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Effect of the moisture content on the physical properties of bitter gourd seed

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A b s t r a c t. Some physical and germination properties of bitter gourd seed were determined in a moisture content range of 9.3-32.1% d.b. For this moisture, the average length, width, and thickness of seed increased by 3.68, 4.07, and 4.56%, respectively. The geometric properties increased with increasing moisture content. The bulk density and rupture force decreased while thousand seed mass, true density, porosity, terminal velocity and static coefficient of friction increased with increasing moisture content. At all moisture contents, the maximum friction was offered by rubber, followed by plywood, aluminum, and galvanized iron surface. The seed germination duration, seedling emergence percentage, and germination index values gave the best results at the 19.9% moisture content, whereas fresh seedling mass was not affected by different moisture contents.

K e y w o r d s: bitter gourd seed, moisture content, physical properties, germination properties

INTRODUCTION

Bitter gourd is a tropical and subtropical vine of the family *Cucurbitaceae*, widely grown for edible fruit, which is among the most bitter of all fruits. Other common names include Papara, Momordica charantia, Balsam apple, Momordica, or Bitter melon. It is Turkish name is known as 'Kudret Narı'.

The original home of the species is not known, other than that it is native to the tropics. It is widely grown in India, Nepal and other parts of the Indian subcontinent, Southeast Asia, China, Africa, the Caribbean, and Mediterranean countries such as Turkey and Italy. In Turkey, it is usually grown in Bursa and Yalova provinces.

Bitter gourd (*Momordica charantia*, L.), a *cucurbitaceous* fruit-vegetable is popular as a medicinal vegetable (Anonymous, 2011).

Bitter gourd is an annual plant of the *Cucurbitaceae* family with slender vine characteristics. The leaves are palmate and have a pedicel. The fruit splits at maturity. The fruits are 8-15 cm in length and 4-10 cm in width, the fruit surface is rough and sharpens at the tip. The fruit, which is green initially, turns to yellow and golden yellow as it matures and contains 20-30 dark red bean-like seeds. It is used as a natural drug after mixing with olive oil (Anonymous, 2012a, 2012b).

Bitter gourd is grown by seed or seedlings obtained from seeds. Seeds are sown in April or May into containers or directly to the field when the soil temperature rises 8-10°C. Planting seedlings is advisable since the germination rate of seeds is not 100% (Baryeh, 2002).

Bitter gourd is little known in Turkey and grown in minute quantities, despite its many useful characteristics. Agricultural subventions are essential so that cultivation thereof becomes widespread over the country. Therefore, construction of machinery and equipment and modelling research related to sowing, care, harvest, and handling processes for the crop is also of importance. The physical properties of bitter gourd seed, like those of other grains and seeds, are essential for the design of equipment for handling, harvesting, processing, and storing the kernels. Various types of cleaning, grading, and separation equipment are designed on the basis of the physical properties of the seeds or kernels. Threshing is usually carried out on a hard floor with homemade threshing machines. To optimize threshing performance, pneumatic conveying, and storage of bitter gourd, its physical properties must be known as a function of the moisture content (Srivastava *et al*., 1990).

Researchers have investigated the physical properties of several agricultural products for a similar purpose (Aghkhani *et al.*, 2012; Baryeh, 2002). These investigators

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determined the size of various grains and seeds by measuring their principal axial dimensions. Garavand *et al.* (2012), Balakrishnan *et al.* (2011), and Aviara *et al.* (1999) investigated the variation of these dimensions with moisture the content for hemp seed, cardamom, and guna seed, respectively. Balakrishnan *et al.* (2011) employed the geometric mean and equivalent sphere effective diameters of the three principal axes of mass in calculating the volume of the seed. The results reported showed that these diameters approximately predicted the experimentally determined values. In a similar work on guna seeds, Aviara *et al*. (1999) reported that it was the geometric diameter that gave the closest values to the experimentally determined volume of guna seeds.

Two basic studies were applied to bitter gourd seeds with different moisture contents. These consisted of determining physical properties and germination rates of the seeds. Our primary objective was to investigate some moisture-dependent physical and mechanical properties of the bitter gourd seed, namely; linear dimensions, sphericity, volume, surface area, thousand seed mass, bulk and true densities, porosity, terminal velocity, coefficient of static friction and rupture strength. Our secondary objective was to determine the germination ratios and indexes of bitter gourd seeds at different moisture contents.

MATERIAL AND METHODS

Dry mature bitter gourd seeds (*Momordica charantia* L.) were used for all the experiments in this study. The seeds were grown in the 2010-2011 growing season at the experimental farm of the Protected Cultivation Programme in Yenişehir Vocational School of Uludağ University. The seeds were cleaned in an air screen cleaner where all foreign matter such as dust, dirt, stones, and chaff as well as immature and broken seeds was removed. Then, they were stored in plastic buckets with a cover and kept in cold storage at 5°C. The seeds were removed and kept at room temperature of 20-25°C for 3 h before making any measurement (ASAE, 1997).

The moisture content of the seed samples was determined in three replicates using the air oven method according to the ASAE Standard S352.2 (ASAE, 1997) for bitter gourd. About 15 g grain was dried in a convection oven at 103°C for 72 h. A cabinet drier (Nuve, EN500S, accuracy ±1°C, Turkey) with a front panel made of heat resistant glass was used for the drying experiments. The average moisture content was found to be 9.3% d.b.

Seed samples were conditioned to obtain different moisture contents in the range of 9.3-32.1% d.b. The samples of the desired moisture level were prepared by adding the amount of distilled water (Mohsenin, 1986).

To determine the average size of the bitter gourd seed, 100 grains were randomly picked and their three axial dimensions, namely length L, width W, and thickness T were measured using a digital calliper with a sensitivity of 0.01 mm. The geometric mean diameter (D_g), sphericity (ϕ), surface area (A_s) and volume of seeds (V) were computed at the different moisture contents according to Garavand *et al.* (2012) and Mohsenin (1986).

Thousand seed mass (M_{1000}) was determined using an electronic balance (MP-300 Chyo) weighing to an accuracy of 0.001 g.

Bulk density (ρ_b) is the ratio of grain mass to the volume of the sample container. True density (ρ_t) was determined using the Toluene displacement method (Balakrishnan *et al.,* 2011). Porosity (e) was computed from the values of the true and bulk density of seeds using the relationship given by Izli *et al.* (2009).

The terminal velocity which kept the grain in suspension was recorded by a digital anemometer (Thies clima, Germany) having a least count of 0.1 m s^{-1} (Unal *et al.,* 2008).

The static coefficient of friction was obtained through the use of an inclinometer and 4 friction plates (rubber, galvanized iron, aluminum, and plywood) (Nimkar *et al.,* 2005).

The rupture strength of bitter gourd seed was tested to know the magnitude of force that was required to break the seed in the axial dimension (thickness). Rupture forces were measured using a dynamometer (Sundoo, 500 SH, accuracy 0.1 N, China) with 500 N capacity. The loading velocity of the dynamometer was constant at 35 mm min^{-1} during measurements. For each test, a single seed was placed on its thickness axes on a flat plate and then compressed with a 12 mm diameter probe. The process was replicated 30 times and the average of the 30 readings was taken as the representative value.

The seeds were divided into three groups for each moisture content in order to determine the germination characteristics of bitter gourd seeds with different moisture contents. 10 seeds chosen at random for each group were sown into multicellular containers. Peat was used as germination medium. The containers were regularly irrigated and the emergence of seeds was observed daily and recorded along the germination period. At the end of the trials, the germination period, germination rate, germination index, and fresh seedling mass were determined for the seeds with different moisture contents. The relation of the seed moisture content and seed coat firmness with the germination period and germination rates were investigated.

The results were processed by the MINITAB (Version 14, University of Texas, Austin, USA) and MS-Excel software programs. One way analysis of variance and LSD test MSTAT_C (Version 2.1., Michigan State University, USA) software program were used to analyse the results. Differences were considered significant at $p<0.01$ and $p<0.05$, unless otherwise specified.

RESULTS AND DISCUSSION

The average values of the three principal dimensions of bitter gourd seed *ie* length, width and thickness determined in this study at different moisture contents are presented in

Table 1. A very high correlation was observed between the three principal dimensions and the moisture content indicating that upon moisture absorption, the bitter gourd seed expands in length, width, and thickness within the moisture range of 9.3-32.1% d.b. The mean dimensions of 100 seeds measured at a moisture content of 9.3% d.b. are: length 13.85 mm, width 7.61 mm, and thickness 4.17 mm. Differences between the values are statistically significant at $p<0.05$.

The frequency distribution curves of length, width, thickness, geometric mean diameter, and sphericity of the bitter gourd seed showed a trend towards a normal distribution (Fig. 1). The results showed that the length, width, and thickness of the seed ranged between 12.05-15.77, 6.34-9.21, and 3.22-5.05 mm, respectively, while the geometric mean diameter and sphericity ranged between 7.47-8.68 mm and 51.34-61.61%, respectively. About 72% of bitter gourd seeds are between 12.79 and 15.03 mm in length, 80% of them were between 6.91 and 8.63 mm in width, and 86% of them were between 3.58 and 4.68 mm in thickness. Also, 76% of seeds were between 7.47 and 8.26 mm in geometric mean diameter and 92% of them were between 51.34 and 59.55% in sphericity.

The values of sphericity were calculated individually using the data on the geometric mean diameter and the major axis of the seed and the results obtained are presented in Table 1. It can be seen that the grain has mean values of sphericity ranging from 54.86 to 55.09%. Aydin and Ozcan (2007) has reported the value for sphericity of myrtle fruits to be 58.30%, which is close to the results of this investigation. Sacilik *et al*. (2003) and Dursun and Dursun (2005) considered the grain as spherical when the sphericity value was higher than 0.80 and 0.73, respectively. In this study, bitter gourd seed should not be treated as an equivalent sphere for calculation of the surface area.

T a b l e 1. Axial dimensions, geometric mean diameter, and sphericity of bitter gourd seed at different moisture contents

Moisture content (% d.b.)	Length	Width	Thickness	Geometric mean diameter	Sphericity (%)
	(mm)				
9.3	13.85 b (0.96)	7.61 b (0.66)	4.17 b (0.39)	7.59 b (0.50)	54.86 ns (2.11)
19.9	13.97 b (0.98)	7.68 ab (0.58)	4.23 ab (0.40)	7.68 b (0.51)	55.02 ns (2.27)
25.0	14.20 ab (0.84)	7.75 ab (0.64)	4.27 ab (0.41)	7.77 ab (0.51)	54.75 ns (2.86)
32.1	14.36 a (0.90)	7.92 a (0.75)	4.36 a (0.39)	7.91 a (0.57)	55.09 ns (2.68)

All data represent the mean 100 determinations. Values in the same columns followed by different letters (a-b) are significantly different ($p<0.05$). Standard deviation is given in parenthesis, ns – not significant.

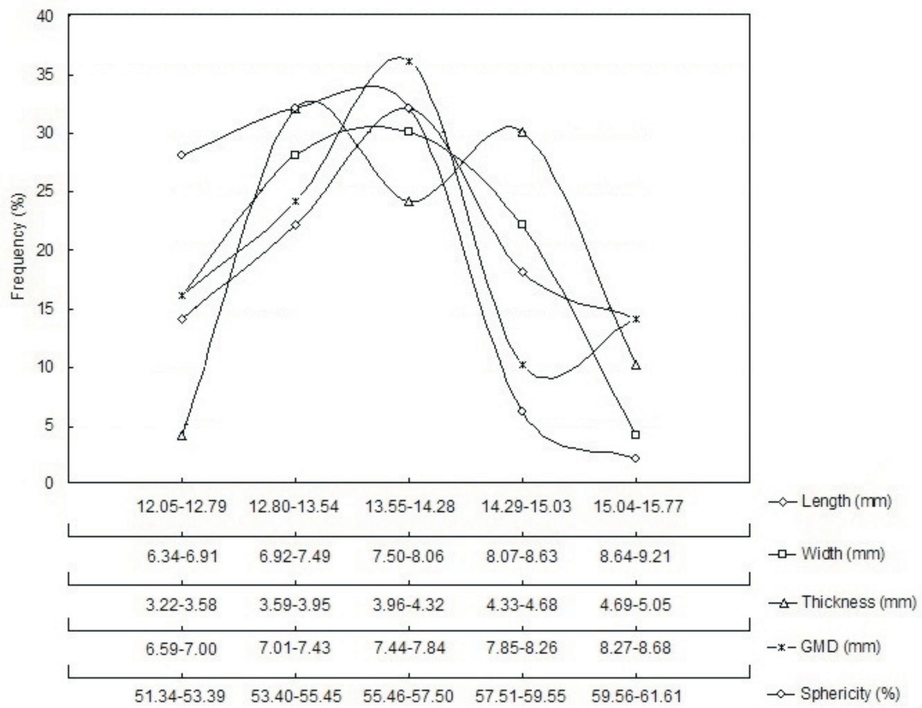


Fig. 1. Frequency distribution curves of bitter gourd seed dimension and shape at 9.3% average moisture content (d.b.).

The surface area of seed increases linearly from 181.91 to 197.42 mm^2 (statistically significant at $p<0.05$) when the moisture content increased from 9.3 to 32.1% d.b. (Fig. 2a). A similar trend has been reported for millet (Baryeh, 2002), hemp seed (Sacilik *et al*., 2003), and caper seed (Dursun and Dursun, 2005).

The values obtained for seed volume of bitter gourd are shown in Fig. 2b. The values obtained for seed volume increa- ses linearly from 232.21 to 262.83 mm^3 with the increase in the moisture content and the change was significant ($p<0.05$). Similar results of an increase in seed volume, due to an increase in the grain moisture content, were reported for millet (Baryeh, 2002) and hemp seed (Sacilik *et al*., 2003).

The thousand seed mass of bitter gourd seed, M_{1000} (g) increased from 188.7 to 262.0 g ($p<0.01$) as the moisture content increased from 9.3 to 32.1% d.b. (Fig. 2c). Similar trends have been reported by Aviara *et al*. (1999) for guna seed, Sacilik *et al*. (2003) for hemp seed, and Balakrishnan *et al*. (2011) for cardamom.

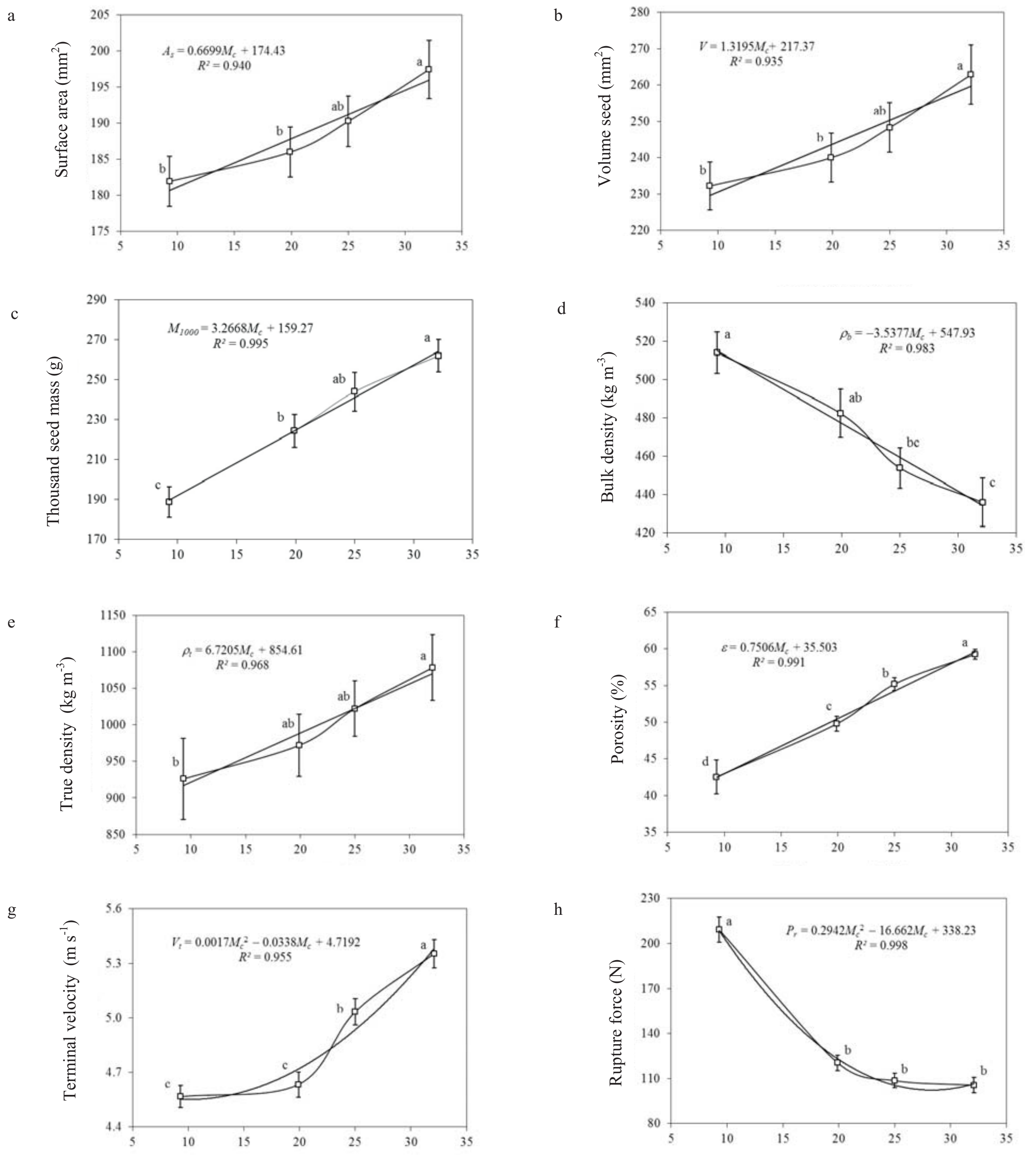
The seed bulk density at different moisture levels varied from 514.1 to 435.9 kg m^{-3} ($p<0.01$) (Fig. 2d) and indicated a decrease in bulk density with an increase in the moisture content from 9.3 to 32.1% d.b. This was due to the fact that the increase in mass owing to moisture gain in the grain sample was lower than the accompanying volumetric expansion of the bulk. The negative linear relationship of bulk density with the moisture content was also observed by Sacilik *et al*. (2003), Dursun and Dursun (2005), and Aydin and Ozcan (2007) for hemp seed, caper seed and myrtle fruits, respectively. The true density of seeds was found to vary from 969.7 to 1134.2 kg m^{-3}, when the moisture level increased from about 9.3 to 32.1% d.b. (Fig. 2e). The variation in true density with the moisture content was significant ($p<0.05$). The increase in true density varying with the increase in the moisture content might be attributed to the relatively low true volume as compared to the corresponding mass of the seed attained due to adsorption of water. Although the results were similar to those reported by Aydin and Ozcan (2007) for myrtle fruit and Pradhan *et al*. (2008) for karanja kernel, a different trend was reported by Suthar and Das (1996) for karinga seed.

The variation of porosity depending upon the moisture content is shown in Fig. 2f. Porosity was found to increase linearly from 42.5 to 59.3% ($p<0.05$) at the specified moisture levels. Aydin and Ozcan (2007) for myrtle fruit and Pradhan *et al*. (2008) for karanja kernel stated that as the moisture content increased, the porosity value also increased, but Dursun and Dursun (2005) and Aghkhani *et al*. (2012) reported a decreasing trend for caper and Christmas Lima bean, respectively.

The variation in terminal velocity values of bitter gourd seed with the increase in the moisture content is shown in Fig. 2g. It was observed that terminal velocity increased linearly from 4.57 to 5.35 m s^{-1} with the increase in the moisture content and this change was significant ($p<0.01$). The results indicated that the percent increase in terminal velocity of mung bean was 17% for the corresponding increase in the moisture content of 9.3 to 32.1% d.b. At the moisture content of 9.3% d.b. the terminal velocity of bitter gourd seed was found to be smaller than that of moth gram (Nimkar *et al*., 2005), mung bean (Unal *et al*., 2008), and Christmas Lima bean (Aghkhani *et al*., 2012), while it was greater than that of psyllium seed (Ahmadi *et al*., 2012).

Experimental data of the static coefficient of friction for bitter gourd seed on frictional surfaces of rubber, plywood, aluminum, and galvanized iron sheet at various moisture levels are presented against the moisture content, as shown in Table 2. It can be seen that the static coefficient of friction increased logarithmically with the increase in the moisture content for all the contact surfaces. The cause of the increased friction coefficient at the higher moisture content may be the water present in the seed, offering a cohesive force on the surface of contact. Increases of 74.2, 64.2, 73.8, and 70.0% were recorded in the case of rubber, plywood, aluminum, and galvanized iron, respectively, as the moisture content increased from 9.3 to 32.1% d.b. The static coefficient of friction is important for designing storage bins, hoppers, pneumatic conveying systems, screw conveyors, forage harvesters, threshers, *etc*. (Pradhan *et al*., 2008). At all the moisture contents, the maximum friction was offered by rubber, followed by plywood, aluminum, and galvanized iron surface. The lowest static coefficient of friction may be relaed to the smoother and more polished surface of the galvanized iron sheet than the other materials used. Rubber also offered the maximum friction for caper seed, mung bean, and Christmas Lima bean and the coefficient of friction increased with the moisture content (Aghkhani *et al*., 2012; Dursun and Dursun, 2005; Unal *et al*., 2008). The relationship between the coefficient of static friction and the moisture content for the surfaces considered was found to be logarithmic as presented in Table 3.

The rupture force of bitter gourd seed as a function of the moisture content is presented in Fig. 2h. At a moisture content of 9.3% d.b., the rupture strength is 209.2 N for the seeds. As can be seen in Fig. 2i the strength decreases strongly with the increase in the moisture content until it reaches a moisture content of about 19.9% d.b. Thereafter, the decrease in strength with the increase in the moisture content appear to accelerate gradually. The values of seed strength found in this study are within the range of 240-10 N found by Paksoy and Aydin (2006) while working on pea seed, 37-19 N found by Garavand *et al.* (2006) while



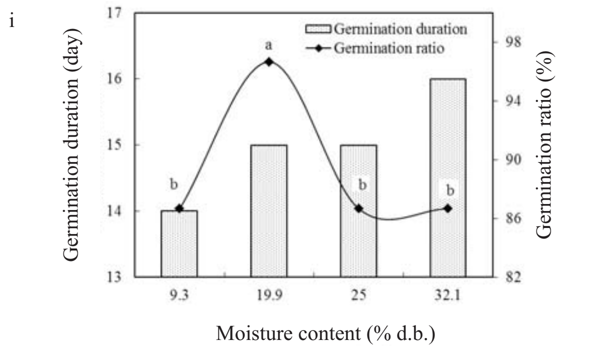


Fig. 2. Effect of moisture content on: a – surface area, b – volume seed, c – thousand seed mass, d – bulk density, e – true density, f – porosity, g – terminal velocity, h – rupture force, i – germination duration and ratio of bitter gourd seed.

T a b l e 2. Coefficient of static friction of bitter gourd seed

Moisture content (% d.b.)	Coefficient of static friction				Significance level
	Rubber	Plywood	Aluminium	Galvanized iron	
9.3	0.695 A,c (0.023)	0.668 AB,c (0.024)	0.613 BC,c (0.011)	0.603 C,c (0.015)	**
19.9	1.026 A,b (0.040)	0.924 B,b (0.030)	0.880 B,b (0.033)	0.851 B,b (0.020)	**
25.0	1.113 A,ab (0.047)	1.033 A,a (0.027)	0.939 B,b (0.033)	0.916 B,b (0.027)	**
32.1	1.219 A,a (0.067)	1.099 AB,a (0.043)	1.056 B,a (0.040)	1.015 B,a (0.042)	**
Significance level	**	*	*	*	

All data represent the mean 10 determinations. Standard deviation is given in parenthesis. Means followed by the same letter between rows (a, b, c) and between columns (A, B, C) within each surface are significant. *, ** Significance levels at $p<0.05$, $p<0.01$, respectively.

T a b l e 3. Regression equations related to coefficients of static friction of bitter gourd seed

Surface	Regression equations	R^2
Rubber	$\mu_{ru} = 0.423\ln(M_c) - 0.2472$	0.999
Plywood	$\mu_{plw} = 0.354\ln(M_c) - 0.1229$	0.996
Aluminium	$\mu_{al} = 0.349\ln(M_c) - 0.1675$	0.996
Galvanized iron	$\mu_{gi} = 0.328\ln(M_c) - 0.1307$	0.998

working on hemp seed, and the values of 1-30 N found by Aydin and Ozcan (2007) while working on myrtle fruit. The differences between the rupture force values of seeds at different moisture contents have been found to be statistically significant ($p<0.01$).

Germination results related to seed samples used for germination trials, as well as the physical properties of bitter gourd seeds are given in Table 4. As can be seen in the table, there was no significant effect of the change in the moisture content on the germination period and seedling mass. On the other hand, the effect of the 19.9% moisture content on the germination rate and germination index was found to be more significant than the other moisture contents ($p<0.05$). The germination period and germination index values of seeds used in this trial were similar to those reported by Bewley (1997), Wang *et al*. (2003), and Thirusenduraselvi and Jerlin (2007). The germination duration and germination ratio values of bitter gourd seeds are shown comparatively in Fig. 2i.

CONCLUSIONS

1. The average length, width, thickness, geometric mean diameter, surface area and unit volume of seed increased linearly with the increasing moisture content from 9.3 to 32.1% d.b.

2. Similarly, thousand seed mass, true density, porosity and terminal velocity increased linearly whereas bulk density decreased linearly with the increasing moisture content.

3. The highest static coefficient of friction was found on rubber, followed by plywood, aluminium sheet, and galvanized iron sheet.

4. The rupture force was highly dependent on the moisture content. The highest rupture strength obtained was 209.2 N at the moisture content of 9.3% d.b.

5. The seed germination duration, seedling emergence percentage, and germination index values gave the best results at the 19.9% moisture content.

T a b l e 4. Mean germinaton duration, germination ratio, germination index, and fresh seedling mass changes occurring at different moisture contents of bitter gourd seed

Moisture content (% d.b.)	Mean germination duration (days)	Germination ratio (%)	Germination index	Fresh seedling mass (g)
9.3	14 ns	86.7 b	0.762 b (0.071)	3.1 ns (0.3)
19.9	15 ns	96.7 a	0.806 a (0.035)	3.0 ns (0.2)
25.0	15 ns	86.7 b	0.717 c (0.078)	3.3 ns (0.2)
32.1	16 ns	86.7 b	0.719 c (0.031)	3.0 ns (0.2)

All data represent the mean 30 determinations. Standard deviation is given in parenthesis, a-c letters indicate the statistical difference in same columns ($p<0.05$), ns – not significant.

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