Journal of Scientific Research and Reports

Volume 30, Issue 9, Page 205-216, 2024; Article no.JSRR.121228
ISSN: 2320-0227

Engineering Properties of Groundnut for Designing a Battery-operated Decorticator

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: https://doi.org/10.9734/jsrr/2024/v30i92345

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/121228

Original Research Article

Received: 20/06/2024
Accepted: 22/08/2024
Published: 29/08/2024

ABSTRACT

Design of groundnut decorticators needs a substantial knowledge of physical properties of groundnut, whose outcome will be an efficient decorticating machine. A properly designed groundnut decorticator will have less brokens and more whole kernels. Thus, it is necessary to study about the physical properties of groundnut before designing a groundnut decorticator. The important physical properties which effect the battery-operated groundnut decorticator were size (length and width) of kernels, size (length, width and thickness), 1000 pod mass, bulk density, angle of repose, moisture content and rupture force of groundnut pods. The size of kernels and groundnut pods were measured using a vernier caliper. It was observed that the average length of pod was 30.84, 28.02 and 36.80 mm, average width of pod was 12.01, 12.59 and 14.33 mm and average thickness of pod was 10.79, 10.91 and 14.31 mm for variety 1, 2 and 3 respectively. For varieties 1, 2 and 3, the average kernel length was 16.68, 19.28, and 18.70 mm and the average kernel width

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Cite as: *Ugargol, Megha, Gowtham, and Santosh. 2024. "Engineering Properties of Groundnut for Designing a Battery-Operated Decorticator". Journal of Scientific Research and Reports 30 (9):205-16. https://doi.org/10.9734/jsrr/2024/v30i92345.*

was 11.59, 9.080 and 8.00 mm respectively. The bulk density was determined by finding the mass/volume relationship. The bulk densities of groundnut pods were found to have an average value of 0.36, 0.35 and 0.26 g/cm^3 for variety 1, 2, 3 respectively. The angle of repose was calculated by lifting a cylinder filled with groundnuts. The average angle of repose values for variety 1, 2 and 3 was 26.59°, 26.54° and 24.22°. The moisture content was determined using the oven method. The average values of moisture content were found to have 5.37%, 4.52% and 4.5% for variety 1, 2 and 3 respectively. Rupture force was calculated by using Texture Analyzer. The average rupture force for breaking shell of variety 1, 2 and 3 was 237.61 N, 231.01 N and 337.86 N. These values of physical properties will form a basis for designing a battery-operated groundnut decorticator.

Keywords: Groundnut; pod; kernel; physical properties and decorticator.

1. INTRODUCTION

Groundnut or peanut (*Arachis Hypogaea Linn*) is commonly known as the poor man's nut. It is an important oil seed and food crop [1]. The whole pod is frequently referred to as a monkey nut. According to studies by Jambunathan et al. [2] groundnut seeds (kernels) contain 35.8–54.2% oil, 16.2-36.0% protein, and 10–20% carbohydrates. The seeds are also a good source of vitamins E, niacin, folacin, riboflavin, and thiamine, as well as minerals including calcium, phosphorus, and iron. Haulms of groundnuts are a wholesome source of feed for animals. They have larger concentrations of protein (8–15%), fats (1-3%), minerals (9–17%), and carbohydrates (38–45%) than cereal fodders. Animal's digestibility of crude protein is 88% and that of nutrients in groundnut haulm is approximately 53% [3-6].

Physical properties of groundnut play a significant role in their handling, processing and storage. The knowledge of physical properties of biological material gives a basis for the design and selection of appropriate equipment for post-harvest operations. Groundnut decorticator, also called shell removers and skin separator, is the machine used for stripping the skin or hulls of seeds. A groundnut decorticator is specifically designed to crack the outer shell of groundnut pods to obtain the kernels. On Indian farm, many groundnut decorticators are used. The selection and design of groundnut decorticating machines is directly related to physical properties of groundnut.

Determination of physical properties such as size of pod and kernels, moisture content, angle of repose, bulk density, 1000 pod weight and rupture force of pod were required for the design of various machine parts. The purpose of this study was to determine the physical properties of groundnut and select the most significant values for the design and development of battery-operated groundnut decorticator.

2. MATERIALS AND METHODS

The experiments were carried out in Energy Laboratory of Division of Agricultural Engineering, ICAR-Indian Agricultural Research Institute (IARI), New Delhi. As our aim is to make the decorticator more robust and flexible, we randomly bought three different varieties of groundnut pods from local market of New Delhi and were named as variety 1, 2 and 3. The physical properties of these three varieties were determined and the methodology is described in the further section of this paper. The plan of experiment to study the physical properties of groundnut pod was given in Table 1.

Table 1. Experimental plan to study the physical properties of groundnut varieties

Parameters (Independent variables)	Levels	Parameters (Dependent variables/ performance parameters)
Varieties of pod	3	Size
Replication	3	Bulk density
Total number of experiments	9	1000 pods weight
		Angle of repose
		Moisture content
		Rupture force

2.1 Determination of size of groundnut pods and seeds

Size (length and width) of kernels and size (length, width and thickness) of three different varieties of groundnut were measured using a digital vernier caliper with an accuracy of ±0.02mm [7-8]. Twenty samples from one hundred groundnut pods were selected randomly from a bulk quantity of groundnut pods. Length, width and thickness were measured by holding each groundnut pod and kernel with the help of vernier caliper (Fig. 1 and Fig. 2). The size measurement of groundnut pods and kernels were replicated three times and the observed values were recorded in datasheet (Appendix A.1 and A.2). The specifications of vernier caliper was given in Appendix B.1.

Fig. 1. Measurement of size of groundnut pods

Fig. 2. Measurement of size of groundnut kernels

2.2 Determination of 1000 Pod Mass

The 1000 pod mass gives a substantial knowledge in calculating variety of grain holding units i.e., hopper. A one kilogram of groundnut pods was taken and divided into 10 equal portions. Five replications were made to get average value of 1000 pod mass (Appendix A.3). The thousand pod mass was randomly selected from each portion and weighed separately using a digital electronic balance [4]. The specifications of vernier caliper was given in Appendix B.2.

2.3 Determination of Bulk Density of Groundnut Pods

The bulk density is determined by finding the mass/volume relationship (Fig. 3). First an empty cylindrical container (9 cm diameter and 11.8 cm height) of predetermined volume was taken. Container is kept on the digital weighing balance (10 kg and L.C. 0.1g) and the container weight is tarred. Bulk of groundnut pods were poured into the container up to a constant height and top of container is labeled off and weighed on same digital balance. Bulk density is calculated by equation 1 (Nalladurai et al. 2002). Five replications were done and values were given in Appendix A.4.

$$\rho = \frac{M}{V} \quad (1)$$

where,

ρ - bulk density (kg/m^3)

M - weight of pods (kg)

V - volume of container (m^3)

2.4 Determination of Angle of Repose of Groundnut Pods

Angle of repose is the angle between the base and the slope of cone formed on a vertical fall of the granular material to a horizontal plane. The values of angle of repose of groundnut pods were useful in determining the angle of inclination of the feeding chute. A cylinder of diameter 148 mm and 300 mm height was taken for measuring angle of repose. The cylinder was open from both sides. The cylinder was kept on a plane horizontal surface and it was filled with groundnut pods. After that cylinder was gently lifted up above the flat surface and it was continued gradually until all the groundnut pods formed a conical heap on the surface (Fig. 4). This procedure was repeated five times and recorded in data sheet. Angle of repose Θ_f was calculated by equation 2 [9,10]]. Five replications were done and the values were given in Appendix A.5.

$$\Theta_f = \tan^{-1}\left(\frac{2H}{D}\right) \quad (2)$$

where Θ_f, H and Dare angle of repose (degrees), height of heap (mm) and diameter of heap (mm) respectively.

2.5 Determination of Moisture Content of Groundnut Pods

Moisture content of groundnut pod refers to the amount of water contained in the pod. A groundnut decorticator consumes more energy in breaking the pods and will lead to crush the seeds when the moisture content is high. Therefore, before shelling, it is desirable to dry them sufficiently. The moisture content of groundnut pods was determined using the oven method [9]. The initial weights of samples were determined using the digital electric balance. Three samples were dried in convection air oven which is set at temperature of 105˚C and monitored over a period of 24 h at 6 h intervals until the weights of the samples were found to be constant. The moisture content (wet basis) was calculated as the weight of moisture (initial weight minus final weight of sample) divide by the initial weight of sample and expressed in percentage. The values were provided in Appendix A.6. The formula employed in the process according to Sahay and Singh [9] is as follows (equation 3):

$$MC(wb) = \frac{M1-M2}{M1-M3} \times 100 \quad (3)$$

Where,

M1 = Weight of the wet sample, g

M2 = Weight of the dry sample, g

M3 = Weight of the moisture can, g

2.6 Determination of Rupture Force for Groundnut Pods

Rupture force indicates the minimum force which is required to break the groundnut pods and it must be exceeded to separate the kernel from the pod. This property is very important

parameter in designing of equipment for shelling, milling, handling, storage, transportation. Insufficient data on this property leads to mechanical damage to pods in decortication operations which cause reduction in germination power and viability of seeds. The individual sample from three varieties of groundnut pods was loaded in Texture Analyzer (Model: TA-HDplusC, Stable Micro Systems, UK) each time and compressed at a loading speed of 2mm/s until fracture occur (Fig. 5). This was replicated five times to get an average rupture force. Data of rupture force are given in Appendix A.7. On seeing the initial crack, the loading was stopped. Thus, the rupture force and deformation at rupture point were displayed on a computer attached with a Texture Analyzer automatically. This experiment was conducted at the Division of Post Harvest Technology of the Institute.

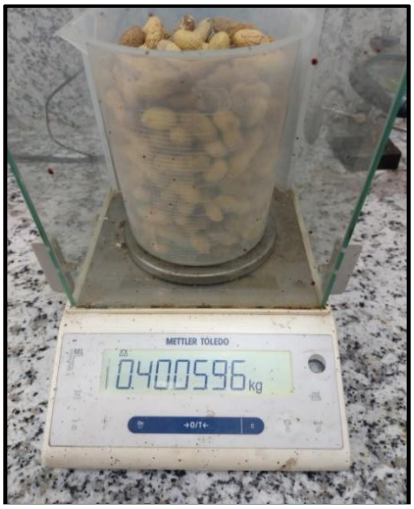

Fig. 3. Weighing of groundnut pods for finding bulk density

Fig. 4. Determination of angle of repose of groundnut pods

List 1. Texture analyser setting which was followed during experiment was mentioned below:

Parameter	Value
Mode	Measure force in compression
Option	Return to start
Pre-test speed	2 mm/s
Test speed	1 mm/s
Post test speed	3 mm/s
Deformation	60%
Load cell	500kg

Fig. 5. Determination of rupture force of groundnut pod on Texture analyzer

2.7 Statistical Analysis of the Collected Data

The obtained data from the measurement of physical properties was arranged in proper format and analysed. The data was formatted in correct tabular form in MS Excel package. After analysis the average values were obtained from each physical property.

3. RESULTS AND DISCUSSION

3.1 Size of Groundnut Pods

The average length of variety 1, 2 and 3 groundnut pods were 30.84, 28.02 and 36.80 mm, respectively (Table 2). The mean width of groundnut pods of variety 1, 2 and 3 were 12.01, 12.95 and 14.33 mm, respectively. The mean thickness of groundnut pods of variety 1, 2 and 3 were 10.79, 10.91 and 14.31 mm respectively. Among the width and thickness values, the highest value was selected for keeping the clearance between decorticating shoe and bottom sieve that was kept as 12 mm for variety 1, 13 mm for variety 2 and 14 mm for variety 3. These values were closer to values obtained by Muhammad et al. 2015. The length helped in deciding the length of sieve opening. Both width and thickness helped in deciding the concave clearance between the decorticating shoes and sieve as reported by Maduako and Hamman [11,12]. All the values of length, width and thickness of groundnut pods of variety 1, 2 and 3 are given in Appendix-A.1. The mean length of groundnut kernels of variety 1, 2 and 3 were 16.68, 19.28 and 18.70 mm respectively which is given in Table 2. Correspondingly, the width of groundnut kernels was 9.08, 8.00 and 11.59 mm. These values were near to values obtained by Maduako and Hamman [11]. The width of rectangular sieve was decided based on the mean width value of groundnut kernels. It was observed that the size (length and width) of kernel is significant factor for determining the width of rectangular sieve because it was also seen that low kernel size was obtained with greater size of groundnut pods. Therefore, width of rectangular sieve was taken. The length and width of kernels helped in deciding the width of sieve opening. The length and width of kernels of variety 1, 2 and 3 are given in Appendix-A.2.

Table 2. Mean values of groundnut pods and kernel dimensions

	Dimensions	Number of samples	Dimensions of different variety of groundnut pods, mm		
			Varieties		
			1	2	3
Groundnut pods	Length	20	30.84±3.74	28.02±6.62	36.8±3.1
	Width	20	12.01±0.91	12.95±0.87	14.33±0.59
	Thickness	20	10.79±0.85	10.91±0.92	14.31±0.69
Groundnut kernels	Length	20	16.68±1.95	19.28±1.92	18.70±1.60
	Width	20	9.08±0.48	8.00±0.52	11.59±0.68

Table 3. Mean values 1000 pod mass of groundnut

Parameter	Number of samples	Weight of 1000 pod mass of different varieties of groundnut pods, g		
		Varieties		
		1	2	3
1000 pod mass	5	1270.66±23.89	1266.88±23.29	1334.14±20.61

Table 4. Mean values of bulk density of groundnut pods

Parameter	Number of samples	Bulk density of different varieties of groundnut pods, g/cm^3		
		Varieties		
		1	2	3
Bulk density	5	0.36±0.03	0.35±0.01	0.26±0.02

3.2 1000 Pod Mass of Groundnut Pods

The mean 1000 pod mass of groundnut pods of variety 1, 2 and 3 were 1270.66, 1266.88 and 1334.14 g respectively (Table 3). It is clear from table that the mass of groundnut pod increased with the increase in size of pods. Based on these values the feeding chute was designed so that it can occupy the maximum pod mass of 1334.14 g. It helped in designing the feeding chute. These values were in confirmation with study of Manjunatha et al. 2017. The 1000 pod mass of groundnut pods of variety 1, 2 and 3 are given in Appendix-A.3.

3.3 Bulk Density of Groundnuts Pods

The mean bulk density of groundnut pods of variety 1, 2 and 3 were 0.36, 0.35 and 0.26 g/cm^3, respectively (Table 4). Similar findings were observed by Muhammad et al. 2015. These values helped in designing the feeding chute to decide the bulk of pods that can accommodate in feeding chute. As the size of pod increased the bulk density decreased. Therefore, highest value of bulk density was considered with aim to accommodate the variety of size of groundnut pods. It also helped in designing the feeding chute volume. The bulk density of groundnut pods of variety 1, 2 and 3 are given in Appendix-A.4.

3.4 Angle of Repose of Groundnut Pods

The mean angle of repose of groundnut pods of variety 1, 2 and 3 were 26.59°, 26.54° and 24.22° g/cm^3, respectively (Table 5). As the pod size increases, the angle of repose of groundnut pods also decreased. The angle of inclination of feeding chute selected for variety 1 and 2 was 27° while for variety 3 was 25°angle. These values helped in deciding the angle of inclination of feeding chute. Hence, higher value of angle repose was considered. The similar values were reported by Maduako and Hamman [11]. The angle of repose of groundnut pods of variety 1, 2 and 3 are given in Appendix-A.5.

3.5 Moisture content of groundnut pods

The mean moisture content values of groundnut pods of variety 1, 2 and 3 were 5.37%, 4.52% and 4.5% respectively (Table 6). The moisture content of pods affects the decorticating efficiency of the decorticator. The high moisture content tends to increase the power consumption so it is necessary to dry the pods if moisture content is high before decortication. The values obtained were similar to Muhammad et al. 2015.The moisture content of groundnut pods of variety 1, 2 and 3 are given in Appendix-A.6.

Table 5. Mean values of angle of repose of groundnut pods

Parameter	Number of samples	Angle of repose of different varieties of groundnut pods, degrees		
		Varieties		
		1	2	3
Angle of repose	5	26.59±1.27	26.54±1.63	24.22±0.64

Table 6. Mean moisture content values of groundnut pods

Parameter	Number of samples	Moisture content (w.b.) of different varieties of groundnut pods, %		
		Varieties		
		1	2	3
Moisture content	5	5.37±0.4	4.52±0.17	4.5±0.19

Table 7. Mean rupture force of groundnut pods

Parameter	Number of samples	Rupture force of different varieties of groundnut pods, N		
		Varieties		
		1	2	3
Rupture force	5	237.61±25.36	231.01±24.71	337.86±44.13

3.6 Rupture Force of Groundnut Pods

The mean rupture force values for groundnut pods of variety 1, 2 and 3 were 237.61, 231.01 and 337.86 N, respectively (Table 7**)**. It helps in designing the force needed by the four-bar linkage of crank that operated the decorticator shoe to decorticate the groundnut pods through its lever. It helps in designing the force needed by the four-bar linkage of decorticator to just rupture the groundnut pods through decorticating lever. The similar values were obtained by Muhammad et al. 2015. The rupture force of groundnut pods of variety 1, 2 and 3 were given in Appendix-A.7.

4. CONCLUSION

The physical properties of three varieties of groundnut were studied. It was observed that among the three varieties, the length of pod was found to have an average value of 30.84 mm for variety 1, 28.02 mm for variety 2 and 36.80 mm for variety 3. The width was found to have an average value of 12.01, 12.59 and 14.33 mm for variety 1, 2 and 3 respectively. The average value of thickness was found to have 10.79 mm for variety 1, 10.91 mm for variety 2 and 14.31 mm for variety 3. The length of kernels was found to have average values of 16.68 mm for variety 1, 19.28 mm for variety 2 and 18.7 mm for variety 3. The width of kernels was found to have average values of 11.59 mm for variety 1, 9.08 mm for variety 2 and 8 mm for variety 3. The 1000 pod mass were found to have an average values of 1270.66 g for variety 1, 1266.88 g for variety 2 and 1334.14 g for variety 3. The bulk densities were found to have an average value of 0.36 g/cm^3 for variety 1, 0.35 g/cm^3 for variety 2 and 0.26 g/cm^3 for variety 3 of groundnut pods. The average angle of repose values for variety 1, 2 and 3 was 26.59° and 26.54° and 24.22°. The average values of moisture content were found to have 5.37, 4.52 and 4.5 % for variety 1, 2 and 3 was respectively. The average values of rupture force for variety 1 was 237.61 N, variety 2 was 231.01 N and for variety 3 was 337.86 N. The obtained average values of these physical properties of groundnut pods and kernels will be further adopted in designing the battery-operated groundnut decorticator.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

ACKNOWLEDGEMENTS

I sincerely thank to all the scientific personnel and students of the Division of Agricultural Engineering, ICAR-IARI, New Delhi, India for your guidance.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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APPENDIX

APPENDIX-A

Table A.1. Length, width and thickness of variety 1, variety 2 and variety 3 groundnut pods

Sample	Variety 1			Variety 2			Variety 3		
	L (mm)	W (mm)	T (mm)	L (mm)	W (mm)	T (mm)	L (mm)	W (mm)	T (mm)
1	38.7	14.71	14.40	33.76	12.51	10.30	31.58	13.65	9.49
2	37.8	14.63	15.01	35.12	11.60	11.06	36.06	13.24	10.96
3	39.9	14.06	14.20	34.73	13.36	10.58	34.79	13.18	11.34
4	39.3	14.34	14.01	35.45	11.86	11.34	36.42	12.64	11.25
5	39.6	14.20	13.16	37.34	12.40	10.96	36.94	12.77	10.87
6	35.2	14.60	14.49	27.65	11.75	10.01	28.60	12.72	10.68
7	32.7	14.09	14.30	27.09	12.33	11.06	26.18	12.54	10.96
8	36.1	13.65	14.68	27.83	13.16	12.30	29.24	13.75	12.39
9	35.7	14.76	13.44	29.94	12.95	11.82	29.13	13.53	12.30
10	35.2	14.07	14.59	26.18	11.91	11.25	26.18	13.19	11.15
11	35.5	14.15	14.63	28.89	11.51	9.82	19.07	13.06	9.91
12	32.7	14.59	14.20	31.25	11.75	10.87	18.76	12.54	10.30
13	36.1	14.33	14.36	28.35	10.65	10.01	18.97	12.27	10.44
14	34.7	14.76	14.11	28.06	11.34	9.58	20.12	12.21	10.43
15	35.2	14.62	14.30	33.13	10.49	10.18	17.45	12.14	10.28
16	41.3	14.14	14.91	25.46	12.38	11.06	24.64	12.93	11.13
17	38.0	14.14	14.11	30.40	12.00	10.43	29.27	13.54	11.01
18	37.0	14.18	15.33	32.06	12.34	11.29	32.25	13.14	11.13
19	38.1	14.19	13.90	32.00	11.63	11.18	32.50	13.17	11.37
20	37.5	14.35	14.08	32.03	12.25	10.71	32.22	12.79	10.75
Mean	36.8	14.33	14.31	30.84	12.01	10.79	28.02	12.95	10.91
SD	3.1	0.67	0.65	3.74	0.91	0.85	6.62	0.80	0.92

Table A. 2. Length and width of variety 1, variety 2 and variety 3 groundnut kernels

Sample	Variety 1		Variety 2		Variety 3	
	L(mm)	W(mm)	L(mm)	W(mm)	L(mm)	W(mm)
1	4.81	11.75	14.81	9.19	19.57	7.80
2	19.42	11.51	19.53	9.23	19.25	7.96
3	18.61	11.84	17.78	8.90	19.53	8.06
4	18.94	12.20	14.64	9.28	18.11	8.01
5	16.99	11.74	17.02	9.47	15.92	7.86
6	19.66	11.32	20.61	9.02	18.07	8.05
7	20.57	11.61	14.55	8.44	20.59	7.95
8	18.33	11.68	17.09	9.14	18.93	7.96
9	17.64	11.06	15.24	8.52	18.87	7.90
10	17.80	12.33	15.50	9.24	19.43	8.41
11	20.52	10.92	19.41	9.41	22.10	7.89
12	19.53	11.64	17.67	9.08	22.77	7.81
13	19.06	11.88	16.35	9.16	21.83	7.87
14	18.58	11.56	16.37	8.84	22.17	8.19
15	16.18	11.72	17.41	8.68	16.08	8.53
16	18.53	11.41	13.58	9.10	17.08	7.57
17	17.66	10.81	15.22	9.14	18.72	7.63
18	18.83	11.66	18.91	9.12	18.84	8.50
19	18.06	11.70	17.15	9.10	19.02	8.07
20	19.03	11.54	14.82	9.51	18.68	7.99
Mean	18.70	11.59	16.68	9.08	19.28	8.00
SD	1.60	0.68	1.95	0.48	1.92	0.52

Table A. 3. 1000 pod mass of variety 1, variety 2 and variety 3 of groundnut pods

Sample	1000 pod mass(g)		
	Variety 1	Variety 2	Variety 3
1	1326.82	1256.63	1257.58
2	1344.74	1250.45	1257.23
3	1364.57	1296.47	1294.17
4	1321.67	1254.79	1273.39
5	1312.90	1281.53	1252.01
Mean	1334.14	1270.66	1266.88
SD	20.61	23.89	23.29

Table A. 4. Bulk density of variety 1, variety 2 and variety 3 of groundnut pods

Sample	Bulk density(g/cm^3)		
	Variety 1	Variety 2	Variety 3
1	0.35	0.32	0.37
2	0.37	0.40	0.35
3	0.35	0.38	0.31
4	0.36	0.38	0.35
5	0.37	0.40	0.39
Mean	0.36	0.38	0.35
SD	0.01	0.04	0.03

Table A. 5. Angle of repose of variety 1, variety 2 and variety 3 of groundnut pods

Sample	Angle of repose(°)		
	Variety 1	Variety 2	Variety 3
1	25.10	23.72	24.92
2	26.67	24.21	24.86
3	28.61	24.87	24.49
4	27.03	24.31	24.24
5	25.27	24.00	24.59
Mean	26.54	24.22	24.62
SD	1.63	0.64	0.67

Table A. 6. Moisture content of variety 1, variety 2 and variety 3 of groundnut pods

Sample	Moisture content(%)		
	Variety 1	Variety 2	Variety 3
1	4.33	5.65	4.71
2	4.59	5.43	4.40
3	4.58	5.02	4.47
Mean	4.50	5.37	4.52
SD	0.19	0.40	0.17

Table A. 7. Rupture force of variety 1, variety 2 and variety 3 of groundnut pods

Sample	Rupture force(N)		
	Variety 1	Variety 2	Variety 3
1	326.39	222.26	253.42
2	409.93	238.80	229.46
3	340.71	195.83	262.28
4	291.27	265.57	199.15
5	320.99	232.59	243.73
Mean	337.86	231.01	237.61
SD	44.13	25.36	24.71

Appendix-B

Table B. 1. Specifications of vernier calipher

Sl.no	Particulars	Specifications
1	Model	AOS Digimatic Caliper
2	Range	0-150mm
3	Accuracy	±0.02mm
4	Resolution	0.01mm or .0005”/0.01mm
5	Display	LCD
6	Max response speed	unlimited
7	Battery	SR44(1pc),938882
8	Battery life	Approx. 3.5 years under normal use

Table B. 2. Specifications of weighing balance

Sl.no	Particulars	Specifications
1	Brand	Generic
2	Material	Plastic
3	Measurement accuracy	100%
4	Model number	ISCALE-0
5	Power source type	Battery powered
6	Readout accuracy	1000
7	Size	10Kgs

Peer-review history:
The peer review history for this paper can be accessed here:
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