation frequency. The impact of the parameters related to four air velocity settings of 3.6, 4.5, 5.7, and 6.6 m s^{-1} and two amplitude frequencies of 5 and 7 mm, investigated in a completely randomized design with five replications for each test. In each test, some lentil seeds were collected together with external materials from the output of light seeds (box number 1). Then using an electronic seed counter, five groups of seed which each group containing 100 seeds were counted and selected. Next, each single seed was observed and the average for separation percentage of wild oat weed seeds from lentil seeds was determined for each replication and thus in each test. After determination of the most suitable table settings for amplitude of oscillation and air velocity using the information on longitudinal slope, latitudinal slope, and frequency of oscillation, the relations related to calculation of the separation percentage of wild oat weed from lentil were derived by Datafit Software. Data analysis and comparison of means were done by Dunkin multi-domain mean comparison test using MSTAT-C Software.

3. Results and Discussion

Results for some physical properties of lentil and wild oat weed are shown in Table 1. Also the initial moisture content of the lentil seeds was 9.2% (wb) and wild oat weed was 10.1%.

Table 1 shows the results of the mean comparison data obtained from measuring such some of physical properties as mass of 1000 seeds, true density, bulk density, porosity and coefficient of static friction of lentil seeds and wild oat weed. As the mean mass of 1000 seeds of the lentil seeds had the maximum value (57.3 g) that the reason for this result is that the lentil seeds is larger than wild oat weed, the mean bulk density of the lentil seeds had the maximum value (1.214 g cm^{-3}) that the reasons for this result are more sphericity, more regular grain placement, and smaller holes, the mean true density of the lentil seeds had the maximum value (0.782 g cm^{-3}) that the reason for this result is the difference in cell structure and texture between the lentil seeds and wild oat weed, the mean porosity of wild oat weed had the maximum value (37.2%) that the reason for this result is that wild oat weed had the lower bulk density than lentil seeds, the mean the static coefficient of friction of wild oat weed had the maximum value

Table 1- The results of mean comparison of some physical properties of lentil seeds and wild oat seed

Çizelge 1- Mercimek ve yabani yulaf tohumlarının kimi fiziksel özelliklerine ait ortalama değerler

Physical properties	*Lentil seed*	*Wild oat seed*
Mass of 1000 seeds (g)	57.3 a*	5.69 b
True density (g cm^{-3})	1.214 a	0.857 b
Bulk density (g cm^{-3})	0.782 a	0.538 b
Porosity (%)	35.59 b	37.2 a
Coefficient of static friction (galvanized iron sheet (degrees))	0.39 a	0.32 b
Coefficient of static friction (particle board (degrees))	0.37 b	0.40 a

*, different letters show significant differences at probability level of 1%

for surfaces of galvanized iron sheet (0.40%) and shows that the mean bulk density of the lentil seeds had the maximum value for surfaces of particle board (0.39%) that the reason for the difference in the quality of the frictional contact surfaces is the quality of wild oat weed and lentil seeds, and the different appearance of lentil seeds and wild oat weed. The geometric properties of a variety of products including amaranth seeds and faba bean grains were also examined (Mwithiga & Sifuna 2006; Jannatizadeh et al 2008). Like the results achieved by Bagherpour et al (2010), results of this study showed lentil mass of 1000 seeds (56.1 to 64.1 g), true density (1.194 to 1.330 g cm^{-3}), bulk density (0.68 to 0.79 g cm^{-3}), porosity (40.6 to 43.05%), and coefficient of static friction (galvanized steel (33%) and plywood (17%)) in moisture content from 8% to 20% (wb) (Bagherpour et al 2010).

The results of variance analysis of the factorial design with three factors of table settings; (longitudinal slope at 3 levels, latitudinal slope at 3 levels, and frequency of oscillation of the Table at 3 levels) are demonstrated in Table 2.

Table 2- The results of variance analysis of separation percentage of wild oat weed from lentil with the factors including longitudinal slope, latitudinal slope, and frequency of oscillation

Çizelge 2- Enlem ve boylam açıları ile titreşim frekansı faktörlerine bağlı olarak yabani yulaf tohumlarının mercimek tohumlarından ayrılma oranına ilişkin varyans analiz sonuçları

Source	*Degrees of freedom*	*Mean square*
Longitudinal slope (LO)	2	366.326^{**}
Latitudinal slope (LA)	2	1590.770^{**}
LO X LA	4	35.452^{**}
Frequency of oscillation (F)	2	1353.170^{**}
LO X F	4	24.358^{*}
LA X F	4	94.607^{**}
LO X LA X F	8	12.504^{ns}
Error	108	190
Total	134	

**, significant at P<0.01; *, significant at P<0.05; ns, not significant; CV= 4.8%

Table 2 shows the main effect of table settings; oscillation of frequency, latitudinal slope, and longitudinal slope, the mutual binary effect of latitudinal and longitudinal slope, the mutual binary effect of the latitudinal slope and the frequency of oscillation significant at a 1% and the mutual binary effect of the longitudinal slope and the frequency of oscillation significant at a 5%. However, the mutual triple effect of oscillation frequency, longitudinal slope, and latitudinal slope was not significant. Figure 3 demonstrates the mean comparison of two-fold interactive effects (the mutual binary effect of longitudinal and latitudinal slope of the table, the mutual binary effect of longitudinal and frequency of oscillation, and the mutual binary effect of latitudinal slope and frequency of oscillation).

Figure 3 illustrates that increased longitudinal slope from 1.5 to 2°, increased latitudinal slope from 0.5 to 1°, and elevated frequency of oscillation from 380 to 400 cycles min^{-1} resulted in the development of separation percentage of wild oat weed along with lentil seeds. This was evident under all circumstances. The conditions were, frequency of oscillation was set at 400 cycles min^{-1}, longitudinal slope was 2°, and latitudinal slope was 1°, the distribution of materials on the table was more homogeneous and resulted in better flotation of wild oat weed and lentil seeds and thus led to increased separation by the gravity separator. Furthermore, at the frequency of 420 cycles min^{-1}, movement of seeds on the table surface was not homogenous, demonstrating decreased separation compared with the frequency of 400 cycles min^{-1} because of disturbance in the movement of materials on the surface of the table. The results shown in Figure 3 demonstrate that at settings of longitudinal slope of 2°, latitudinal slope 1°, and frequency of oscillation 400 cycles min^{-1}, the maximum separation was 37%. Results of Rasekh (2006) showed demonstrate that at settings of increase of latitudinal slope of table from 0.5° to 2° and reduction of longitudinal slope from 5° to 3°, along the frequency of oscillation 450 cycle min^{-1} and air velocity 8 m s^{-1}, increased separation percentage of sun pest-damaged wheat (Rasekh 2006).

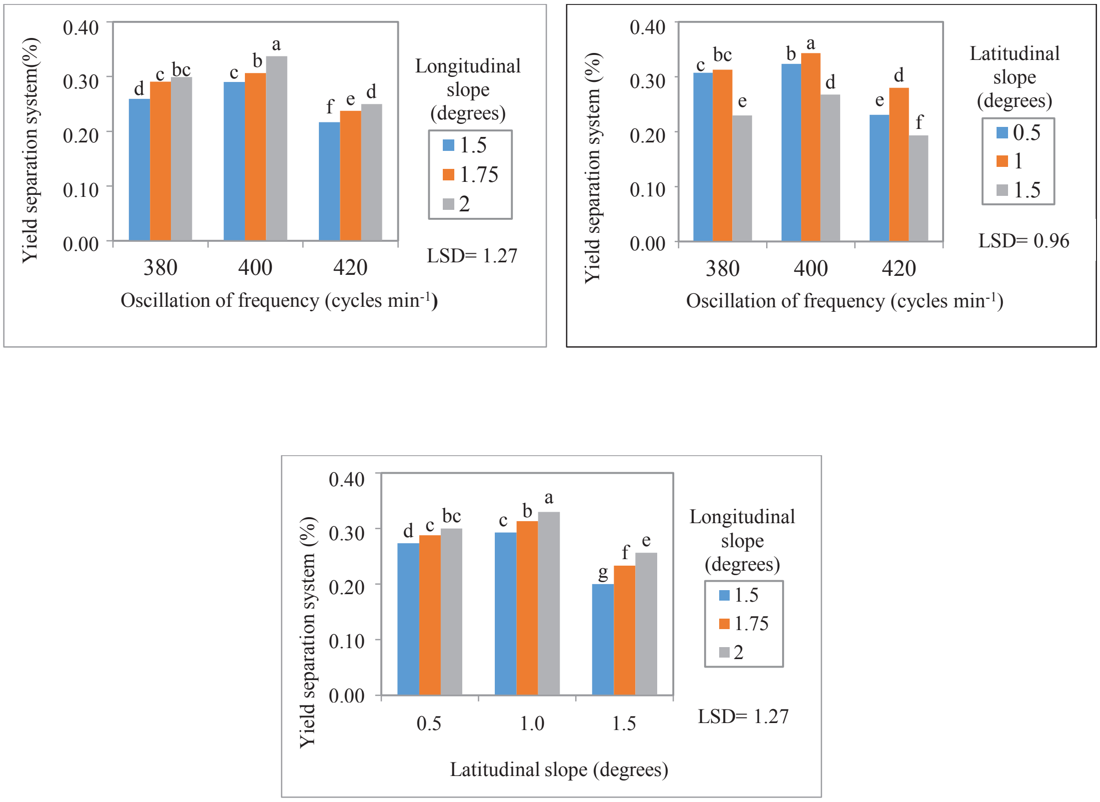

Figure 3- The results of the mean comparison of mutual binary effects; a, longitudinal slope and frequency of oscillation; b, latitudinal slope and frequency of oscillation; c, longitudinal slope and latitudinal

Şekil 3- Karşılıklı ikili değerlerin karşılaştırma sonuçları; a, boylam açısı ve titreşim sıklığı; b, enlem açısı ve titreim sıklığı; c, boylam açısı ve enlem açısı

The results of variance analysis of factorial design with two factors; table oscillation at two levels of 5 and 7 mm, and air velocity at 4 levels, 3.6, 4.5, 5.7 and 6.6 m s^{-1} and at optimal conditions, the longitudinal slope of 2°, latitudinal slope of 1°, and frequency of oscillation of 400 cycles min^{-1}, at the completely randomized design at 5 replications, are indicated in Table 3.

Table 3 clarifies that the main impact of table settings for air velocity and amplitude of oscillation together with the dual interactive effects of air velocity and amplitude of oscillation was significant at 1% level.

Table 3- The results of variance analysis of separation percentage of wild oat weed from lentil with the factors of air velocity and amplitude of oscillation

Çizelge 3- Hava hızı ve amplitüd titreşime bağlı olarak yabani yulaf tohumlarının mercimek tohumlarından ayrılma oranına ilişkin varyans analizi sonuçları

Source	*Degree of freedom*	*Mean square*
Amplitude of oscillation (AO)	1	164.0**
Air velocity (AV)	3	2147.7**
AV X AO	3	1544.5**
Error	32	86.8
Total	39	

**, significant at less than 1% probability level; CV= 7.76%

Figure 4 shows the results of means comparison of the dual impact of air velocity and the amplitude of oscillation of the table.

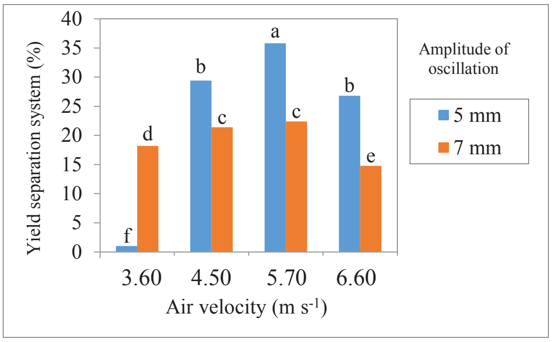

Figure 4- The results of the mean comparison of mutual binary effects of air velocity and the amplitude of oscillation of the table for separation percentage of wild oat weed from lentil, LSD= 2.85

Şekil 4- Hava hızı ve amplitude titreşim karşılaştırma sonuçlarına göre yabani yulaf tohumlarının mercimek tohumlarından tohumlarından ayrılma oranı, LSD= 2.85

Figure 4 demonstrates that the best settings for air velocity and amplitude of oscillation for separation of wild oat weed from lentil seeds were 5.7 m s^{-1} and 5 mm, respectively. This was is due to the fact that under the stated conditions, distribution of seeds on the surface of the table (the height of seeds on the table) was more homogenous, because first, negative impact of the mutual triple effect of length, slope and frequency was the lowest and second, for a longer time on the surface of the table, thus the distribution of materials on the table Therefore, in response to the wind force blown on to the seeds from under the table, the flotation improved, and in turn, resulted in increased separation of wild oat weed from lentil seeds. Note that at the amplitude of oscillation of 7 mm, transference of materials towards the right side of the table output edge was halted and the surface of the table was not fully covered by the fed materials, this deceased separation. Results of Kashi (2009) showed that maximum level of separation of wild oat weed from wheat occurred under the mentioned conditions (the longitudinal slope of table 4°, latitudinal slope of table 2°, frequency of oscillation 450 cycle min^{-1}, air velocity 5.7 m s^{-1} and amplitude of oscillation of 7 mm) (Kashi 2009).

Figure 5 and 6 show results obtained from the values of air velocity (5.7 m s^{-1}), amplitude of oscillation (5 mm), frequency of oscillation (380, 400, and 420 cycles min^{-1}), longitudinal slope (1.5, 1.75, and 2°), and latitudinal slope (0.5, 1, and 1.5°), together with the most suitable mathematical relation, for determination of the separation percentage of wild oat weed from the lentil using Datafit Software.

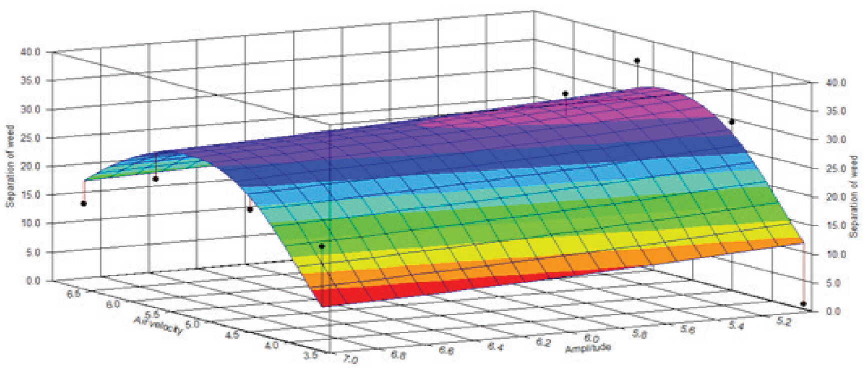

Figure 5- The extent of separation of wild oat weed from lentil bulk with air velocity and amplitude of oscillation of the table

Şekil 5- Amplitüd titreşimi ve hava hızına göre yabani yulaf tohumlarının mercimek tohumlarından ayrılma durumu

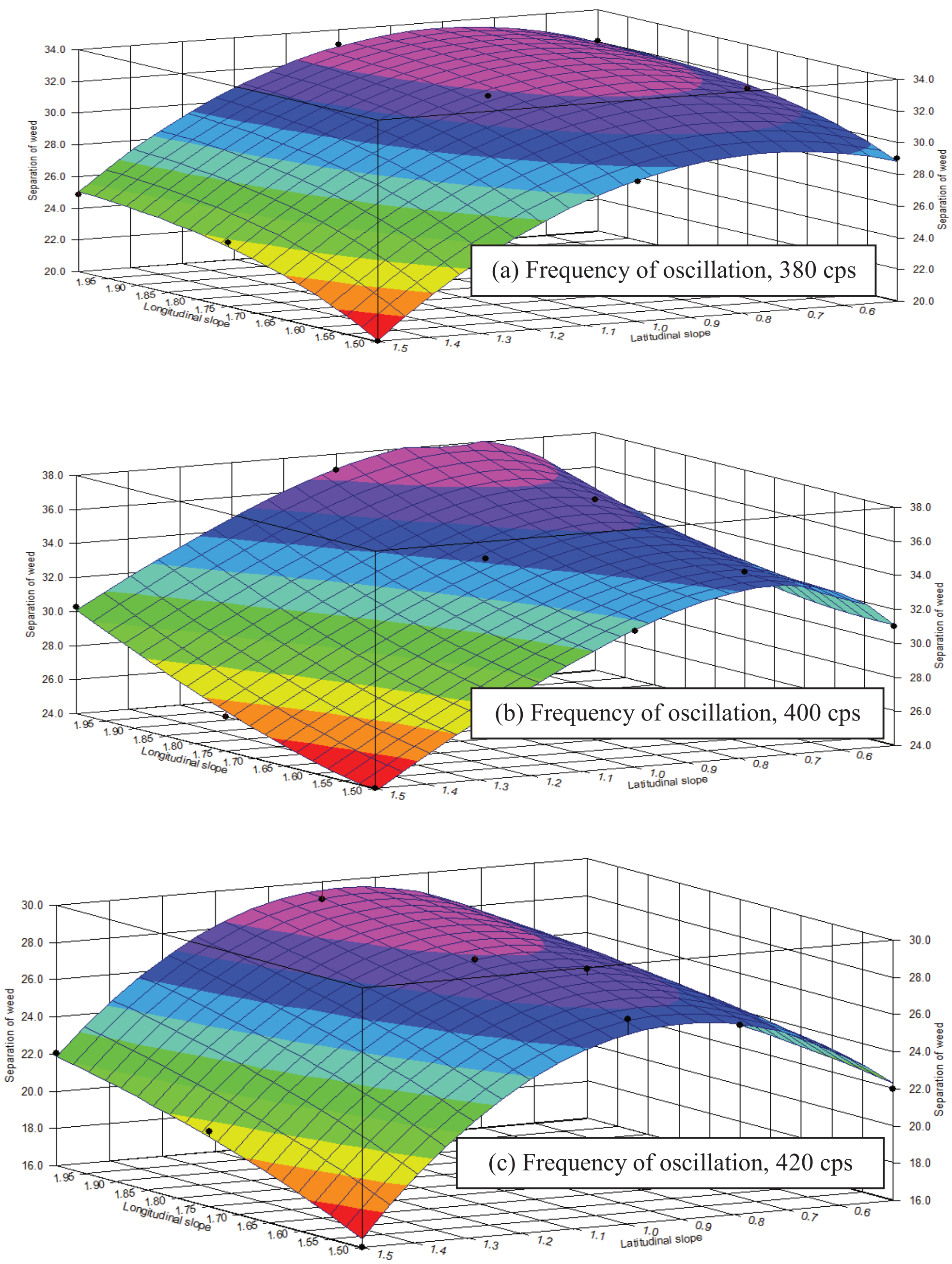

Figure 6- The extent of separation of wild oat weed from the lentil bulk with the longitudinal and latitudinal slopes under the conditions oscillation of frequency of the table

Şekil 6- Titreşim frekansına bağlı olarak enlem ve boylam açılarına göre yabani yulaf tohumlarının mercimek tohumlarından ayrılma durumu

Figure 5 shows that amplitude of oscillation (5 mm) and air velocity (5.7 m s^{-1}) resulted in increased separation of wild oat weed from the lentil bulk.

Similarly, Figure 6 (a-c), indicate that increased longitudinal slope from 1.5° to 2°, latitudinal slope from 0.5°-1°, and frequency of oscillation from 380 to 400 cycles min^{-1} led to better separation of wild oat weed from the lentil bulk. The results Figure 5 and Figure 6, shown demonstrate that at settings of air velocity 5.7 m s^{-1}, amplitude of oscillation 5 mm, frequency of oscillation 400 cycles min^{-1}, longitudinal slope 2°, and latitudinal slope 1°, the maximum separation percentage of wild oat weed from lentil bulk was 37%. This was is due to the fact that under the stated conditions, distribution of seeds on the surface of the table was more homogenous. Therefore, in response to the wind force blown on to the seeds from under the table, the flotation improved, and in turn, resulted in increased separation of wild oat weed from lentil seeds. Results of Rasekh (2006) showed that under the mentioned conditions (dimensionless number $\frac{V}{a\omega} = 152.3$ (A dimensionless number ($V/a\omega$) which shows ration of intertie force of air current blown to lentil to force arising from oscillation, was considered in ratio of separation.), latitudinal slope of table 2° and longitudinal slope 3°) the maximum separating percentage of sunnpest-damaged wheat from undamaged wheat was 95.14% (Rasekh 2006).

Table 4 summarizes the mathematical models predicted under different conditions of longitudinal slope of table (x_1), latitudinal slope of table (x_2), oscillation of frequency of table, amplitude of oscillation of table (x_3), and air velocity (x_4) with a high determination of coefficient.

4. Conclusions

Physical properties obtained for lentil were as follows; weight of 1000 seeds (57.03 g), true density (1.214 g cm^{-3}), bulk density (0.782 g cm^{-3}), coefficient of static friction (galvanized iron sheet (0.394 degrees) and particle board (0.37 degrees)), porosity (35.59%), and the wild oat weed including weight of 1000 seeds (5.69 g), true density (0.857 g cm^{-3}), bulk density (0.538 g cm^{-3}), coefficient of static friction (galvanized iron sheet (0.32 degrees) and particle board (0.40 degrees)), porosity (37.2%).

Table 4- The predicted mathematical models (longitudinal slope (x_1), latitudinal slope (x_2), air velocity (x_3) and amplitude of oscillation (x_4))

Çizelge 4- Boylam açısı (x_1), enlem açısı (x_2), hava hızı (x_3) ve amplitüd titreşimini (x_4) tahmin için matematik modeler

		Predicted mathematical models	*R^2*
Amplitude of oscillation (mm) and air velocity (m s^{-1})		$Y = -392.1 + \frac{5475.7}{x_4} - \frac{23505.9}{x_4^2} + \frac{31830.8}{x_4^3} + \frac{70.87}{x_3}$	0.60
Frequency of oscillation (cycles min^{-1})	380	$Y = 13.1 + \frac{132.6}{x_1} + 34.1\,x_2 - \frac{124.6}{x_1^2} - 17.7\,x_2^2 - 11\frac{x_2}{x_1}$	0.99
	400	$Y = 46.85 - 24.3\,x_1 - 19.6\,(\ln(x_2)) + 9.6x_1^2 - 20.1\,(\ln(x_2^2)) = 4.9\,x_1(\ln(x_1))$	0.99
	420	$Y = -5.9 + \frac{32.1}{x_1} + 64.7\,x_2 - \frac{23.8}{x_1^2} - 27.2\,x_2^2 - 24.3\frac{x_2}{x_1}$	0.98

Increased latitudinal slope of the table from 0.5° to 1° and longitudinal slope of table from 1.5° to 2° result in increased separation percentage of wild oat weed from lentil seeds.

Under the mentioned conditions (oscillation frequency setting of 400 cycle min^{-1}, amplitude of oscillation of the Figure 3 mm, air velocity 5.7 m s^{-1}, latitudinal slope 1° and longitudinal slope 2°), the maximum separation percentage was 37%. In this case, the output lentil seeds contained the least amount of wild oat weeds.

References

Amin M N, Hussein M A & Roy K C (2004). Effects of moisture content on some physical properties of lentil seeds. *Journal of Food Engineering* **65**(1): 83-87

Aydin C (2003). Physical properties of almond nut and kernel. *Journal of Food Engineering* **60**(3): 315-320

Bagherpour H, Minaei S & Khoshtaghaza M H (2010). Selected physico-mechanical properties of lentil seed. *International Agrophysics* **24**(1): 81-84

Coskuner Y & Karababa E (2007). Some physical properties of flax seed (*Linum usitatissimum* L.). *Journal of Food Engineering* **78**(3): 1067-1073

Dhuppar P, Gupta A & Rao D S (2013). Chemical weed management in lentil. *Indian Journal of Weed Science* **45**(3): 189-191

Falconer A (2003). Gravity separation: Old technique/ new methods. *Physical Separation in Science and Engineering* **12**(1): 31-48

Gupta R K, Gopika A & Sharma R (2007). Aerodynamic properties of sunflower seed. *Journal of Food Engineering* **79**(3): 899-904

Hollatz B & Quick G R (2003). Combine tailings returns, part 1: the effects of combine performance and settings on tailings. In: e- Proceedings of the International Conference on Crop Harvesting and Processing. Kentucky USA. ASAE Publication Number 701P1103e. St Joseph, Mich. ASAE

Innocentini M D M, Barizan W S, Alves M N O & Pisani Jr R (2009). Pneumatic separation of hulls and meats from cracked soybeans. *Food and Bioproducts Processing* **87**(4): 237-246

Jannatizadeh A, Naderi Boldaji M, Fatahi R, Ghasemi Varnamkhasti M & Tabatabaeefar A (2008). Some postharvest physical properties of Iranian apricot (*Prunus armeniaca* L.) fruit. *International Agrophysics* **22**(2): 125-131

Joshi M, Aldred P, McKnight S, Panozzo J F, Kasapis S, Adhikari R & Adhikari B (2013). Physicochemical and functional characteristics of lentil starch. *Carbohydrate Polymers* **92**(2): 1484-1496

Kashi M (2009). Investigate the possibility of separation the wheat from wild oats by gravity separator. Master's Thesis, Ardebil University (Unpublished), IRAN

Kaur S, Cogan N, Stephens A, Noy D, Butsch M, Forster J & Materne M (2014). EST-SNP discovery and dense genetic mapping in lentil (*Lens culinaris* Medik.) enable candidate gene selection for boron tolerance. *Theoretical and Applied Genetics* **127**(3): 703-713

Konak M, Carman K & Aydin C (2002). Physical properties of chick pea seeds. *Biosystems Engineering* **82**(1): 73-78

Mohsenin N N (1986). Physical Properties of Plant and Animal Materials. Gordon and Breach Science Publishers, New York

Mollazade K, Ahmadi H, Khorshidi J, Rajabipour A & Mohtasebi S S (2009). Moisture-dependent physical and mechanical properties of cumin (*Cuminum cyminum* L.) seed. *International Journal of Agricultural and Biological Engineering* **2**(2): 49-56

Mwithiga G & Sifuna M M (2006). Effect of moisture content on the physical properties of three varieties of sorghum seeds. *Journal of Food Engineering* **75**(4): 480-486

Owolarafe O K, Olabige M T & Faborode M O (2007). Physical and mechanical properties of two varieties of fresh oil palm fruit. *Journal of Food Engineering* **78**(4): 1228-1232

Perez E E, Crapiste G H & Carelli A A (2007). Some physical and morphological properties of wild sunflower seeds. *Biosystems Engineering* **96**(1): 41-45

Rasekh M (2006). Effective parameters in gravity separator apparatus of sunn pest-damaged wheat. Faculty of Agriculture, Tarbiat Modares University, Tehran, IRAN

Reddy B S & Chakraverty A (2004). Physical properties of raw and parboiled paddy. *Biosystems Engineering* **88**(4): 461-466

Sonawane S P, Sharma G P, Thakor N J & Verma R C (2014). Moisture-dependent physical properties of kokum seed (*Garcinia indica* Choisy). *Research in Agricultural Engineering* **60**(2): 75-82

Varnamkhasti M G, Mobli H, Jafari A, Keyhani A R, Soltanabadi M H, Rafiee S & Kheiralipour K (2008). Some physical properties of rough rice (*Oryza sativa* L.) grain. *Journal of Cereal Science* **47**(3): 496-501