International Journal of Chemical Studies

P-ISSN: 2349–8528
E-ISSN: 2321–4902
IJCS 2018; 6(5): 1850-1854

Received: 19-07-2018
Accepted: 24-08-2018

BN Patil
Department of Agricultural Process Engineering, Faculty of Agricultural Engineering, Panjabrao Deshmukh Krishi Vidyapeeth, Akola, Maharashtra, India

SV Gupta
Department of Agricultural Process Engineering, Faculty of Agricultural Engineering, Panjabrao Deshmukh Krishi Vidyapeeth, Akola, Maharashtra, India

SB Solanke
Department of Agricultural Process Engineering, Faculty of Agricultural Engineering, Panjabrao Deshmukh Krishi Vidyapeeth, Akola, Maharashtra, India

AS Mulani
Department of Agricultural Process Engineering, Faculty of Agricultural Engineering, Panjabrao Deshmukh Krishi Vidyapeeth, Akola, Maharashtra, India

Correspondence
BN Patil
Department of Agricultural Process Engineering, Faculty of Agricultural Engineering, Panjabrao Deshmukh Krishi Vidyapeeth, Akola, Maharashtra, India

Study of mechanical properties of marking nut (*Semecarpus anacardium* L.)

BN Patil, SV Gupta, SB Solanke and AS Mulani

Abstract
The aim of this study was to determine the mechanical properties of marking nut for designing a marking nut cracker which reduces the kernel breakage and also optimization of moisture content is important for efficient cracking of nuts. In this study, The angle of repose of marking nut and kernel were 50.20 to 53.86º and 33.17 to 37.16º. The force needed to rupture; deformation at rupture point, energy used for rupture and hardness of marking nut (37.17 kg, 3.61 mm, 134.80 kg mm and 10.82 kg mm-1) is higher as compared to the kernel (17.20 kg, 2.65 mm, 45.58 kg mm and 6.49 kg mm-1) which indicates that kernel needed the lowest strain to rupture as compared to marking nut.

Keywords: marking nut S*emecarpus Anacardium* L., mechanical properties, drying

Introduction
Marking nut (*Semecarpus Anacardium* L.) is a native of India. It is also known as ker beeja in Kannada and bibba in Marathi. The plant is found in abundance in Assam, Bihar, Bengal, Orissa, Chittagong, Central India and Northern Australia. Chemical and phyto chemical analyses of marking nut reveal the presence of biflavonoids, phenolic compounds, bhilawanols, minerals, vitamins and amino acids. (Majumdar, *et. al*. 2008) [14]. It is a rich source of phenols and traditionally used for marking lines. It is also used for water proofing textile fabrics, imparting lather finish to cloth, paper boards and card boards, in production of insecticides, antiseptics, termite repellents and moth proofing agents, in synthetic detergents, herbicides and fire proofing plastics. Also it can be used to cure esophagus and mouth cancer, leprosy and sciatica, against the bacterial infections etc.

The quality of the kernel depends upon an efficient nut cracking which was enhancing effective separation of the kernel from the shell. Cracking is implied when a material breaks without entire separation. Marking-nut cracking, therefore, occurs when nuts are loaded to rupture without crushing the embedded kernel. Prior to cracking, the nuts are dried sufficiently to enable the kernel to shrink away from the shell to minimise kernel breakage. Optimum moisture content at the time of cracking is much important for kernel separation and minimizes the breakage losses of kernel. These study help to decide optimum drying time at various temperatures for traditional sun-drying and tray drying, which helps to improve whole kernel recovery (Gabadam, *et. al.*, 2009) [7].

The Study of Marking-nut is necessary. The conventional method of cracking was done manual which involves the use of stones for the cracking. In the processing of kernel seperation, nut shell cracking is the most critical and delicate operation. Its major concern is to extract the fragile kernel whole from the shell. Cracking marking nuts to release the kernels is a critical step and it also affects the quality of kernel. The disadvantage of the manual method is less in productivity and time consuming process. For design of marking nut cracker necessary design data regarding physical and mechanical properties of marking-nut have not been reported in the literature.

Mechanical properties are much important in design of machine components which was required for post-harvest operations like harvesting, separation, shelling of nuts etc. Mechanical properties give information about nut characteristics as hardness, rupture force, rupture point, deformation, and energy required for rupture and point of application of force for performing the better operation. (Khazaei, 2007) [11]. Therefore, the present study was planned with an objective to determine different mechanical properties of marking nut and kernel.

Material and Methods

Preparation of sample

For this experiment the marking-nuts were procured from local market of Akola and Titwan, Taluka Barshitakali, Dist. Akola. The nut were cleaned manually to remove all foreign matter such as stones and some part of flower attached on nuts, broken, oversized and under sized nuts etc. The cleaned nuts were divided into three fractions small, medium and large for conducting experimentation at Department of Agricultural Process Engineering, Dr. PDKV, Akola during 2011-2012. Moisture content of sample was determined by using a standard oven drying method at an air temperature of 105 ± 2ºC for 24 h (AOAC, 2000) [1]. The initial moisture content of nut and kernel was found to be 7.60% and 2.03% (d.b.), respectively.

Determination of mechanical properties of Marking-nut, Kernel and Shell

Mechanical properties are most important parameter in design of machines required for agricultural processing. The mechanical properties required for the design of marking-nut Sheller are rupture force, deformation at rupture point, hardness, deformation ratio at rupture point and energy used for rupture. The mechanical properties were determined using Texture analyser (TA.XT Plus, Stable Micro System, UK). The effect of moisture content on mechanical properties were studied at different moisture content ranges from 1.96 to 19.59% (d.b.) for deformation speed at 1.0 mm s^{-1} for nut. The same procedure was carried out for kernel at 2.03% (d.b.) moisture content in three fractions viz., small, medium and large.

The flat plate compression test was carried out using texture analyzer (TA.XT Plus, Stable Micro System, UK). Each sample of nut and kernel was aligned horizontally from stem end to the apex on the platform. A circular flat aluminum plate (70 mm x 5 mm) was used to compress the sample at deformation speed of 1.0 mm s^{-1}. The plate compressed the sample up to 4 mm for nut and kernel. These set values passed the point that the sample was broken and given the rupture force and deformation at rupture point. Averages of ten replications were taken for each sample. (Sirisomboon *et al.*, 2007) [17].

Rupture force

The rupture force is the minimum force required to break the sample (Mohsenin, 1986) [12]. Rupture force of marking-nut and kernel were directly measured by texture analyzer (TA.XT Plus, Stable Micro System, UK).The rupture force of kernel are important to minimize breaking of kernel during nut shelling.

Deformation at rupture point

Deformation at rupture point of marking-nut, kernel and shell were directly measured by texture analyzer (TA.XT Plus, Stable Micro System, UK). Nut deformation at rupture point was determined at compression speed 1.0 mm s^{-1} with 4 mm penetration into sample. For kernel deformation at rupture point was determined at compression speed 1.0 mm s^{-1} at moisture content 2.03% (d.b.).

Hardness

Hardness is the ratio of rupture force and deformation at rupture point. Hardness is the measure of how resistant solid matter is to various kinds of permanent shape change when a force is applied. Hardness of marking-nut and kernel were determined by using rupture force and deformation at rupture point given by texture analyzer (TA.XT Plus, Stable Micro System, UK). Study of hardness of marking-nut was important to evaluate the cracking force required to break down the outer shell and feeding value of marking-nut.

Deformation ratio at rupture point

Deformation ratio at rupture point is the ratio of deformation at rupture point to the dimension of the sample in the direction of compression force at the loading point, i.e. the equatorial width perpendicular to the length. Deformation ratio at rupture of marking-nut and kernel were determined by using deformation at rupture point and length of marking-nut.

Energy used for rupture

Energy used for rupture is the work required to cause rupture in the marking-nut, kernel and shell. It is approximately equal to area under force deformation curve to rupture point. Energy used for rupture is most important mechanical property which decides minimum energy required for sheller for interruption of marking-nut. Energy used for rupture of marking-nut and kernel were directly determined by using rupture force and deformation at rupture point.

Result and Discussion

The results obtained by mechanical properties viz., rupture force, hardness, deformation at rupture point, deformation ratio at rupture point and energy used for rupture of marking-nut and kernel are presented in Table 1. Mechanical properties of marking-nut were determined in the range of 1.96 to 19.59% (d.b.) and for kernels 2.06% (d.b.) moisture content. The results obtained from analysis of variance shown effects of moisture content on these mechanical properties are given in Table 2. The mechanical properties increased in second degree polynomial with increase in moisture content, while for a further increase in moisture content mechanical properties decreased. This may be due to the fact that at low moisture content nuts are hard and brittle; also it may be due to softening effect of water added which make nuts to be tending towards flowing or ductile. (Bamgboye and Adejome, 2011 and Jafari, 2011) [4, 10].

Rupture force

The data obtained for rupture force of marking-nut at different moisture level presented in Table 1 and results are shown graphically in Fig. 1 indicated that rupture force increased in second degree polynomial with increase in moisture content. The average values of the rupture force of marking-nut were found increased in second degree polynomial from 32.42 to 38.83 kg for corresponding increase in moisture content within the range of 1.96 to 10.22%, while for a further increase in moisture content 10.22 to 19.59 % (d.b.) rupture force decreased from 38.83 to 37.20 kg. The percent increase in rupture force was 19.77%, thereafter decrease 4.38%. These variations in rupture force with moisture content were significant at 1% level of significance. The coefficients of determination (R^2) value for axial dimensions are high (>0.94) indicating high proportion of variability in Fig 1.

The linear relationship of rupture force (F) with moisture content (M) is given for marking-nut at 1.96 to 19.59% (d.b.) moisture content.

$$F = - 0.047M^2 + 1.2624M + 30.20 \quad (R^2 = 0.948) \qquad \text{----- (1)}$$

Where, F = Rupture force, kg
M = Moisture content, % (d.b.)

The rupture force increased in second degree polynomial with increase in moisture contents. Similar treads were observed for Melon seeds (Makanjoula, 1972) [13], wheat (Haddad *et al*., 2001) [8], barberry (Fathollaahzadeh *et al.*, 2008) [5], Roselle seeds (Bamgboye and Adejumo, 2011) [4] and sunflower seeds (Jafari *et al*., 2011) [10].

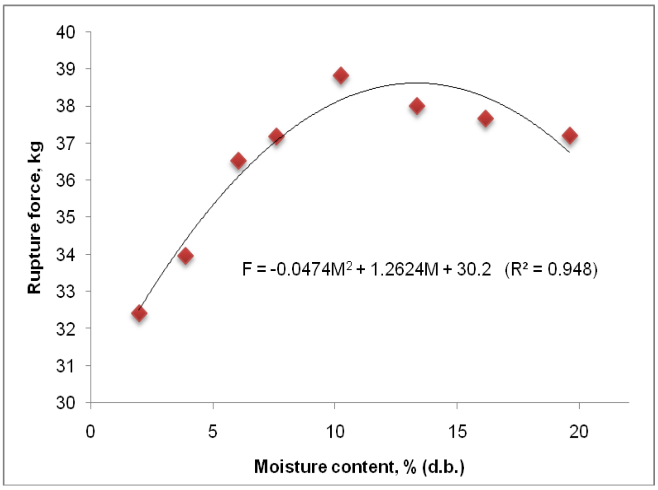

Fig 1: Effect of moisture content on rupture force of marking-nut.

Deformation at rupture point

From Fig. 2 indicated that deformation at rupture point increased in second degree polynomial with increase in moisture content. The average values of the deformation at rupture point of marking-nut were found increased in second degree polynomial from 3.14 to 3.78 mm for corresponding increase in moisture content within the range of 1.96 to 13.35 % (d.b.), while for a further increase in moisture content 13.35 to 19.59 % (d.b.) deformation at rupture point decreased from 3.78 to 3.47 mm. The percent increase in deformation at rupture point were 20.38%, thereafter decrease 8.93%.

These variations in deformation at rupture point with moisture content were significant at 1% level of significance. The coefficients of determination (R^2) value for deformation at rupture point are high (>0.95) indicating high proportion of variability.

The linear relationship of deformation at rupture point (X) with moisture content (M) is given for marking-nut at 1.96 to 19.59% (d.b.) moisture content.

$$X = -0.0052M^2 + 0.1324M + 2.8826 \ (R^2 = 0.950) \quad \text{----- (2)}$$

Where, X = Deformation at rupture point, mm
M = Moisture content, % (d.b.)

The deformation at rupture point increased in second degree polynomial with increase in moisture content. Similar treads were observed for Melon seeds (Makanjoula, 1972) [13], soybean (Poulsen, 1978) [15], pumpkin seed (Joshi *et al*., 1993) [9], African nutmeg (Burubai *et al.*, 2007) [3] and sunflower seeds (Jafari *et al*., 2011) [10].

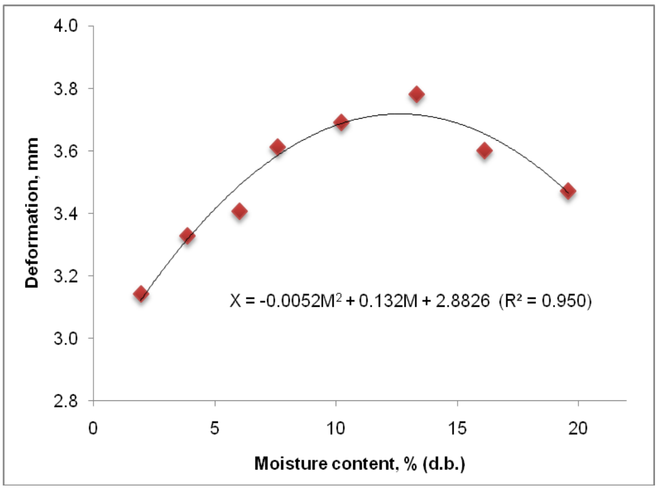

Fig 2: Effect of moisture content on deformation of marking-nut.

Hardness

The data obtained for hardness of marking-nut at different moisture level presented in Table. 1 and results are shown graphically in Fig. 3 indicated that hardness decreased linearly with increase in moisture content. The average values of the hardness of marking-nut were found decreased linearly from 11.18 to 10.55 kg mm^{-1} for corresponding increase in moisture content within the range of 1.96 to 19.59 % (d.b.) The percent increase in hardness were 5.97%. These variations in hardness with moisture content were significant at 1% level of significance. The coefficients of determination (R^2) value for hardness are high (>0.90) indicating high proportion of variability.

The linear relationship of hardness (X) with moisture content (M) is given for marking-nut at 1.96 to 19.59% (d.b.) moisture content.

$$X = -0.0362M + 11.174 \ (R^2 = 0.905) \quad \text{------ (3)}$$

Where, H = Hardness, kg mm^{-1}
M = Moisture content, % (d.b.)

The hardness decreased linearly with increase in moisture contents the reason of these decrease was probably increase in moisture content increases softness in the material which decreases hardness. Similar treads were observed for Melon seeds (Makanjoula, 1972) [13], soybean (Poulsen, 1978) [15] and for jatropha seed (Pradhan *et al*. 2009) [16].

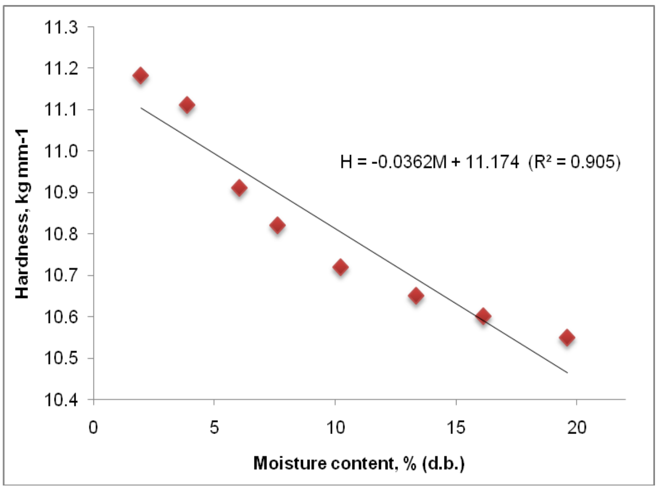

Fig 3: Effect of moisture content on hardness of marking-nut.

Energy used for rupture

The data obtained for energy used for rupture of marking-nut at different moisture level presented in Table 1 and results are shown graphically in Fig. 4 indicated that energy used for rupture increased second degree polynomial with increase in moisture content.

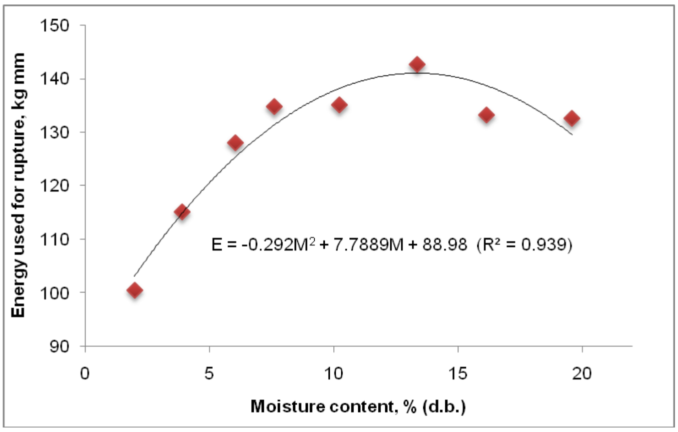

Fig 4: Effect of moisture content on energy used for rupture of marking-nut.

Average values of the energy used for rupture of marking-nut were found increased second degree polynomial from 100.55 to 142.57 kg mm for corresponding increase in moisture content within the range of 1.96 to 13.35 % (d.b.), while for a further increase in moisture content 13.35 to 19.59 % (d.b.) energy used for rupture decreased from 142.57 to 132.52 kg mm. The percent increase in energy used for rupture were 41.79%, thereafter decreases 7.58%.

These variations in energy used for rupture with moisture content were significant at 1% level of significance. The coefficients of determination (R^2) value for energy used for rupture are high (>0.93) indicating high proportion of variability. The linear relationship of energy used for rupture (E) with moisture content (M) is given for marking-nut at 1.96 to 19.59% (d.b.) moisture content.

$$E = - 0.292M^2 + 7.7889M + 88.98 \ (R^2 = 0.939) \quad \text{----- (4)}$$

Where, E = Energy used for rupture, kg mm

M = Moisture content, % (d.b.)

The energy used for rupture increased in second degree polynomial with increase in moisture content. Similar treads were observed for Hazelnut (Guner *et al.*, 2003) [6], Faba beans (Altuntas and Yildiz, 2007) [2], Corn (Saifi and Alimardani, 2010) [18] and sunflower seeds (Jafari *et al*., 2011) [10].

Deformation ratio at rupture point

The data obtained for deformation ratio at rupture point of marking-nut at different moisture level is presented in Table 1 and results are shown graphically in Fig. 5 indicated that deformation ratio at rupture point increased in polynomial of second degree with increase in moisture content. Average values of the deformation ratio at rupture point of marking-nut were found increased in polynomial of second degree from 0.182 to 0.197 for corresponding increase in moisture content within the range of 1.96 to 10.22 % (d.b.), while for a further increase in moisture content 10.22 to 19.59 % (d.b.) deformation ratio at rupture point decreased from 0.197 to 0.185. The percent increase in deformation ratio at rupture point were 8.24%, thereafter decreases upto 6.50%.

These variations in deformation ratio at rupture point with moisture content were significant at 1% level of significance. The coefficients of determination (R^2) value for deformation ratio at rupture point are high (>0.91) indicating high proportion of variability.

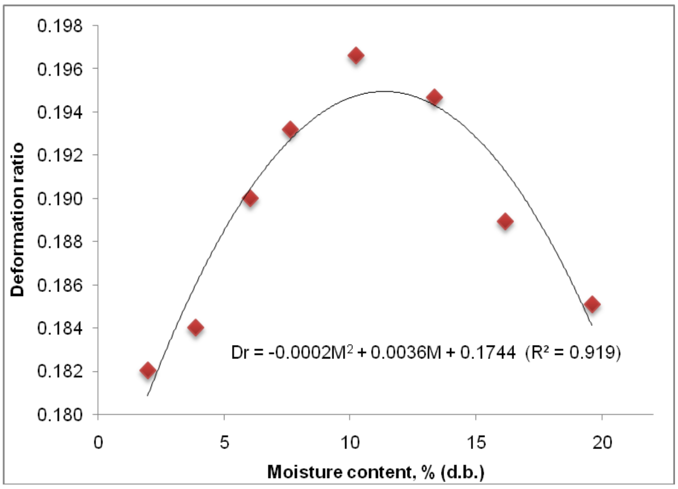

Fig 5: Effect of moisture content on deformation ratio at rupture point of marking-nut.

The linear relationship of deformation ratio at rupture point (Dr) with moisture content (M) is given for marking-nut at 1.96 to 19.59% (d.b.) moisture content.

$$Dr = - 0.0002M^2 + 0.0036M + 0.1744 \ (R^2 = 0.950) \quad \text{------- (5)}$$

Where, Dr = Deformation ratio at rupture point

M = Moisture content, % (d.b.)

The deformation ratio at rupture point increased in second degree polynomial with increase in moisture content. Similar trends was observed for jatropha fruits and kernel (Pradhan *et al.* 2009) [16].

Table 1: Mechanical properties of marking-nut at varying moisture content

Moisture content, % (d.b.)	Rupture force, (kg)	Deformation (mm)	Hardness, (kg mm-1)	Energy used for rupture, (kg mm)	Deformation ratio at rupture point
1.96	32.41 (6.30)	3.14(0.68)	11.18 (5.39)	100.55(55.98)	0.18(0.04)
3.87	33.97 (3.95)	3.33(0.41)	11.11 (1.48)	115.06(53.87)	0.18(0.02)
6.03	37.53 (5.27)	3.41(0.31)	10.91 (1.53)	128.07(46.33)	0.19(0.02)
7.6	37.17 (4.69)	3.61(0.60)	10.82 (2.96)	134.80(61.88)	0.20(0.03)
10.22	38.83 (5.38)	3.69(0.24)	10.72 (1.10)	135.12(26.70)	0.20(0.01)
13.35	38.00 (5.43)	3.78(0.19)	10.65 (1.80)	142.57(18.44)	0.20(0.01)
16.14	37.67 (5.29)	3.60(0.53)	10.60 (2.66)	133.25(47.18)	0.19(0.03)
19.59	37.20 (5.29)	3.47(0.053)	10.55 (2.66)	132.52(47.18)	0.19(0.03)

(Values given in the parentheses are standard deviation)

From Table 2 the coefficient of variance for Rupture force, Deformation at rupture point, Hardness, Energy used for rupture, Deformation ratio at rupture point was found 5.96%, 5.96%, 2.16%, 10.57%, 2.80% respectively. The coefficient of variance for energy used for rupture force was maximum i.e. 10.57%. Hence it indicates better precision and reliability of experiment carried out.

Table 2: Analysis of variance showing the effect of moisture content on mechanical properties of marking-nut

Parameters	SS	df	MS	F	CV, %
Rupture force, kg	2835.93	7	2835.93	133.44**	5.96
Deformation at rupture point, mm	160.86	7	160.86	8.51**	5.96
Hardness, kg mm^{-1}	57.80	7	8.26	3.13**	2.16
Energy used for rupture, kg mm	55599.24	7	55599.24	504.87**	10.57
Deformation ratio at rupture point	372.93	7	372.93	19.74**	2.80

(** Significant at 1% level)

References

1. AOAC. Official methods of analysis. Arrincon association of American chemists, 2000.
2. Altuntas E, Yildiz M. Effect of moisture content on some physical and mechanical properties of faba bean (*Vicia faba* L.) grains. J. of food engineering 2007; 78:174-183.
3. Burubai W, Akor AJ, Igoni AH, Puyate YT. Effects of temperature and moisture content on the strength properties of African nutmeg (*Monodora myristica*). Int. Agroph. 2007; 21:217-223.
4. Bamgboye I, Adejumo OI. Mechanical properties of Roselle (*Hibiscus sabdariffa* L) seeds. Agricultural science research journals. 2011; 1(8):178-183.
5. Fathollahzadeh H, Mobli H, Jafari A, Rajabipour A, Ahmadi H, Borghei M. Effect of moisture content on some physical properties of barberry. American-eurasian J Agric. & Environ. Sci. 2008; 3(5):789-794.
6. Guner M, Dursun E, Dursun IG. Mechanical behaviour of hazelnut under compression loading. Biosystem engineering. 2003; 85(4):485-491.
7. Gabadam EK, Anthony S, Asiam EK. The determination of some design parameters for palm nut crackers. European J of scientific research 2009; 38(2):315-325.
8. Haddad Y, Benet JC, Delenne JY, Merme A, Abecassis J. Rheological behaviour of wheat endosperm-proposal for classification based on rheological characteristics of endosperm test samples. J cereal Sci., 2001; 34:105-113.
9. Joshi DC, Das SK, Mukherjee RK. Physical properties of pumpkin seed. J agril. engg. Research. 1993; 54:219-229.
10. Jafari S, Khazaei J, Arabhosseini A, Massah J, Khoshtaghaza M. Study on mechanical properties of sunflower seeds. Elecronic J of polish agricultural university. 2011; 14(1):06.
11. Khazaei J. Characteristics of mechanical strength and water absorption in almond and its kernel. J. of cercetari agronomice in moldova. 2007; 1(133):37-51.
12. Mohsenin NN. Physical properties of plant and animal materials. Gordon and breach science publishers, New York, 1986.
13. Makanjuola GA. A study of some of the physical properties of melon seeds. J Agric Engg. Res, 1972; 17:128-137.
14. Mujumdar SH, Chakraborthy GS, Kulkarni KS. Medicinal potentials of *Semecarpus anacardium* nut - a review. J. of herbal medicine and toxicology. 2008; 2(2):9-13.
15. Poulsen MR. Fracture resistance of soybeans to compressive loading. Trans. of the ASAE, 1978; 21(6):1210-1216.
16. Pradhan RC, Naik SN, Bhatnagar N, Vijay VK. Moisture-dependent physical properties of jatropha fruit. J. of industrial crops and products 2009; 29:341-347.
17. Sirisomboon P, Kitchaiya P, Pholpho T, Mahuttanyavanitch W. Physical and mechanical properties of (*Jatropha curcas* L.) fruits, nuts and kernels. Biosyst. engg. 2007; 97(2):201-207.
18. Seifi MR, Alimardani R. Comparison of moisture-dependent physical and mechanical properties of two varieties of corn (Sc 704 and Dc 370). Australian J of agricultural engineering. 2010; 1(5):170-178.