Journal of Engineering Research and Reports

3(4): 1-7, 2018; Article no.JERR.46574

Compressive Resistance of Groundnut Kernels as Influenced by Kernel Size

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Authors' contributions

This work was carried out in collaboration between both authors. Author CU designed the study and performed the statistical analysis of the results. Author HU wrote the protocol and the first draft of the manuscript and managed the literature searches. Both authors read and approved the final manuscript.

Article Information

DOI: 10.9734/JERR/2018/v3i416887
Editor(s):
(1) Dr. Djordje Cica, Associate Professor, Faculty of Mechanical Engineering, University of Banja Luka, Bosnia and Herzegovina.
Reviewers:
(1) Nnaemeka R. Nwakuba, Michael Okpara University of Agriculture, Umudike, Nigeria.
(2) Benjawan Chutichudet, Mahasarakham University, Thailand.
(3) Jaime Cuauhtemoc Negrete, Autonomous Agrarian Antonio Narro University, Mexico.
Complete Peer review History: http://www.sdiarticle3.com/review-history/46574

Received 26 October 2018
Accepted 17 January 2019
Published 12 February 2019

Original Research Article

ABSTRACT

Mechanical properties of agricultural materials are essential for the proper design and fabrication of harvesting, handling, and processing equipment/machineries. In this research, some compressive resistance (force, energy and deformation at rupture point) of two groundnut (SAMNUT 10 and SAMNUT 11) kernels were investigated in terms of kernel sizes. During the test, the groundnut kernels were loaded quasi-statically in the axial orientation at a compressive loading rate of 20 mm/min, using the Universal Testing Machine. Results obtained from the test showed that kernel size and groundnut variety had significant ($P \leq 0.05$) effect on all the mechanical parameters studied. The force required for initiating the kernel rupture increased from 37.21 to 76.10 N for SAMNUT 10; and 30.10 to 64.19 N for SAMNUT 11, as the kernels size increased from small to large size. In addition, the energy absorbed by the kernel at rupture point increased from 0.021 to 0.054 Nm for SAMNUT 10; and 0.016 to 0.044 Nm for SAMNUT 11, for the small and large kernel sizes respectively. Furthermore, the results showed that SAMNUT 10 kernels had slightly higher compressive resistance values than the SAMNUT 11 kernels. Data obtained from this research will help to design and fabricate equipment used in handling and processing of groundnut kernels.

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Keywords: Groundnut; kernel size; mechanical properties; compressive loading; rupture point.

1. INTRODUCTION

Groundnut (*Arachis hypogaea*) belongs to the family leguminosae, with two major varieties, which are the runner and bunch varieties [1-2]. Groundnut plant shows high sensitivity to soil salinity, tolerating a wide range of pH values, but prefers neutral to slightly acidic soils [3]. Groundnut kernels are rich in protein, vitamins and contain significant amount of high quality edible oil. Since 1990, the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), and other research centres like, Institute for Agricultural Research, and the University of Georgia have developed and tested over 30 groundnut varieties, which are less susceptible to foliar diseases and resistant to rosette disease [4].

Mechanical properties of groundnut pod and kernel, such as, rupture force, toughness, failure point, etc. are essential in designing peanut harvesting, handling and processing, machineries. This is because these mechanical properties not only constituted the basic engineering data required for machine and equipment design, but also they assist the selection of suitable methods for obtaining those data [5]. In addition, Davies [6] stated that, the knowledge of physical and mechanical properties of groundnut are important in order to facilitate the design and development of its harvesting, shelling, conveying, cleaning, delivering, separation, packing, storing, drying, mechanical oil expelling and processing equipment and machineries.

In order to design efficient handling and processing equipment for agricultural products, it is necessary to have the knowledge of their fracture characteristics under compressive loading rate. Mechanical properties of several agricultural materials had been studied by many researchers, in the past four decades. Kang *et al.* [7] reported that mean values of bio-yield strain and energy to bio-yield of wheat decreased as the moisture content increased at a loading rate of 1 to 25 mm/min. Also, [8] investigated some moisture dependent engineering properties of the peanut kernels. His results showed that rupture strength of groundnut kernel was highly dependent on moisture content. The highest rupture strength was obtained as 13.22 N/mm^2 at the moisture content of 11.3% d.b. in addition, Braga et al. [9] determined the force, deformation, and energy required to initiate macadamia nut rupture under compression, with respect to moisture content, nut size, and loading position. They reported that the required force, deformation, and energy to initiate the rupture of macadamia nuts were higher when compressed perpendicular to split plane, depending on both moisture content and size. Seed and kernel sizes played significant roles in engineering design, and they vary greatly both among plant individuals, populations or species [10].

Currently, there is dearth information on the effect of kernel size on the mechanical properties of SAMNUT 10 and SAMNUT 11 groundnut kernels. Therefore, the objective of this study was to investigate compressive resistances (rupture force, rupture energy and deformation at rupture point) of two groundnut varieties (SAMNUT 10 and SAMNUT 11) kernels, classified into three categories as large, medium and small sizes. The results that would be obtained from this research will provide useful data from the design and development of efficient groundnut processing machines.

2. MATERIALS AND METHODS

2.1 Samples Collection and Preparation

Two popular varieties of groundnut (SAMNUT 10 and SAMNUT 11) widely cultivated in Nigeria, due to its high tolerance to diseases were used for this research. The groundnut were obtained from ICRISAT Kano State, Nigeria, and planted in the research farm of Delta State Polytechnic, Ozoro, Nigeria, in April 2018. The groundnuts were grown under organic farming practices, with no artificial fertilizers or chemicals used during the growing period. Since groundnut did not responds better to direct fertilization [11], poultry waste and cattle dumps were broadcast and incorporated into the soil during the land preparation. Weeding was done manually, while disease infested plants were uprooted and burnt.

The groundnut samples were harvested at full maturity stage, when about 80% of the kernels were plump and showing their true colour [11]. After harvesting, they were sun-dried for five days on an elevated platform, to facilitate their threshing. The threshed groundnut pods were shelled carefully, to prevent mechanical damage to the kernels. In order to attained lower uniformed moisture content, the shelled kernels were air-dried for another ten days. Lastly, the kernels were checked carefully, to remove contaminants such as, foreign materials, premature and damage kernels, disease and pest infested kernels, etc.

The groundnut kernels used for this research had moisture content of 20% wet basis. Moisture content of the groundnut kernels were determined by using gravimetrical method, and was calculated using Equation (1) [12-13].

$$\text{Moisture content} = \frac{\text{Weight of wet sample} - \text{weight of dry sample}}{\text{Weight of wet sample}} \times 100 \quad (1)$$

Furthermore, the selected groundnut kernels were classified into three categories (large, medium and small sizes). In order to determine the kernel size, the three main dimensions, length (L), width (W) and thickness (T), of groundnut kernels were measured using a digital vernier caliper with accuracy of 0.01 mm. The size classifications of the kernels used for this research are shown in Table 1.

2.2 Compression Test

The mechanical test of the groundnut kernels was carried out at the National Centre for Agricultural Mechanization (NCAM), Ilorin, Kwara State, Nigeria. During the test, each sample (groundnut kernel) was placed under the loading cell of the Universal Testing Machine (Testometric model, manufactured in England), with accuracy of 0.001 N, ensuring that the sample was at alignment with the loading cell, and compressed at the speed of 20 mm/min [14-15]. As quasi compression of the sample progressed, a force-deflection curve was plotted automatically by the Universal Testing Machine (Fig. 1), in relation of the sample to the compression, up to the rupture point. From each test, these compressive parameters (rupture force, deformation at rupture, and rupture energy) of the sample were calculated automatically by Machine. According to [16], the rupture point of material correlates to the macroscopic failure (breaking point) of the sample. The rupture energy (Toughness) is the work required to initiate rupture of the groundnut kernel, which is the area under the force-deformation curve up to the rupture point [17]. Fifteen samples were tested individually, under each variety and size category and the average value recorded.

2.3 Statistical Analysis

A 2 x 3 factorial experiment in a Completely Randomized Design (CRD) was employed to study the effects of groundnut variety and kernel size on selected mechanical properties of groundnut kernels. Two groundnut varieties (SAMNUT 10 and SAMNUT 11), and three kernel sizes (Large, medium and small) were the considered experimental factors which were replicated fifteen times. The Results obtained from this research were subjected to analysis of variance, using SPSS 20.0 statistical software. In addition, the mean separation was done by using Duncan's Multiple Range tests at 95% confidence level.

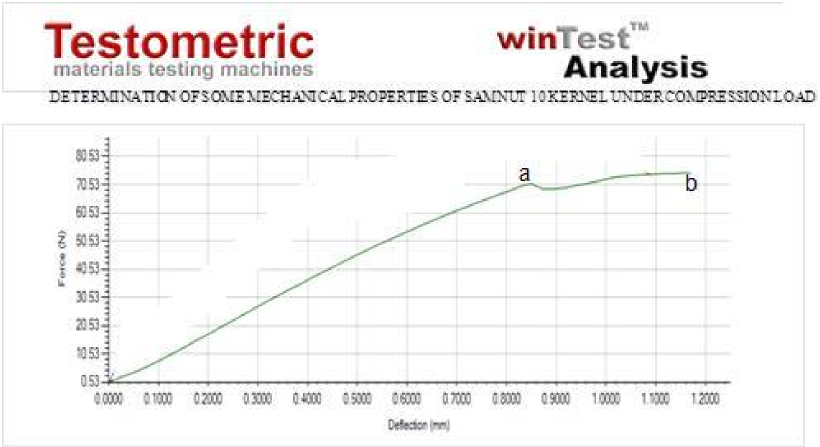

Fig. 1. A force-deformation curve of SAMNUT 10 kernel under quasi compressive loading

a = bio-yield point, which is also expressed as failure point [16]

b = breaking point, which is also expressed as rupture point [16]

Table 1. Size classifications of the groundnut kernels

Variety	Size (mm)		
	Small	Medium	Large
SAMNUT 10	L <12.5	12.5 ≤ L ≤ 17.5	L >17.5
	W <7.5	7.5 ≤ W ≤ 9.5	W >9.5
	T < 6.5	6.5 ≤ T ≤ 8.5	T >8.5
SAMNUT 11	L <12.5	12.5 ≤ L ≤ 17.5	L >17.5
	W <7.5	7.5 ≤ W ≤ 9.5	W >9.5
	T < 6.5	6.5 ≤ T ≤ 8.5	T >8.5

3. RESULTS AND DISCUSSION

The effect of kernel size on the compressive resistance of the two groundnut varieties was statistically found significant ($P < 0.05$), in the three parameters studied, as shown by the analysis of variance (ANOVA) presented in Table 2. In addition, the interaction effect of kernel size and groundnut variety was not significant on the compressive resistance parameters of the groundnut kernel.

The compressive resistance (rupture force, rupture energy, and deformation at rupture) of the groundnut kernels (large, medium and small sizes), with their respective separated means are presented in Table 3. Furthermore, the regression relationship between kernel size and the mechanical parameters are represented by linear equations presented in Table 4.

From the results, all the compressive resistance parameters (force, energy and relative deformation at rupture point) increased with increase in the kernel's size. In addition, the compressive resistance of the SAMNUT 10 kernels was statistically higher than those of the SAMNUT 11 kernels (Table 3). This could be attributed to the differences in the structural compositions of the two groundnut varieties. The results of the effect of kernel size on the deformation of the groundnut kernel presented in Table 3 revealed that, deformation at kernel rupture point increased with increase in kernel size. This depicted that, at larger kernel size, the kernel will experience more deformation, therefore absorbing more compressive loading. Furthermore, the high values of the correlation ($r \geq 0.850$), presented in Table 4, showed that there is strong regression relationship between the kernel size and its compressive resistance. This behavioural trend of the kernels could be attributed to the fact that, increment in the kernel size will lead to its more resistance to rupture. Also, larger kernel possessed larger modulus of elasticity and capable of having more deformable power under compressive loading [18]. From the results, SAMNUT 10 groundnut kernels will withstand more loading before rupture than the SAMNUT 11 groundnut kernels, during their handling and packaging operations. Also during processing operation like oil extraction, SAMNUT 11 kernels will require lesser compressive energy and lower power consumption than the SAMNUT 10 kernels. According to Sadowska [19], despite variability of the size and the fracture force of seeds representing different accessions and varieties, there was a clear tendency towards an increase in fracture force along with an increase in seed size. These results were similar to those reported by Aydin C and Ozcan M [20] for terebinth and [21] for almond kernel. Similar trend was also reported by Saiedirad [22], on cumin seed, where the force and energy required initiating the seed rupture increased as the seed size increased from small to large.

These results confirm the sensitivity of agricultural materials to mechanical damage due to variation in their variety and size. Groundnut rupture force which is affected by variety and kernel size, are significant factors that influenced its mechanical damage during handling and storage. Due to changing surface area contact between groundnut kernel and the compressive plate during quasi compressive loading, the rupture stress of the kernel is difficult to determine; therefore, rupture energy seems to be a better parameter of the kernel hardness [23], Additionally, [24] determined strain rate and size effects on pear tissue failure. They observed that as the strain rate increased, the failure stress also increased while failure strain remained nearly the same. Thus, toughness and stiffness of pear both increased with increasing strain rate. Ince [25] reported that the rupture force of peanut statistically ($P \leq 0.01$ level of significance) increased with an increase in size of hulled peanut and kernel. According to their results, the rupture force of peanut kernels increased 38.03 N (small size) to 59.30 N (large size). Compressive resistance of groundnut kernel is a

Table 2. ANOVA of the compressive resistance of groundnut kernels

Source of variation	df	Rupture force	Rupture energy	Def. at rupture
Variety	1	5.34E-07*	3.12E-02*	4.51E-03*
Size	2	2.54E-07*	9.04E-05*	2.04E-08*
Variety x Size	2	0.6588^{ns}	0.6202^{ns}	0.1466^{ns}

** =Significant at ($P \leq 0.05$); ns = non-significant at ($P \leq 0.05$); df = degree of freedom*

Table 3. Some descriptive statistics for the compressive resistance of groundnut kernels

Parameter	Variety	Large	Medium	Small
Rupture force (N)	SAMNUT 10	76.10^{c} ±5.28	52.74^{b}±1.73	37.31^{a}±6.17
	SAMNUT 11	64.19^{c}±7.49	46.08^{b}±4.18	30.10^{a}±5.55
Rupture energy (Nm)	SAMNUT 10	0.054c±0.004	0.032^{b}±0.005	0.021^{a}±0.003
	SAMNUT 11	0.044^{c}±0.019	0.018^{b}±0.001	0.016^{a}±0.004
Def. at rupture (mm)	SAMNUT 10	1.399^{c}±0.082	0.781^{b}±0.056	0.687^{a}±0.035
	SAMNUT 11	1.156^{c}±0.152	0.719^{b}±0.048	0.599^{a}±0.041

Values are mean ± SD; Means with the same common letter in superscript in the same row are not significantly different ($P < 0.05$) according to Duncan's multiple range test

Table 4. Regression equations of compressive resistance of groundnut kernel as a function of its size

Parameter	Variety	Linear equation	R^2	r
Rupture force	SAMNUT 10	$y = -19.39x + 94.16$	0.986	0.993
	SAMNUT 11	$y = -17.04x + 80.87$	0.998	0.999
Rupture energy (Nm)	SAMNUT 10	$y = -0.016x + 0.068$	0.964	0.981
	SAMNUT 11	$y = -0.014x + 0.054$	0.803	0.896
Deformation at rupture (mm)	SAMNUT 10	$y = -0.356x + 1.667$	0.847	0.920
	SAMNUT 11	$y = -0.278x + 1.381$	0.902	0.950

y = the compressive parameter, x = kernel size, R^2 = Coefficient of determination, r = correlation

vital attribute in the design of its handling, processing and packaging systems. In addition, rupture force is one of the significant parameters in determining the shelling method of groundnut, and in the design of groundnut sheller [25].

3.1 Engineering Implication of the Results

The results of this results showed that it is important to sort groundnut kernels into size categories, before their processing operation to save energy. This is because larger groundnut kernels will require more force, to initiate their rupture than smaller groundnut kernels.

4. CONCLUSIONS

This research paper focused on the effect of kernel size on the compressive resistance of SAMNUT 10 and SAMNUT 11 groundnut kernels. From the results obtained, it can be seen that kernels size had significant influence on the compressive resistance of the two groundnut varieties studied. The results showed that rupture force, rupture energy and deformation at rupture increased with increase in kernel size, for both groundnut varieties. This showed that lager kernel can withstand more deformation, therefore absorbing more compressive loading. The knowledge of compressive resistance of groundnut kernel is essential for the design and fabrication of its handling and processing machines.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Asiedu JJ. Processing of tropical crops- a technological approach. Basingstoke, London: Macmillan; 1992.
2. Muhammad AI, Isiaka M, Fagge AA, Attanda ML, Lawan I, Dangora ND. Some engineering properties of three varieties of groundnut pods and kernels. Arid Zone Journal of Engineering, Technology and Environment. 2015;11:61-75.
3. Tsigbey FK, Brandenburg RL, Clottey VA. Peanut production methods in northern Ghana and some disease perspectives. Online Journal of Agron. 2003;34(2):36-47.
4. Ndjeunga J, Ntare BR, Ajeigbe H, Echekwu CA, Ibro A, Amadou A. Adoption and impacts of modern groundnut varieties in Nigeria; 2013. Available:http://grainlegumes.cgiar.org/wp-content/uploads/2016/08/2013_Groundnut_Nigeria_Early-adoption-of-groundnut.pdf
5. Bagheri I, Payman SH, Rahimi- Ajdadi F. Mechanical behavior of peanut kernel under compression loading as a function of moisture contents. Elixir Agriculture. 2011; 36:3552-3557.
6. Davies RM. Some physical properties of groundnut grains. Research Journal of Applied Sciences, Engineering and Technology. 2009;1(2):10–13.
7. Kang YS, Spillman CK, Steele JL, Chung DS. Mechanical properties of wheat. Trans. ASAE. 1995;38(2):573-578.
8. Aydin C. Some engineering properties of peanut and kernel. Journal of Food Engineering. 2007;810–816.
9. Braga GC, Couto SM, Hara T, Neto JTPA. Mechanical behaviour of macadamia nut under compression loading. Journal of Agricultural Engineering Research. 1999; 72:239–245.
10. Xiao Z, Zhang Z, Krebs CJ. Seed size and number make contrasting predictions on seed survival and dispersal dynamics: A case study from oil tea *Camellia oleifera*. Forest Ecology and Management. 2015; 343:1-8.
11. Ajeigbe HA, Waliyar F, Echekwu CA, Ayuba K, Motagi BN, Eniayeju D, Inuwa A. A farmer’s guide to groundnut production in Nigeria. Patancheru 502 324, Telangana, India: International Crops Research Institute for the Semi-Arid Tropics. 2014;36.
12. Altuntas E, Ozkan Y. Physical and mechanical properties of some walnut (*Juglans regia* L.) cultivars. International Journal of Food Engineering. 2008;4: Article 10.
13. Akpokodje O, Uguru H, Esegbuyota D. Remediation of cassava effluent contaminated soil using organic soap solution: Case study of soil physical properties and plant growth performance. Journal of Scientific Research and Reports. 2018;21(3):1-11.
14. Ozturk I, Ercisli S, Kalkan F and Demir B. Some chemical and physico-mechanical properties of pear cultivars. African Journal of Biosystems. 2009;8:687-693.
15. Eboibi O, Uguru H. Storage conditions effect on physic-mechanical properties of Nandini cucumber. International Journal of Engineering and Technical Research. 2017;7(10):76 -82.
16. Steffe JF. Rheological methods in food process engineering. (Second Edition). Freeman Press, USA. 1996;72-90.
17. Mohsenin NN. Physical properties of plant and animal materials. 2nd Edition. Gordon and Breach Science Publishers, New York; 1986.
18. Oghenerukevwe PO, Uguru H. Effect of fruit size and orientation on mechanical properties of gmelina fruit (*Gmelina arborea*) under quasi-Static loading. International Journal of Engineering and Technical Research. 2018;8:47-51.
19. Sadowska J, Jeliński T, Błaszczak W, Konopka S, Fornal J, Rybiński W. The effect of seed size and microstructure on their mechanical properties and frictional behavior. International Journal of Food Properties. 2013;16:814-825.
20. Aydin C, Ozcan M. Some physico-mechanic properties of terebinth (*Pictacia terebinthus* L.) fruits. Journal of Food Engineering. 2002;53:97–101.
21. Aydin C. Physical properties of almond nut and kernel. Journal of Food Engineering. 2003;60:315–320.
22. Saiedirad MH, Tabatabaeefar A, Borghei A, Mirsalehi M, Badii F, Ghasemi Varnamkhasti M. Effects of moisture content, seed size, loading rate and seed orientation on force and energy required for fracturing cumin seed (*Cuminum cyminum* Linn.) under quasi-static loading.

Journal of Food Engineering. 2008;86: 565–572.

23. Nyorere O, Uguru H. Effect of loading rate and moisture content on the fracture resistance of beechwood (*Gmelina arborea*) seed. J. Appl. Sci. Environ. Manage. 2018;22(10):1609–1613.
24. Baritelle A, Hyde GM. Strain rate and size effects on pear tissue failure. Transactions of the ASAE. 2000;43(1):95–98.
25. Ince A, Ugurluay S, Güzel E, Özcan MT. Mechanical behavior of hulled peanut and its kernel during the shelling process. Philipp Agric Scientis. 2009;92(1):92-99.

Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sdiarticle3.com/review-history/46574