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Effects of Moisture Content on Selected Physical and Mechanical Properties of Alfalfa Seeds

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Abstract
Alfalfa is one of the most widely planted forage legume in the world and that because of its tolerance, adaptation, high yield and nutritious value. Physico-mechanical properties of alfalfa seed are very crucial in the machine designing and processing operations. In this study, some of the physical and mechanical properties of alfalfa seed cultivar were investigated under laboratory condition, as desired for the design of a metering device. Seven moisture contents were introduced to the initial content of 7.98%, d.b. The geometric and gravimetric characteristics were determined. Correlation equation models were developed based on the function of moisture contents. The means average parameter values of the length, width, thickness, aspect ratio, seed mass, arithmetic, geometric mean diameter, true and bulk density, porosity seed volume, and surface area ranged between 2.356 to 2.718mm, 1.390 to 1.473mm, 1.071 to 1.345mm, 0.68 to 0.776%, 1.7968 to 2.295g, 1.466 to 1.589mm, 1.141 to 1.517mm and 1.466 to 1.589g/cm^{3}1.199 to 0.830g/cm^3, 0.10 to 0.44%, 0.7383 to 0.79426, and 6.305 to 7.2438mm^2, respectively. While, the plywood surface had the highest value of the coefficient of friction as the roughest, followed by polished steel and rubber, glass the least surface roughness. However, the germination rate (%) increased as seed damages decreased, as the coefficient of internal friction decreases from 0.127 to 0.095, while the cohesion increasing from 2.11 to 5.95. The angle of repose resulted in a non-linear increase from 27.05^o to 28.68^o, 28.86^o to 29.86^o, 31.49^o to 32.35^o, and 32.47^o to 33.21^o as moisture content increased from7.98 to 22.12% d.b.
Keywords: alfalfa seed, moisture content, mechanical property, physical property

1. Introduction

Development of seeding machinery often relied on seed physical characteristics of agricultural crops. Alfalfa (Medicago Sativa) is a perennial legume plant known as small seeded crop, rich of protein sources fodder, with a dominant shoot buds on crown enabling it re-growing after harvesting or grazing, tolerant to water stress, widely grown on approximately 30 million hectares worldwide , thus alfalfa growing area is rapidly increasing corresponding to expansion of the dairy industry in the past few decades (Anderson, 2017).

The physical properties, such as length, width, thickness, bulk and true density, 1000 seed weight, surface area, and sphericity, are basic characteristic parameters for optimization and design of internal run roller plate seed metering structure. Information on physical properties can be valuable for plant breeders, engineers, scientists, and seed industries experts, machine designers, processing structures and controls; and to determining machine performance efficiency. Variation in grain properties caused by the genetic pattern, environmental conditions or handling may influence the processing and utilization of seed. Physical characteristics of alfalfa seed can be affected during harvest at high moisture content, by postharvest handling, and by drying air temperatures (Sangamithra et al., 2016).

Physical properties of field crops including alfalfa, peanuts, and rice have been investigated previously by a number of research studies (Davies 2009; Ghorbani et al., 2012). Recently, alfalfa seed sorting and harvesting machinery were investigated by Junjun, (2017).In addition, designing and developing equipment and structures for transporting, handling, processing, storage and seed quality were also reported (Yalçın et al., 2007).

Most of the alfalfa seeding machines obtain a high volume rate and mechanical precision, and semi-precision plating technology are challenged by a nasty germination rate as a result of seeds crushing and damage. According to Yu et al. (2016), high seeds damage and inefficiency of various seeding machinery were attributed to some dynamic and the mechanical reasons. To develop a reliable machinery type, design, and manufacturing model package, the moisture content of alfalfa seeds as a critical aspect must be considered for effective and efficient seeding. The present study is an attempt to optimize the moisture content of alfalfa seed based on the physical and mechanical properties under laboratory condition. The levels of moisture content were selected based on the handling and processing operations. The findings of this study could be used for developing engineering models to optimize the accuracy of metering device techniques.

2. Material and methods

2.1 Experiment design

The experimental layout was in randomized complement block design (RCBD). The experiments were performed on alfalfa seeds. Eight moisture content groups of 7.98, 10, 12.12, 14.12, 16.12, 18.12, 20.12 and 22.12% d.b, with three replications per each moisture level.

2.2 Seed sampling and moisture content scaling

The alfalfa (Medicago Sativa) seeds used in this study was collected from Shandong province (Shandong seed Co. Ltd, China), harvested in 2016. The samples were selected, cleaned and sorted, then stored at normal room temperature, and the initial seed moisture content was 7.98% (d.b), obtained by drying samples at 104oC for 24 hours (ASABE, 2012).

The sample moisture content was controlled to seven different desired water content levels by adding distilled water, as reported by (Hossein Mirzabe et al., 2017). The mass of water to be added was calculated as follows:

$$\mathrm{Mc_Q} = \frac{\mathrm{W_{si}(M_R - M_E)}}{(100 - \mathrm{M_R})}$$

Where: Mc_Q is the mass of water to be added (g), Wsi is initial weight of the sample (g), ME is the initial moisture content %, (d.b), MR is the desired moisture content % (d.b).

Then, seeds were kept in well-sealed polyethylene bags at 5oC for 10 days to attain uniform moisture content. The samples needed for testing were removed from the refrigerator and kept at room temperature for at least 2 hours (Sangamithra et al., 2016).

The final seven moisture contents of 10, 12.12, 14.12, 16.12, 18.12, 20.12 and 22.12 % (d.b), were introduced. then from the selected portion randomly selection was conducted and measurements were carried out.

2.3 Physical properties

Studying the physical properties of alfalfa seeds aims to determine the effect of dependent moisture content on seeds parameters as such of length, width, thickness, aspect ratio, seed mass, arithmetic, geometric mean diameter, true and bulk density, porosity seed volume, surface area and static coefficient of friction. However, the seed turnings occurred were observed, which form the bases for describing some of the consequences of particular moisture influences, and provide a basis for predicting the outcome.

2.3.1 Seed dimensions and seed mass

A vernier caliper with the accuracy of 0.001mm was used to measure the seed dimensions namely; length (XL), width (YW) and thickness (ZT). 200 seeds were randomly picked (Figure1). The average values of seed dimensions, the arithmetic, and geometric mean diameter was obtained. However, the sensitive balance of 0.001g is introduced, as the 250 alfalfa grains were counted, weighted and extrapolating to the mass to 1000 seeds mass.

The arithmetic mean diameter (Amd) and geometric mean diameter (Gmd) of the alfalfa seed were obtained by using the following relationship reported by (R M Davies, 2009)

$$A_{md} = 0.333\,(X_L + Y_W + Z_T)$$
$$G_{md} = (X_L Y_W Z_T)^{\,0.333}$$

Where A_{md} and G_{md} are arithmetic and geometric mean diameter (mm), respectively, X_L, Y_W and Z_T are the length, width, and Thickness (mm), respectively (Jilani, Wyk and Cruywagen, 2009).

2.3.2 Sphericity

The sphericity was calculated by applying the mathematical relationship of geometric mean diameter divided by the length, recommended by (Khazaei, *et al.,* 2008)., as follows:

$$\varphi = G\_md/X\_L$$

Where: Ø is the sphericity (%).

2.3.3 Surface area and volume

The surface area and volume were calculated with a sphere of same geometric mean diameter (Chavoshgoli *et al.*, 2015), by using the following expressions:

$$S_a = \pi\,(G_{md})^2 \qquad Vu = 0.167(X_L + Y_W + Z_T)$$

Where S_a *and* V are the surface area (mm^2) and unit volume (mm^3), respectively.

2.3.4 Bulk density and true density

According to Özgüven et al., (2005) and Milani et al., (2007). A container with known volume was used to obtain the bulk density, the container was filled with alfalfa seeds sample, then was weighed. The mass of the container was subtracted to get the mass of alfalfa seeds. The bulk density (Pb) was calculated by the ratio of the mass of alfalfa seeds and volume of therconthe tainer (Sangamithra et al., 2016).

The true density (Pt) is the ratio between the mass of the sample and the true volume of the samples, as described by Mohsenin (1986).

Dobrzański et al., (2013) and Varnamkhasti et al., (2007). The toluene displacement method in which a known weight of seed sample has been submerged into a known volume of toluene and then the density has been calculated by recording the value of the change in volume

2.3.5 Porosity

The porosity can be calculated by using the following relationship reported by Asoegwu et al. (2006).:

$$\epsilon = (1 - \mathrm{Pb/Pt}).100$$

Where: ϵ is the porosity (%).

2.3.6 Coefficient of static friction

The static friction coefficient of alfalfa seed was determined with regards to four different surfaces (plywood, polished steel, rubber, and glass). An individual seed was placed on the surface and gradually until the seed starts to slide, The coefficient of static friction (μ) was determined by the following equation (Ghorbani, Hemmat and Masoumi, 2012):

$$\mu = \tan \alpha$$

Where μ, α are cthe oefficient of static friction and angle of filling.

2.4 Mechanical properties

examining the mechanical properties of alfalfa seeds intended to determine the effect of moisture content clout on forces, potential energy, kinetic friction, the angle of repose (filling angle), the coefficient of internal friction, cohesion to steel surface and loading compression. However, seed damages occurred were observed, as the germination tests were carried, findings of particular moisture influences, and provide a baseline for predicting the outcome.

2.4.1 Compression property.

Loading compression test at alfalfa seeds aiming to identify the applied forces may be expected between seeds and seeds the material surface produced by the metering device that causes seed lost on the metering device, as results of crushing and seed damage

- **Loading compression.**

The universal test machine was used in this test; the grain was placed between two metal jaws. The upper moveable jaw approached the bottom fixed jaw with 10 mm.min-1 speed. The shear forces applied on the grains were measured by an electric load cell ranged between 5 to 17 N and under real-time condition. The data are recorded on computer and automatically appeared in form of the displacement-force graph.

- **Seed germination test**

Alfalfa seeds are very small and crisp when subjected to a little load can cause damage. therefore, to determine the impacts of loading forces on alfalfa seeds, the seeds were placed under five different compression loading forces ranged between 5 - 17N at speed of 10mm/sec, then germination tests were conducted on the same seeds, as moisture contents increase from 7.98 to 22.12% d.b.

2.4.2 Angle of repose

The angle of repose alfalfa seeds was determined at a various moisture content of 8 to 20% d.b. The funnel of a 20ml letter filled with alfalfa seed and sealed, then placed on stand vertically fitted and positioned downward at 10 cm height from the surface, the seal was carefully disclosed allow smooth flow of seeds, then seed piles were established for each moisture level.

2.4.3 Coefficient of internal friction and cohesion

In the paper, the coefficient of internal friction and cohesion of the alfalfa seeds were measured by a friction device. The device of friction force measuring was formed by a metal box, a friction surface, and an electronic. Friction force was measured with a load cell, converted by the (ELE international digital converter) and the data were recorded in a computer.

The coefficient of friction (μ) is defined as the ratio between the measured friction force (F) and normal force (N). The maximum value of the friction force was obtained when the box started operating. This value was used to calculate the static coefficient of friction. While the box continued to slide on the friction surface at 2m/s velocity, the dynamic coefficient of friction (average value) was measured.

The experiments were conducted using friction surfaces of steel. For each experiment, the sample box was emptied and refilled with a different sample of the various moisture contents(Altuntas and Erkol, 2010).

$$\tau = \mu_s \sigma + C$$

2.4.4Statistical analysis

SSPS statistical program was used; One-way ANOVA was applied to determine the significant differences between seed physical and mechanical properties as a function of moisture content effects on alfalfa seed Duncan significant difference was for multiple mean comparisons.

3. Results and discussion

3.1 Seed dimensions and geometric parameters

The seed dimensions variation characterized by moisture content increase from 7.98 to 22.12% d.b, as revealed in Figure 2. The means seed dimensions ranged from 2.04 to 2.38 mm, 1.25 to 1.42 mm, and 0.98 to 1.16 mm, with an expansion, increase average values of 16.7, 13.6 and 18.4% along the length, width and thickness respectively. Differences between these values were significant at P < 0.05. The highest expansion was observed along the thickness and length, width shows the least value. These results could illustrate the isomerism seeds shapes and cells arrangement.

The following equations were modeled for length(X_L), width (Y_W) and thickness (Z_T) of alfalfa seeds with moisture content (M_c):

$$X_L = 0.0240\, M_c + 1.8357, (R^2 = 0.929)$$

$$Y_W = 0.0361\, M_c + 0.8554, (R^2 = 0.974)$$

$$Z_T = 0.0192\, M_c + 0.9538, (R^2 = 0.979)$$

Therefore the arithmetic and the geometric mean diameter of alfalfa seeds were shown in Table 1. The mean values mean diameters ranged between 1.03 to 1.58mm and 1.42 to 1.48mm for arithmetic and geometric respectively. The mean equivalent increased linearly with increase in moisture content arrangement P < 0.05.

Therefore the arithmetic and the geometric mean diameter of alfalfa seeds were shown in Table 1. The mean values mean diameters ranged between 1.03 to 1.58mm and 1.42 to 1.48mm for arithmetic and geometric respectively. The mean equivalent increased linearly with increase in moisture content arrangement P < 0.05.

The relationship between the arithmetic (A_{md}) and geometric (G_{md}) mean diameter of alfalfa seed as expressed in regression formula as follow:

$$A_{md} = 0.011M_c + 1.3580, (R^2 = 0.843)$$

$$G_{md} = 0.005M_c + 1.3540, (R^2 = 0.875)$$

The similar results were found between alfalfa seeds, Maringa oliefera seed, Barely grains, and rough rice grain, reported Adejumo et al. (2012); Sologubik et al.(2013), Khanali et al. (2012), respectively. The information's of alfalfa seeds parameters obtained at the particular moisture content and its influences on seed particle size can be used for appropriate machine design and development of metering devices.

Table 1: Statically mean values of arithmetic (Amd), geometric mean diameter (Gmd), Sphericity, aspect ratio and unit volume of alfalfa seed at moisture content ranged 7.98 to 22.12% (d.b)

Moisture content %, d.b	A_{nd} (mm)	G_{md} (mm)	ϕ (%)	Sa (mm^2)	Vu (mm^3)
7.98	1.466±0.16[a]	1.410±0.05[a]	0.610±0.02[c]	6.305±0.40[a]	0.7383±0.08[a]
10.00	1.476±0.09[a]	1.415±0.02[a]	0.630±0.03[ab]	6.308±0.20[a]	0.7412±0.04[a]
12.12	1.493±0.17[a]	1.417±0.04[a]	0.671±0.01[ab]	6.355±0.36[a]	0.7418±0.07[a]
14.12	1.498±0.10[a]	1.428±0.03[a]	0.675±0.02[a]	6.452±0.38[a]	0.7474±0.07[a]
16.12	1.537±0.15[a]	1.435±0.04[a]	0.680±0.02[a]	6.533±0.43[a]	0.7516±0.07[a]
18.12	1.548±0.01[a]	1.469±0.03[a]	0.685±0.01[a]	6.883±0.24[a]	0.7691±0.04[a]
20.12	1.576±0.11[a]	1.478±0.01[a]	0.692±0.02[a]	7.483±0.23[a]	0.7739±0.04[a]
22.12	1.589±0.16[a]	1.517±0.05[a]	0.696±0.02[a]	7.533±0.24[a]	0.7942±0.05[a]

The means with a significant level at P < 0.05 according to Duncan's multiple ranges

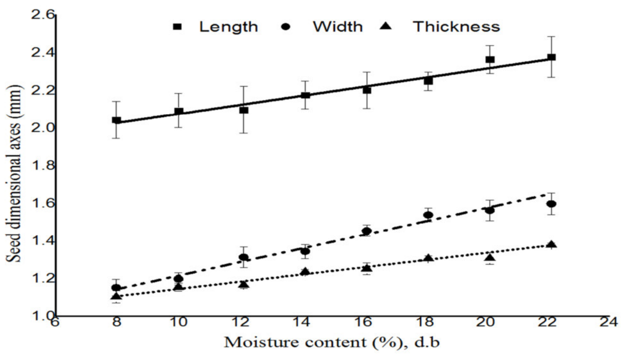

Figure.2: Effect of moisture content on alfalfa axial dimensions

4. Aspect ratio, surface area, unit volume and sphericity

The aspect ratio, surface area, unit volume, and sphericity increased displayed in Table1. The average values were ranged between 1.6283 to 6.7696, 6.3051 to 6.5331mm2, 0.7383 to 0.7942mm3 and 0.6104 to 0.6959% for aspect ratio, surface area, unit volume, and sphericity respectively. The parameters values were linearly increased, although no significant difference was found between the aspect ratio, surface area, and unit volume the parameters, while the sphericity had shown a level of significant at P<0.05 as moisture content increased.

The relationship between the aspect ratio, surface area (S_a), unit volume(V_u), and sphericity(∅) and an increase in moisture content can be indecated as follows:

$S_a = 0.1081M_c + 5.2418, \quad (R^2 = 0.9512)$

$V_u = 0.0036M_c + 0.7028, \quad (R^2 = 0.8883)$

$\emptyset = 0.0060M_c + 0.5748, \quad (R^2 = 0.8698)$

Where: Ra, Sa, Vu, and Ø are aspect ratio, surface area, unit volume and sphericity respectively

The similar results were stated by Yalçin and Özarslan (2004) for vetch seed, Altuntaş et al. (2005) for fenugreek seeds, Sharma et al. (2011) for Tung seed, Khanal et al. (2012) for rough rice grains and Dursun et al. (2007) for sugar-beet seed, Koocheki et al., (2007) for watermelon seeds, Tarighi et al. (2010) for sunflower seeds, Balasubramanian et al (2012) for coriander seeds, for alfalfa seed, harvesting device for alfalfa, Junjun (2017), and Perez et al. (2007) for wild sunflower seeds respectively.

The information's obtained for the aspect ratio, surface area, unit volume, and sphericity are very substantial and useful for the calculation particle size, shape and compressibility of alfalfa seeds at given moisture content.

3.3 Seed mass

The mean one-thousand seed mass of alfalfa seed was shown in the Figure3. The average values ranged from 1.787g to 2.582g. Showed a linear increasing tendency as moisture contents increased from 7.89% to 22.12% d.b. Difference between the seed masses was significantly found at P <0.05.

The linear relationship can be expressed in the equation as follows:

$M_{1000} = 0.03151M_c + 1.6346, (R^2 = 0.870)$

A similar result presented by Tarighi, Saeid Mohtasebi and Mahmoodi, (2010) for safflower seeds var (Darab); Aviara, Ibrahim and Onuoha, (2014) for Eurycoma seeds, Sangamithra et al., (2016) for maize kernel, Sonawane et al., (2014) for horse gram (black gram).

Where: M1000 is 1000 seed mass (g).

The seed mass is the most significant component and its leverages on designing metering devices, and processing equipment, therefore, determining alfalfa seed mass to acknowledge the influence moisture content on increase of individual seed weight.

3.4 Bulk, true density

The bulk and true density of alfalfa seed was presented in Figure4. The average values of bulk and true density were ranged from 1.199 to 0.830g/cm3, 1.333to 1.483g/cm3 respectively. The variation in bulk and true density linearly increased at a significant level of P <0.05, when moisture content increased from 7.98% to 22.12% d.b.,

The relationship between the bulk and true density as moisture content increasing were expressed in the following equations:

$P_b = 0.0032M_c + 1.1745, (R^2 = 0.974)$

$P_t = 0.0065M_c + 1.2894, (R^2 = 0.934)$

Where: Pb and Pt are the bulk and true density (g/cm3

. the similar trends were reported by H Fathollahzadeh et al., (2008) for apricot kernel; Kibar, Ozturk, and Esen, (2010) for rice grain; Maleki, Milani, and Motamedzadegan, (2013) for azrabayejani hazelnut.

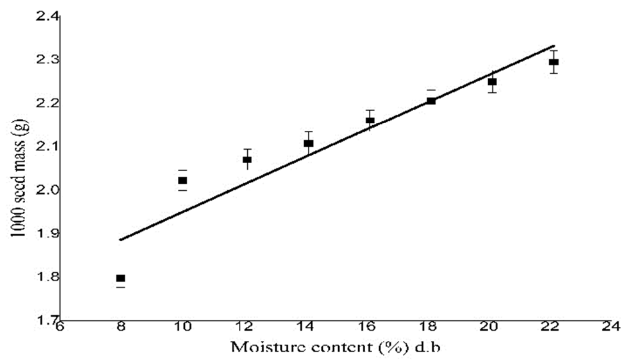

Figure. 3: Effect of moisture content on 1000 seed mass of alfalfa seed

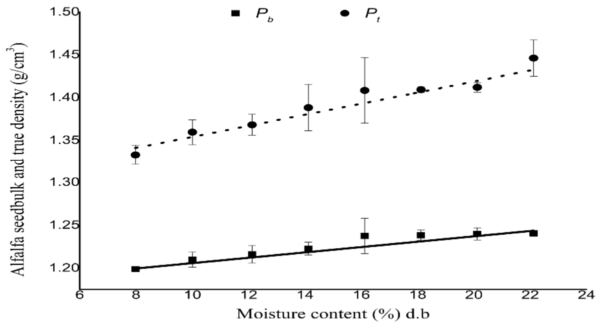

Figure 4. Effect of moisture content on bulk and true density (g/cm^3) of alfalfa seed

3.5 Porosity

The porosity of alfalfa seed increased linearly as shown in fihure5. The average alfalfa porosity values ranged between 10.07 to 14.07%, the variation found to significantly at significant $P < 0.05$.

$$\in = 0.0030M_c + 0.0779, (R^2 = 0.991)$$

Where: ϵ is the porosity (%).

The similar trend has been reported by Koocheki et al., (2007) for watermelon seeds; Adejumo, B. A., 2Abayomi, (2012) for Moringa oleifera seed; Hossein Mirzabe et al., (2017) for cucumber seed. The following equation presented the relationship between the porosity and increase of moisture content:

In order to determine the bulk, true density, and porosity of alfalfa seeds as the fundamental components in which the seed particles and volumes are greatly influenced by the exchange of the moisture content. Hence, to identify them at given moisture level could assist to maintain the efficiency and performance of specific design and handling devices at excellent operation condition

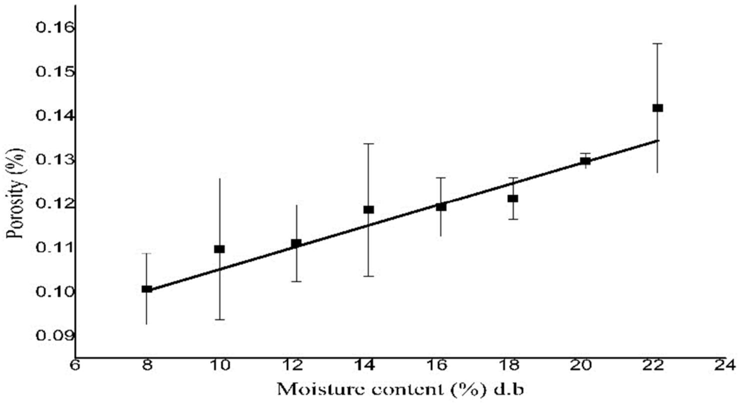

Figure.5: Effect of moisture content on porosity (%) of alfalfa seed

3.5 Static of friction

The coefficient of static friction of alfalfa seed on different surfaces as revealed in figure6. The mean values were ranged between 0.5553 to 0.7682, 0.5409 to 0.7158, 0.4838 to 0.6446 and 0.3725 to 0.6320 for the plywood, polished-steel, rubber, and glass, as moisture content, increased from 7.98% to 22.12% d.b respectively, Difference between the surface was significantly dedicated at $P < 0.01$. The plywood had obtained the highest static coefficient, as the greatest surface roughness, followed by polished steel, and rubber, while the glass had a lower coefficient of friction.

The relationships between the moisture content and the static coefficient of friction on ply-wood (µpw), polished-steel (µps), rubber (µrb) and glass (µgs) can be expressed in the following formula:

$$\mu_{pw} = 0.0152M_c + 0.4348, \quad (R^2 = 0.944)$$
$$\mu_{ps} = 0.0123M_c + 0.4343, \quad (R^2 = 0.941)$$
$$\mu_{rb} = 0.0116M_c + 0.3929, \quad (R^2 = 0.982)$$
$$\mu_{gs} = 0.0124M_c + 0.2705, \quad (R^2 = 0.973)$$

Where: μ_{pw}, μ_{ps}, μ_{rb} and μ_{gs} are the static coefficient of friction of plywood, polished steel, rubber and glass respectively.

The results were similarly stated by Hamzeh Fathollahzadeh et al., (2008); Dursun and Dursun, (2005); Dursun, Tuğrul, and Dursun, (2007); Mirzabe, Khazaei and Chegini, (2013); Adejumo, B. A., 2Abayomi, (2012);

Khanali, Rafiee and Jafari, (2012); Dobrzański and Stępniewski, (2013); Ghorbani, Hemmat and Masoumi, (2012) for Tabarzeh apricot kernel, caper seed, sugar beet seed, virgin olive fruits and moringa oleifera seed rough rice grains, pea seed, seeds in technical processes, alfalfa grind as affected by particle size and moisture content respectively.

This parameter is very critical in designing handling devices, plating equipment. It can be used to calculate and define the flow capability of the material used for designing seed tank and other processing structures The study prevails the influence of moisture contents on adhesion increase between the seed particles and the respective surface, leads to enlarging the rolling angle (Davies, Island and State, 2016).

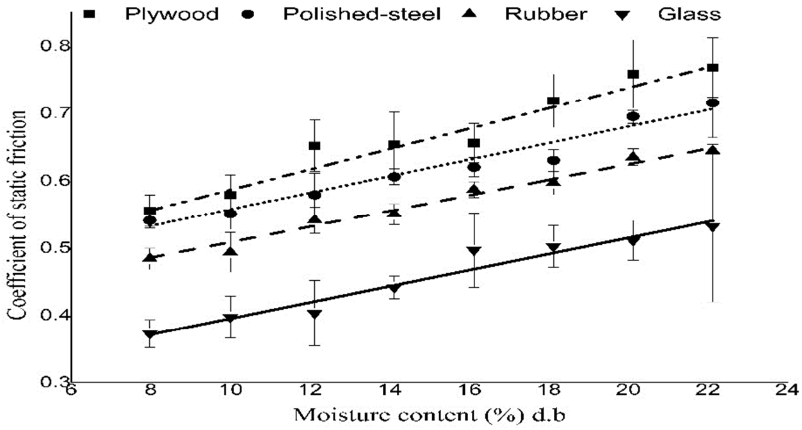

Figure. 6: Effect of moisture content on static coefficient of friction on various friction surfaces of alfalfa seed

3.6 Loading compression and germination test

The loading compression forces and germination rate were presented in figure 7. The average results values varied between 44 to 86%, 51 to 88%, 78 to 88%, and 91 to 99%, as moisture content increased from 7.98 to 22.12% d.b. ANOVA table showed a significant difference at P< 0.01among and within the loading forces increased from 5 to 17N, respectively. Highest moisture content indicated less seed damage and germination rate under different loading forces compared to the lower content.

The data obtained illustrates the viscosity characteristic, which developed by the alfalfa seeds as moisture content increase, which allows the seed particle to expand under force applied.

The results found to be similar to the many reviewed literatures on moisture content dependency for grain crops in case of handling and processing (Ružbarský, Müller and Hrabě, (2014); Ghorbani, Hemmat and Masoumi, (2012); Jadhav et al., (2017); Betancur-Prisco, Mira-Hernández and París-Londoño, (2014); Tavakoli, Mohtasebi and Jafari, (2009); Mani, Tabil and Sokhansanj, (2006); Gezer, Haciseferoğulları and Demir, (2003); Seifi and Alimardani, (2010); Ghorbani et al., (2011)).

Therefore, the explored information are revealed the relationship between the moisture content increase and its influences on seed strength, which provides space for wide range of prediction on seed capability to bear compression loading forces and acknowledge the optimum tolerant.

3.7 The coefficient of internal friction

The coefficient of internal friction and cohesion of alfalfa seed was shown in figure7. The average magnitudes of the coefficient of internal friction showed decreases from 0.127 to 0.095, while the cohesion indicated increases from 2.11 to 5.95, respectively.

The decrease and increase of the coefficient of internal friction and cohesion values were significantly found at P< 0.01 as moisture content increased from 8 to 20%. These results agreed with some studies reported on the effect of moisture content and its influence on different agricultural crops as presented by Tavakoli et al., (2009).

These results have illustrated the importance of the coefficient of internal friction and the cohesion. The information acquired can be utilized to determine an appropriate moisture content to assure a better machine performance in which the influence of moisture can be met to fit the performance in a particular exercise required.

3.9 The angle of repose

The angle repose of alfalfa seed as displayed in figure8. the average value of the angle of repose differed between 27.05o to 28.68o, 28.86o to 29.86o, 31.49o to 32.35o, and 32.47o to 33.21o as moisture content varied from 8 to 20% d.b, respectively. Differences between them were significantly found at P < 0.01.

The regression method was applied to obtain the relation between the angle of repose and the changes in moisture content as the following equation:

$As = 0.4216M_c + 24.7157, (R^2 = 0.923)$

A graph trend obtained for the angle of repose found to be a non-linear, the relation between the moisture contents and seen to be similar to research work that reported on sunflower seeds, and cucumber seeds (Chavoshgoli et al., 2015).

The angle of repose determines the angle of a pile of seed built at the horizontal plane. However, the access data can be used to determine the material surface to achieve a desirable seeds filling, loading, delivery, and discharge. This information allows the designers and the manufactures to have a deeper understanding of particle bulk flow and its complex behavior at given moisture contents.

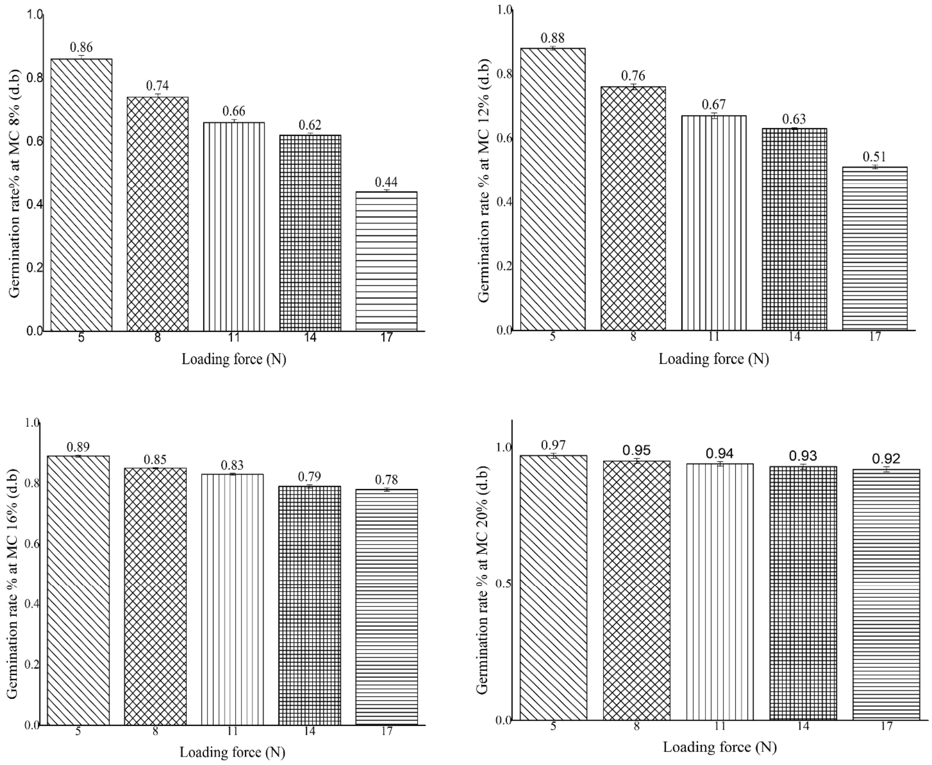

Figure7. Germination rate (%), after placed under loading force (N)

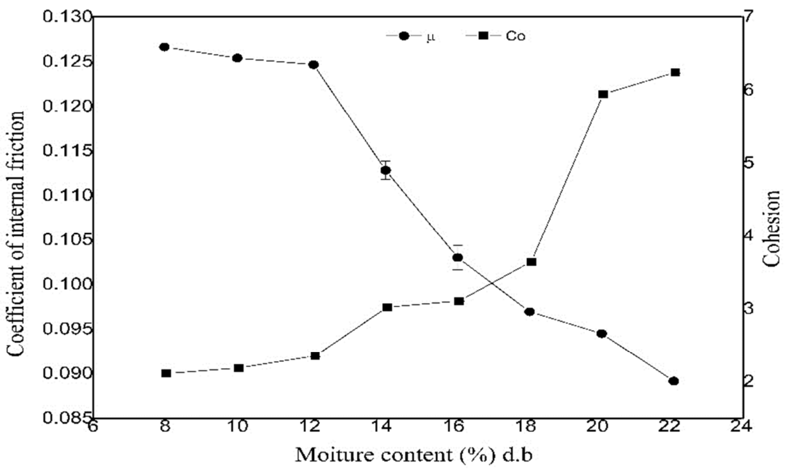

Figure8. Effect moisture content on the coefficient of internal friction and cohesion of alfalfa seeds

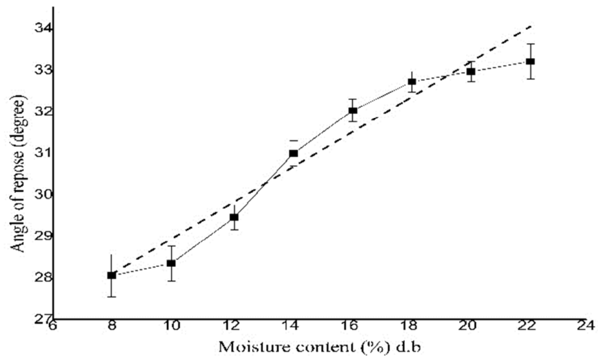

Figure9.Effect of moisture content on the angle of repose of alfalfa seeds

Conclusion

The physical and mechanical properties of alfalfa seeds as such seed axes dimensions, arithmetic, geometric mean diameters, aspect ratio, sphericity and 1000 seed mass, bulk, true density, porosity, the angle of repose, the coefficient of static friction, cohesion, internal friction and compression loading increased as moisture content increased.

The alfalfa seeds geometric and gravimetric properties, the coefficient of static friction, the coefficient of internal friction, cohesion, and compression loading force are linearly increased. The plywood had the highest static coefficient, as the roughest surface, followed by polished steel, and rubber, while the glass had a lower coefficient of friction. While the mean compression force could crush and damage decrease as moisture content increased

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