Exploring the potential applications in post-harvest handling and processing of new groundnut (*Arachis hypogaea* L.) varieties based on their physicochemical properties

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Abstract:
Groundnut *(Arachis hypogaea* L.*)* is a widely consumed nut & oilseed in India. A total of 8 groundnut varieties (J-87, Girnar-4, Girnar-5, GJG-31, GJG-32, GJG-22, GJG-HPS-1, KL-9) were studied for physicochemical and nutritional properties. The highest axial dimensions were observed in the J-87 variety with respect to the length (15.48 mm), width (11.01 mm) & thickness (8.6 mm), followed by a higher 1000 kernel weight (957.8g), indicating the boldness of the variety. Higher sphericity and aspect ratios were observed in GJG-31, attributed to the spherical shape of the kernels. The highest bulk density value (676.33kg/m^3), and true density (1057.57kg/m^3) were observed in GJG-31. The angle of repose values was in the range from 13.65 to 21.59º. The average moisture content of all varieties varied in the range of 5.07 to 5.85 %. The protein content ranged from 18.09 to 31.59 %, while the fat content ranged from 45.97 to 53.63 % among the varieties. The highest amount of energy 626.19 kcal was found in the Girnar-4 variety with 53.63 % fat. Among the identified essential amino acids, Leucine was found to be the most predominant essential amino acid. The J-87 variety has a higher amino acid content with a protein content of 31.59%. In conclusion, varieties J-87, GJG-31, Girnar-4, and Girnar-5 showed good potential for the development of value-added products corresponding to their physicochemical and nutritional properties.

Keywords: Amino acids, High-oleic, Groundnut, High-oleic, Minerals, Physical properties.

Introduction

Groundnut (*Arachis hypogaea* L.) is majorly cultivated for oil extraction due to the higher oil content of the kernel (45-60%) and cost-effectiveness in the Indian subcontinent. In addition to fat, groundnut is also rich in protein (20-32%) and contains other essential nutrients such as vitamin E and minerals (calcium, potassium, and magnesium) Arya et al. (2016). As an important oil seed crop in India, groundnut is grown in several parts of the country. Gujarat is the major producer of groundnuts, along with other states i.e., Andhra Pradesh, Telangana, Maharashtra, Tamil Nadu, Karnataka and Punjab covering almost the overall production of groundnut in the country Pal et al. (2021).

The physical properties of groundnuts are important parameters for quality assessment and design of harvesting machinery and several processing equipment, etc. Some physical properties such as bulk density and true density are directly related to the quality of kernels i.e., lower bulk density of particular kernels was related to the inferior quality due to infestation etc. The frictional properties are important to design the discharge chute, conveyors, etc. and this helps in the construction of storage silos

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in oil processing industries Bepary et al. (2018), Aydin, (2007), Kurt and Arioglu, (2018) and Ofori et al., (2020).

Advancement of breeding techniques has paved the way for the development of improved groundnut varieties in India such as higher-yielding varieties, pest-resistant and aflatoxin-resistant varieties, etc. Pal et al. (2021). In addition, several high oleic varieties were also developed, which have gained popularity in the industrial sector due to the higher oxidative stability compared to conventional varieties Bera et al. (2019) and Wilkin et al. (2014). Due to their genetic diversity, and agro-climatic conditions, the variations in the physical-chemical properties were evident Ingale and Shrivastava (2011) and Shokunbi et al.(2012).

The present study aims toe valuate physicochemical properties of different groundnut varieties, which among most were released in the recent period of 2018-2021, include KL-9, J-87, and two high oleic varieties (Girnar-4, Girnar-5) and other varieties including GJG-31, GJG-32, GJG-22 and GJG-HPS-1. The research outcome of the study would deliver essential scientific information to the food industries regarding the physico-chemical properties of under-explored groundnut varieties of Indian origin.

Materials and Methods

Collection of groundnut varieties

All 8 varieties were procured from authentic sources such as research stations and universities (Fig. 1). Two varieties, i.e., GJG-HPS-1 and GJG-22, were procured from Junagadh Agricultural University, Gujarat, India. Four varieties namely, GJG-32, GJG-31, Girnar-4, and Girnar-5 were collected from the Directorate of Groundnut Research, Junagadh, Gujarat, India. The latter two were high oleic varieties. The KL-9 variety was collected from the Regional Agricultural Research Station, ANGRAU, Kadiri: Andhra Pradesh, and the J-87 variety was procured from Punjab Agricultural University, Punjab. The collected varieties were stored in a laminated pouch at ≤ 5°C.

Chemicals: The chemicals used in the study are AR grade. Waters AccQ tag amino acid analysis kit and mixed amino acid standard (17 amino acids) were procured from Waters Alliance Corporation, USA. Water for HPLC and Acetonitrile used were HPLC grade procured from Quest International, Bangalore, India.

Physical dimensions and other derived parameters:
The major physical dimensions i.e., length L (mm), width W (mm), and thickness T (mm) were determined by using digital vernier calipers (Model: hvd001, Aerospace: accuracy 0.02mm) for 50 replications. Whereas other derived physical parameters such as geometric mean D_g (mm), surface area SA (mm^2), sphericity ϕ (%), and aspect ratio R, were determined as the per methods suggested by Bepary et al. (2018) and Aydin (2007), and the equations are as follows

Geometric mean $D_g = (LWT)^{1/3}$ ....(1)

Sphericity $\phi = \frac{(LWT)^{\frac{1}{3}}}{L}$ ....(2)

Aspect ratio $AR = \frac{L}{W}$ ... . (3)

Surface area $SA = \pi \times Dg^2$ .... (4)

Determination of gravimetric properties:
The gravimetric properties i.e., 1000 kernel weight (g), bulk density (kg/m^3), true density (kg/m^3), and porosity (%) of different groundnut varieties were determined according to the methods with slight modifications of Ofori et al. (2020) and Aydin (2007), and the equations are as follows:

Bulk density $P_b = \frac{M}{V}$ .... (5)

True density $P_t = \frac{M}{V_d}$ .... (6)

Porosity $P_o = \frac{(Pt - Pb)}{Pt} \times 100$ .... (7)

Where 'M', 'V' and V_d are the mass of kernels, total volume of the container and volume displaced.

Determination of frictional properties:

The angle repose was determined according to the method suggested by Bepary et al. (2018). A PVC pipe with both open ends (150x30mm) was filled with groundnut kernels and placed at the centre of the cardboard paper. PVC pipe was slowly lifted until a perfect natural heap of kernels occurred. The corresponding height and diameter of the kernel heap are taken for calculation of the angle of repose. The coefficient friction of the kernel on different surfaces (Plywood, glass, and stainless steel) was determined according to the method suggested by Bepary et al. (2018).

Angle of repose Ar $= tan^{-1}\frac{2H}{D}$............... (8)

Static coefficient of friction SCF = $tan\ (Fa)$... (9)

Where 'Fa' is the Frictional angle, 'H' and 'D' are the height and diameter of the kernel heap.

Determination of proximate composition of different groundnut varieties:

The proximate composition of parameters such as moisture by hot air oven method, crude protein (Kjeldhal method), fat (Soxhlet extraction), and crude fiber were estimated according to the AOAC 2005. The total carbohydrate content was determined by a differential method, and the energy content was calculated as per the formula suggested by Yerlikaya et al. (2012).

Energy (kcal/100g) = 4× (protein (%) + carbohydrates (%)) + 9× fat (%).

Determination of amino acid composition of different groundnut varieties:

A reverse phase chromatographic system was used to determine the amino acid profiles of groundnut varieties according to the suggested method by Azilawati et al. (2014) and Bosch et al. (2006), with minor modifications. Chromatography HPLC system (Waters Alliances system, USA) consisting of a dual pump delivery system attached with a multi-fluorescence detector (Waters 2475, USA), a column heater oven and 5 µl Rheodyne injector port. The separation was done by using the Waters AccQ Tag analysis kit, consisting of an amino acid analysis column (Nova pack C_{18}, 3.9 mm × 150 mm i.d., 4 m). Throughout the analysis, the column was maintained at 34°C. The mobile phase consists of phosphate buffer at 5.1 pH in pump A and 60% Acetonitrile in pump B. The program length was 60 min, the gradient elution program as follows: at time 0.5 min mobile phase A-98%, at 15 min- 93%, at 19 min-90%, at 32 min-67%, at 33min -67% and at 35 min-0% at a flow rate of 1 ml/min. The fluorescence detector settings are as follows: excitation wavelength-295 nm and emission wavelength: 350 nm. Before each injection, the column has been conditioned with mobile phase A -100%.

The sample preparation procedure was adopted from Azilawati et al. (2014) and Bosch et al. (2006) with slight modifications. Approximately, 150-200 mg of sample was digested with 6N HCL added with a pinch of phenol crystal in a sealed evacuated glass vail. The contents in the glass vail were digested at 115°C for 23 h by keeping them in a hot air oven, after that the contents were cooled to ambient temperature and filtered through wet filter paper (Whatman No.1) and finally volume was made up to 100 ml. A 5-microliter sample solution was injected into the column. The amino acids in samples were identified according to the corresponding retention times of standards and quantification was done from the calibration curves of standards. The calibration and integration of peaks were achieved by using Empower-3 software.

Determination of the mineral composition of different varieties of groundnuts:

Sample preparation for mineralization:

Sample preparation for mineral analysis was done according to the methods suggested by Chen et al. (2022) and Phan-Thien et al. (2010) with slight modifications. Approximately 200 mg of properly homogenized sample was weighed in a Teflon digestion vessel and carefully added with 6 ml of conc. nitric acid (Ultra-pure) and 3 ml of Milli-Q water. The digestion vessels were capped properly with lids and kept in a fume hood for about 10 min. After that the digestion was performed in a microwave digestion system (Titan MPS, Perkin Elmer) using a time and temperature-dependent digestion program as follows: initial warming temperature to 140ºC and hold for 10 min, then raised temperature till 190 ºC and hold for 30 min, later the temperature reduced to 50ºC and hold for 10 min, after that the contents in flask were further diluted to 30 ml with water, and stored at ambient temperature until the analysis.

ICP-MS (Inductive Coupled Plasma-Mass Spectroscopy) analysis of minerals:

Analysis of minerals such as Na, K, Ca, Mg, Mn, Cu, Zn, Se, and Fe quantification was achieved by using ICP-MS (Perkin Elmer Nexion, 2000B) in KED (Kinetic energy discrimination) mode of instrument, using Helium as a reaction gas. The linearity of individual mineral standards was achieved from 0.01 to 1 ppm concentration. The quantification of samples against the calibration standards was done with the help of Syngistix software.

Statistical analysis:

Statistically significance at a 5% significance level ($p<0.05$), among the groups of observed data was determined through one way-ANOVA by using the Minitab 16 statistical tool. Tukey multiple comparison test was applied for the comparison of groups with equal variance, whereas the Games-Howell test was applied for unequal variance among the groups. Pearson correlation was applied to determine the relation among the studied parameters.

Results and discussion

Physical dimensions of kernels and other derived parameters:

The axial dimensions (length, width, and thickness) and other derived parameters such as sphericity, surface area, and aspect ratio are determined for 8 groundnut varieties (Table. 1). Aforementioned parameters are essential for the assessment of the quality of agro-commodities, especially in case of cereals, pulses, and oil seeds, etc. The highest values of length (19.32 mm), width (11.01 mm), and thickness (8.60 mm) were observed in the J-87 variety. Whereas, the lowest values of length (12.43 mm), width (6.56 mm), and thickness (6.65 mm) were observed in varieties- GJG-31, GJG-22, and Girnar-5 respectively. However, other varieties have the average values of length, width, and thickness ranges as follows: (12.98-16.17 mm), (7.02-7.88 mm), and (6.92-8.23 mm) respectively. The observed range of length, width, and thickness were in accordance with the previous findings in groundnut varieties Gojiya et al. (2020) and Kurt and Arioglu (2018). The J-87 variety, with respective higher axial dimensions, can be considered as a bold variety, thereby indicating its market value and export potential.

The geometric mean diameter is a derived parameter from the axial physical dimensions. Among the varieties, the J-87 variety was found to have the

Table 1. Physical dimensions of different groundnut varieties:

	Length (mm)	Width (mm)	Thickness (mm)	kernel mass 1000 (gm)*	Geometric mean (mm)	Sphericity (%)	Surface area (mm^2)	Aspect ratio
GJG-HPS-1	16.17±1.99^{b}	7.53±0.60^{bc}	8.23±0.84^{a}	363.3±16.78^{CD}	9.97±0.75^{b}	61.75±0.04^{bc}	314.70±46.69^{b}	46.56±5.98^{de}
GJG-22	14.87±1.21^{cd}	6.56±0.50^{e}	7.47±0.59^{b}	311.00±5.67^{EF}	8.98±0.45^{cd}	60.64±3.78^{d}	254.23±26.04^{cd}	44.380±4.75^{e}
GJG-32	15.48±2.12^{bc}	7.56±1.14^{bc}	6.98±0.83^{c}	276.1±17.31^{F}	9.31±0.91^{c}	60.78±6.89^{d}	274.84±52.39^{c}	49.65±9.48^{cd}
GJG-31	12.43±1.01^{f}	7.02±0.74^{de}	6.92±0.51^{c}	336.80±2.69^{DE}	8.43±0.51^{e}	68.10±4.43^{a}	224.56±27.71^{e}	57.78±7.03^{a}
J-87	19.32±2.28^{a}	11.01±0.87^{a}	8.60±0.68^{a}	957.8±3.02^{A}	12.18±0.53^{a}	63.73±6.32^{cd}	467.01±40.32^{a}	56.87±9.05^{ab}
Girnar-4	14.22±1.28^{de}	7.88±0.95^{b}	6.92±0.76^{c}	398.93±4.58^{C}	9.17±0.82^{c}	64.67±4.42^{bc}	266.64±47.65^{c}	55.60±6.05^{ab}
Girnar-5	13.40±1.08^{ef}	7.10±0.61^{cd}	6.65±0.50^{c}	389.7±18.4^{C}	8.53±0.61^{de}	64.19±3.90^{c}	232.08±28.98^{de}	53.16±5.03^{bc}
KL-9	12.98±1.99^{f}	7.42±0.94^{bcd}	6.96±0.68^{c}	449.27±8.01^{B}	8.72±0.74^{de}	67.72±5.62^{ab}	240.90±42.18^{de}	56.94±9.61^{ab}

The values are mean ± SD (Standard deviation) of (n=50) observations except for (*) (n=3) observations. The values in each column with a different superscript are significantly different ($p<0.05$), The superscripts with capital letters are grouped with the Games-Howell method with unequal variance.

Table 2. Gravimetric and frictional properties of different groundnut varieties

	Moisture (%)	Bulk density (k/gm^3)	True density (kg/m^3)	Porosity (%)	Coefficient of friction			Angle of repose (°)
					Stainless Steel	Plywood	Glass	
GJG-HPS-1	5.3 ± 0.09^{cd}	611.21 ± 4.52^{c}	915.35 ± 12.45^{d}	33.20 ± 1.41^{c}	0.35 ± 0.04^{a}	0.42 ± 0.05^{ab}	0.34 ± 0.03^{a}	21.59 ± 0.12^{a}
GJG-22	5.80 ± 0.10^{ab}	569.45 ± 5.31^{d}	859.99 ± 8.07^{e}	34.40 ± 0.47^{bc}	0.34 ± 0.02^{ab}	0.39 ± 0.01^{ab}	0.28 ± 0.005^{ab}	19.08 ± 0.76^{b}
GJG-32	5.07 ± 0.05^{d}	659.63 ± 5.07^{a}	1010.48 ± 8.01^{b}	34.71 ± 0.57^{b}	0.33 ± 0.01^{ab}	0.44 ± 0.02^{a}	0.29 ± 0.04^{ab}	17.67 ± 0.31^{bc}
GJG-31	5.10 ± 0.06^{d}	676.33 ± 5.51^{a}	1057.57 ± 12.40^{a}	36.05 ± 0.71^{ab}	0.30 ± 0.02^{ab}	0.33 ± 0.005^{c}	0.20 ± 0.02^{ab}	16.74 ± 0.99^{abc}
J-87	5.60 ± 0.21^{abc}	627.38 ± 11.3^{bc}	967.17 ± 6.94^{c}	35.11 ± 1.00^{bc}	0.29 ± 0.01^{b}	0.42 ± 0.02^{ab}	0.29 ± 0.03^{ab}	17.48 ± 0.83^{bc}
Girnar-4	5.39 ± 0.10^{bcd}	622.94 ± 3.90^{b}	1009.42 ± 8.16^{c}	38.28 ± 0.37^{a}	0.33 ± 0.02^{ab}	0.37 ± 0.01^{bc}	0.27 ± 0.01^{b}	13.65 ± 0.65^{d}
Girnar-5	5.85 ± 0.05^{a}	622.76 ± 3.25^{b}	1008.67 ± 6.15^{b}	38.25 ± 0.42^{a}	0.35 ± 0.03^{a}	0.42 ± 0.06^{ab}	0.28 ± 0.03^{ab}	16.64 ± 0.91^{c}
KL-9	5.55 ± 0.07^{abc}	635.36 ± 2.37^{b}	1014.50 ± 3.77^{b}	38.52 ± 0.51^{a}	0.33 ± 0.01^{ab}	0.34 ± 0.01^{c}	0.27 ± 0.005^{b}	16.08 ± 0.60^{c}

The values are mean ± SD (Standard deviation) of (n=3) observations. The values in each column with a different superscript are significantly different ($p<0.05$).

highest geometric mean diameter of 12.18 mm, whereas the lowest was observed in GJG-31 (8.43 mm). The remaining varieties have geometric mean diameters in the range of 8.53 to 9.97 mm, and the same was found to be in line with the range given by Ofori et al.,(2020) and Reddy and Mathew (2021) in groundnuts.

The surface area of grains is important in processing, as the higher surface area of grain facilitates better heat and mass transfer, aiding in the roasting process. J-87 variety found with a highest surface area of 467.01 mm^2, which is mainly pertaining to the higher axial dimensions. Other varieties were found with surface area values in the range of 232.08 to 314.70 mm^2. However, the lowest value of 224.56 was observed in GJG-31. The observed ranges of surface area are in line with the ranges given by Ofori et al., (2020) and Reddy and Mathew (2021).

In the case of plant materials, especially cereals and pulses, a sphericity value greater than 60% are considered to be spherical in shape, thus having a higher tendency to roll freely on surfaces, conveyors, and hoppers during processing Bepary et al. (2018). The observed sphericity values ranged from 68.10% (GJG-31) to 60.64% (GJG-22), indicating that all the studied varieties are spherical in shape. The observed ranges of sphericity values were in accordance with the previous findings in groundnut varieties Ofori et al., (2020) Gojiya et al. (2020) and Kurtand Arioglu (2018).

The aspect ratio is the ratio of length to width, which is considered as an essential parameter in designing grading and cleaning equipment. GJG-31 was found with a higher aspect ratio of 57.78, whereas aspect ratio values of other varieties were in the range of 44.38 to 56.94. The values of aspect ratios were in

Table. 3. Correction analysis for physical properties of different groundnut varieties

	M	L	W	T	TKW	GMD	SP	SA	AR	BD	TD	Po
L	0.153											
W	0.135	0.820^{b}										
T	0.132	0.878^{a}	0.684									
TKW	0.365	0.726^{b}	0.950^{a}	0.666								
GMD	0.146	0.963^{a}	0.930^{a}	0.885^{a}	0.865^{a}							
SP	-0.115	-0.538	-0.001	-0.363	0.129	-0.291						
SA	0.163	0.953^{a}	0.942^{a}	0.873^{a}	0.886^{a}	0.999	-0.260					
AR	-0.111	-0.180	0.412	-0.215	0.455	0.068	0.858^{a}	0.102				
BD	-0.714^{b}	-0.256	0.099	-0.329	-0.023	-0.131	0.550	-0.113	0.651			
TD	-0.452	-0.445	0.043	-0.563	-0.016	-0.284	0.720^{b}	-0.258	0.819^{b}	0.894^{a}		
Po	0.262	-0.571	-0.110	-0.675	-0.005	-0.429	0.669	-0.403	0.667	0.214	0.619	
Ar	-0.021	0.383	-0.080	0.598	-0.084	0.251	-0.565	0.228	-0.725^{b}	-0.346	-0.673	-0.859^{a}

a:significant at $p<0.05$, b: significant at $p<0.01$M: moisture, L: Length, W: Width, T: Thickness, TKW: Thousand kernel weight, GMD: Geometric mean diameter, SP: Sphericity, SA: Surface area, AR: Aspect ratio, BD: Bulk density, TD: True density, Po: Porosity, Ar: Angle of repose.

line with previous findings in groundnut varieties Ofori et al. (2020) Gojiya et al. (2020) and Kurt and Arioglu (2018).

The correlation analysis (Table. 3) shows that the surface area of kernels has a strong positive correlation with axial dimension i.e., length ($r=0.953$, $p<0.05$), width ($r=0.942$, $p<0.05$), thickness ($r=0.873$, $p<0.05$) and also with geometric mean diameter ($r=0.999$, $p<0.05$). Hence, careful consideration is needed for the designing of processing equipment in the case of varieties like J-87, because, it was found to be significantly ($p<0.05$) different from others with respect to physical dimensions. In addition, the sphericity of the kernels showed a positive correlation with aspect ratio ($r=0.858$, $p<0.05$). Therefore, the variety GJG-31 was found to have a higher sphericity and aspect ratio.

Gravimetric parameters of groundnut varieties:
The 1000 kernel weight is an ideal parameter that describes the soundness of the kernels and therefore serves as a key indicator in determining the quality of the kernel prior to the processing. It was observed that the J-87 variety was found to have a highest ($p<0.05$) 1000 kernel weight of 957.8 g. Whereas, other varieties have been found with values of 1000 kernel weight ranging from 276.12 to 449.27 g. Ofori et al. (2020) have also reported similar 1000 kernel weights among studied groundnut varieties and recorded a significantly higher 1000 kernel weight for one of the varieties.

The gravimetric parameters such as bulk density and true density are important parameters during storage and transportation. A higher bulk density of grains is desirable, as the grains with higher bulk density require considerably less area during storage and transportation. These parameters are useful to determine the quality of grains (infested grains have lower densities) and are also important for designing silos Bian et al. (2015). The bulk density and true density values of all varieties were in the range of 569.45 to 676.33 and 859.99 to 1057.57 kg/m^3 at a moisture level of 5.07 to 5.85% (Table. 2). GJG-31 variety has found with higher values of bulk density (676.33 kg/m^3) and true density (1057.57 kg/m^3). However, the lowest values of bulk density (569.45 kg/m^3), and true density (859.99 kg/m^3) were recorded in GJG-22. The recorded ranges of bulk density were slightly varied with the findings of Ofori et al. (2020) which ranged from (758-799 kg/m^3), which may be attributed to the varietal difference. Whereas the true density value range is in line with Aydin (2020).

The porosity of kernels is an important parameter, which denotes the intergranular spaces per prescribed volume of grains, a higher percentage of intergranular voids is useful for several unit operations such as forced convective drying and pneumatic drying Ofori et al. (2020). The KL-9 variety was observed with the highest porosity value of 38.52 % followed by the Girnar-4 variety at 38.28% and the lowest was recorded as 32.20 % in GJG-HPS-1 (Table. 2). The observed values of porosity were in line with previous findings reported in groundnuts Gojiya et al. (2020). However, the observed ranges differed from the previous finding (21-25%) in different Nigerian groundnut varieties Ofori et al. (2020), which may be attributed to genetic variability.

The bulk density of varieties was negatively correlated with the moisture content ($r=-0.712$, $p<0.01$) (Table. 3), which indicates that moisture content plays a role in bulk density and true density of grains. This is due to the increase in the volume of kernels with higher moisture levels. A similar observation of reduction in bulk density with respect to an increase in moisture level was reported in wheat and other grams Karimi et al. (2009) and Chowdhury et al. (2001).

Frictional properties of different groundnut varieties:
The angle of repose corresponds to the free flowability of any material on an inclined plane, as in the case of grains, it is useful in designing the

inclined angles for the hoppers, conveyors, and discharge chutes. The highest repose angle observed was 21.59º in GJG-HPS-1 and the lowest was 13.65º in Girnar-4, whereas the remaining varieties have values in the range of 16.08 to 19.08º (Table. 2). Similar values of angle repose were reported in different groundnut varieties of 17º-19º Olajide and Igbeka (2003) and Ofori et al. (2020).The lower values of angle repose are desirable for easy removal or discharge of materials. However, several factors influence the repose angle of materials, in the case of groundnuts or any seeds the surface smoothness and sphericity of the kernel's effectivity reduce the frictional forces, thereby lower angles are desirable Bepary et al. (2018) and Maduakoand Hamman (2005). It was observed that the aspect ratio was negatively correlated with the angle of repose ($r = -0.725$, $p<0.01$) and porosity ($r = -0.859$, $p<0.05$), which means these parameters are effective and inversely proportional to the angle of repose. Hence, this can be a reason for a significantly ($p<0.05$) higher angle of repose values for both GJG-HPS-1 and GJG-22 varieties.

The static coefficient of friction values for different groundnut varieties are depicted in Table 2. For all studied varieties the values of static coefficient friction for three different surfaces were in increasing order of plywood>stainless steel>glass. Among the studied varieties, the variety GJG-31 was observed with the lowest values of 0.20, and 0.33 for glass and plywood surfaces, whereas J-87 was observed with the lowest values of 0.29 for stainless steel. The higher values of 0.35 on stainless steel and 0.34 on glass were observed in GJG-HPS-1, whereas, a higher value of 0.44 on plywood was observed in the GJG-32 variety (Table. 2). The values are in line with the findings of Ofori et al. (2020), however, all varieties showed variability in the coefficient of friction with respective friction surfaces, due to their inherent physical characteristics and surface roughness of materials Ofori et al. (2020) and Bepary et al. (2018).

Proximate composition of groundnut varieties:

The proximate composition of all 8 varieties was depicted in Table 4. The moisture content in all varieties varied from 5.07 to 5.85%. Similarly, the highest ash content of 2.76% was observed in the Girnar-4 variety and the lowest was 2.01% in GJG-32. Girnar-4 variety was observedwith highest fat($p<0.05$) content of 53.63%, followed by GJG-31 (51.24 %), GJG-22 (50.40 %), KL-9 (50.33 %), GJG-32 (48.97 %), J-87 (48.75 %), GJG-HPS-1 (47.25 %), and Girnar-5 (45.97 %) respectively. The J-87 was found to have highest protein ($p<0.05$) content of 31.59% and the protein content in remaining varieties as follows: 26.57, 26.10, 25.95, 25.63, 24.44, 18.54 and 18.09 %, in GJG-32, GJG-HPS-1, Girnar-5, KL-9, GJG-31, Girnar-4 and GJG-22 respectively. The observed ranges of ash, fat, and protein content of different varieties were found to match the previous findings reported in groundnut varieties Shokunbi et al. (2012) and Ingale and Shrivastava (2011). However, the ash content values were lower than the reported values (3.94 to 6.94%) Nankya et al. (2021). This may be attributed to the variability in agroclimatic conditions and varietal

Table 4. Proximate composition of different groundnut varieties

	Moisture (%)	Ash(%)	Fat(%)	Protein(%)	Fiber(%)	Carbohydrates(%)	Energy(kcal/100g)
GJG-HPS-1	5.3±0.09^{cd}	2.59±0.07^{b}	47.25±0.12^{de}	26.10±0.07^{b}	2.85±0.12^{a}	15.92±0.02^{bc}	593.41±1.31^{de}
GJG-22	5.80±0.10^{ab}	2.14±0.04^{d}	50.40±0.31^{bc}	18.09±1.37^{c}	2.46±0.31^{ab}	21.09±1.2^{a}	610.38±2.22^{bc}
GJG-32	5.07±0.05^{d}	2.01±0.02^{e}	48.97±0.03^{bcd}	26.57±0.86^{b}	2.75±0.007^{ab}	14.60±0.87^{bc}	605.51±0.25^{bcd}
GJG-31	5.10±0.06^{d}	2.23±0.02^{d}	51.24±0.45^{b}	24.44±0.64^{b}	2.54±0.02^{ab}	14.44±1.15^{bc}	616.74±2.06^{ab}
J-87	5.60±0.21^{abc}	2.44±0.03^{c}	48.75±0.60^{cd}	31.59±0.13^{a}	2.43±0.1^{ab}	9.16±0.36^{d}	601.84±3.43^{cd}
Girnar-4	5.39±0.10^{bcd}	2.76±0.01^{a}	53.63±0.17^{a}	18.54±0.09^{c}	2.33±0.04^{ab}	17.33±0.20^{ab}	626.19±1.09^{a}
Girnar-5	5.85±0.05^{a}	2.66±0.02^{ab}	45.97±1.39^{e}	25.95±0.17^{b}	2.81±0.2^{ab}	16.72±1.35^{bc}	584.47±7.87^{e}
KL-9	5.55±0.07^{abc}	2.4±0.04^{c}	50.33±0.24^{bc}	25.63±2.13^{b}	2.21±0.02^{b}	12.88±1.87^{cd}	607±1.11b^{c}

The values are mean ± SD (Standard deviation) of (n=3) observations. The values in each column with a different superscript are significantly different ($p<0.05$).

Table 5. Amino acid composition of different groundnut varieties (g/100g)

	GJG-HPS-1	GJG-22	GJG-32	GJG-31	J-87	Girnar-4	Girnar-5	KL-9
Non-essential amino acids								
Aspartic acid	5.26±0.09[b]	3.50±0.3[c]	4.98±0.09[b]	5.39±0.2[b]	6.91±0.09[a]	5.21±0.05[b]	4.83±0.07[b]	5.55±0.16[b]
Serine	2.65±0.13[bc]	1.79±0.14[d]	2.42±0.09[bc]	2.94±0.1[b]	3.79±0.24[a]	2.38±0.09[c]	2.40±0.06[bc]	2.89±0.11[bc]
Glutamic acid	8.75±0.07[cd]	6.00±0.06[f]	8.09±0.09[e]	9.13±0.16[bc]	11.87±0.17[a]	8.35±0.14[de]	8.06±0.05[e]	9.39±0.22[b]
Glycine	3.15±0.07[abc]	2.37±0.10[c]	2.82±0.1[bc]	3.45±0.49[ab]	3.96±0.08[a]	2.95±0.21[bc]	2.82±0.10[bc]	3.17±0.21[abc]
Arginine	5.52±0.46[b]	3.61±0.5[c]	4.97±0.21[b]	6.06±0.07[b]	7.81±0.23[a]	5.13±0.17[b]	5.32±0.31[b]	5.95±0.14[b]
Alanine	1.93±0.11[ab]	1.3±0.21[c]	1.85±0.14[abc]	2.04±0.07[ab]	2.41±0.23[a]	1.76±0.12[bc]	1.77±0.15[bc]	1.98±0.04 [ab]
Proline	2.26±0.19[b]	1.37±0.11[c]	1.98±0.17[b]	2.45±0.14[b]	3.12±0.18[a]	2±0.41[b]	2.03±0.09[b]	2.29±0.12[b]
Tyrosine	2.13±0.17[bc]	1.35±0.14[d]	1.9±0.07[bc]	2.45±0.141[b]	3.15±0.16[a]	1.85±0.13[c]	1.9±0.12[c]	2.27±0.09[bc]
Essential amino acids								
Histidine	1.44±0.07[bc]	0.96±0.09[c]	1.25±0.14[bc]	1.66±0.12[ab]	1.96±0.12[a]	1.25±0.14[bc]	1.39±0.14[bc]	1.67±0.15[ab]
Isoleucine	1.88±0.13[a]	1.27±0.10[b]	1.87±0.17[a]	2.11±0.12[a]	2.3±0.22[a]	1.76±0.16[ab]	1.79±0.12[ab]	2.17±0.08[a]
Threonine	1.45±0.14[ab]	1.04±0.08[b]	1.35±0.13[ab]	1.70±0.2[a]	1.79±0.12[a]	1.24±0.14[ab]	1.38±0.11[ab]	1.57±0.12[ab]
Methionine	0.4±0.07[ab]	0.37±0.07[b]	0.49±0.04[ab]	0.59±0.01[ab]	0.62±0.04[a]	0.38±0.03[ab]	0.39±0.02[ab]	0.46±0.12[ab]
Lysine	1.6±0.07[ab]	1.37±0.10[b]	1.47±0.11[ab]	1.67±0.11[ab]	1.8±0.07[a]	1.46±0.07[ab]	1.47±0.07[ab]	1.58±0.05[ab]
Valine	1.58±0.09[a]	1.02±0.10[b]	1.5±0.02[a]	1.68±0.09[a]	1.82±0.17[a]	1.57±0.07[a]	1.58±0.06[a]	1.75±0.05[a]
Leucine	3.22±0.28[b]	2.1±0.06[c]	2.98±0.09[b]	3.38±0.09[b]	4.28±0.19[a]	2.96±0.26[b]	2.95±0.08[b]	3.38±0.09[b]
Phenylalanine	2.47±0.11[cd]	1.68±0.09[e]	2.28±0.09[d]	2.8±0.12[b]	3.5±0.07[a]	2.11±0.05[d]	2.38±0.09[d]	2.76±0.06[bc]

The values are mean ± SD (Standard deviation) of (n=3) observations. The values in each row with a different superscript are significantly different ($p<0.05$).

differences. The crude fiber values are in the range of 2.21 to 2.85%. The highest was found in the GJG-HPS-1 and the least was found in KL-9. The values are in agreement with previous findings of crude fiber in different Nigerian groundnut varieties Shokunbi et al. (2012). GJG-22 variety was found to have a higher carbohydrate ($p<0.05$) content of 21.09%, whereas the least was 9.16% observed in J-87, which may be attributed to the higher fat and protein in kernels of the J-87 variety. The remaining 6 varieties have carbohydrate content ranges from 12.88 to 17.33%. The carbohydrate content range is found to be lesser than the previous studies in groundnuts (17.05-18.51%) Shokunbi et al. (2012). This may be due to genetic diversity and variability in agro-climatic conditions. The highest energy content of 626.19 kcal/100g was found in Girnar-4 due to the inherent higher fat content, moderate protein and carbohydrate content, and the lowest was 584.47 kcal/100g found in Girnar-5, which hasthe lowest fat content among the studied varieties.

Amino acid composition of different groundnut varieties:

The amino acid composition (g/100g of sample) of 8 groundnut varieties was presented in Table 5. Among the essential amino acids, leucine is the most predominant amino acid identified in the range of 4.28 to 2.1 (g/100g of sample), similarly other essential amino acids were identified in the ranges of phenylalanine (3.5-1.68), isoleucine (1.82-1.02), lysine (1.8-1.37), valine (2.3–1.27), threonine (1.79 – 1.04) and histidine (1.96 – 0.96) g/100g respectively. Some essential amino acids contain branched side chains (leucine, isoleucine, and valine) and they are also calledas branched-chain amino acids. They play important roles in biological systems; they serve as a direct fuel for muscle and also help in gut health Nie et al. (2018). Methionine was found to be the lowest quantity among the essential amino acids i.e., (0.37-0.62) g/100 g. It is also evident that methionine is the major limiting amino acid in pulses. The total essential amino acids content was found to be highest in the J-87 variety (15.69 g/100g), and the lowest was (8.46 g/100g) in GJG-22. The acidic amino acids such as aspartic acid and glutamic acid were in range from (6.91-3.50) and (11.87-6) g/100g, respectively. The other non-essential amino acids are as follows: serine (3.79-1.79), glycine (3.96-2.37), arginine (7.81-3.61), alanine (2.41-1.3), proline (3.12-1.37) and

Figure 1. Different Indian Groundnut varieties

tyrosine (3.15-1.35) g/100g of sample. Among the studied varieties, the J-87 and GJG-22 varieties contained the highest and lowest amino acid content, respectively, owing to their significant ($p<0.05$) highest (31%) and lowest (18%) protein content (Fig. 1). The observed ranges of all amino acids in 8 varieties were in line with the previous findings of defatted peanut flours and groundnuts Riaz and Cheewapramong (2009), Chung et al. (2013) and Jambunathan et al. (1992). However, the afore mentioned results were slightly different from those reported in Nigerian groundnuts Adeyeye (2010), which may be due to the genetic diversity of the varieties.

Minerals composition of different varieties of groundnuts:

Mineral compositions of 8 different varieties of groundnuts are depicted in Table 6. Potassium, magnesiumand calcium were the major minerals identified among all varieties. The potassium and magnesium were in the range of (701-971), and (149.80-201.93) mg/100g, respectively. The calcium content of 147 mg/100g was found to be the highest among the varieties in GJG-22, and the lowest was 22.7 mg/100g in J-87. The values of current findings regarding the major minerals were consistent with previous findings in groundnuts Chen et al. (2022), Phan-Thien et al. (2010) and Asibuo et al. (2008). Sodium and potassium are crucial in maintaining the electrolyte balance in the biological system, whereas magnesium is involved in several biochemical functions as an important cofactor for many enzymes. Calcium is an essential mineral for cell signallingmechanisms and muscle contraction and is also important for bone health. Other minor minerals such as iron, manganese, zinc, and copper were also found in the ranges as follows: (2.94 -

Table 6. Mineral composition of different groundnut varieties (mg/100g)

	Ca	Fe	K	Mg	Mn	Cu	Zn	Se
GJG-HPS-1	103.7 ± 1.98^{c}	3.10 ± 0.13^{a}	775.1 ± 7.28^{c}	155.96 ± 1.87^{e}	1.23 ± 0.08^{cd}	0.99 ± 0.04^{b}	3.53 ± 0.07^{b}	0.21 ± 0.005^{a}
GJG-22	147 ± 1.23^{a}	10.69 ± 0.8^{a}	871.9 ± 4.79^{b}	167.11 ± 2.62^{d}	1.71 ± 0.02^{ab}	0.89 ± 0.07^{bc}	3.39 ± 0.09^{b}	0.09 ± 0.007^{b}
GJG-32	31.38 ± 1.59^{g}	5.69 ± 0.27^{b}	971 ± 8.49^{a}	149.80 ± 3.11^{e}	0.98 ± 0.12^{d}	0.81 ± 0.07^{bcd}	3.30 ± 0.25^{b}	0.04 ± 0.007^{c}
GJG-31	115.6 ± 1.94^{b}	3.77 ± 0.13^{c}	772.06 ± 1.37^{c}	178.28 ± 1.78^{bc}	1.35 ± 0.08^{bc}	1.27 ± 0.10^{a}	4.18 ± 0.09^{a}	0.09 ± 0.009^{b}
J-87	22.7 ± 2.19^{g}	6.4 ± 0.12^{b}	701.4 ± 2.74^{d}	182.9 ± 1.96^{b}	1.9 ± 0.19^{a}	0.64 ± 0.07^{cd}	4.37 ± 0.14^{b}	0.07 ± 0.004^{b}
Girnar-4	88.4 ± 1.57^{d}	2.94 ± 0.09^{c}	876.4 ± 2.01^{b}	201.93 ± 1.73^{a}	0.94 ± 0.07^{d}	1.28 ± 0.04^{a}	3.42 ± 0.07^{b}	0.06 ± 0.009^{bc}
Girnar-5	59.4 ± 1.29^{e}	3.21 ± 0.12^{c}	885.75 ± 2.92^{b}	170.64 ± 2.26^{cd}	0.96 ± 0.02^{cd}	0.89 ± 0.02^{bc}	3.33 ± 0.07^{b}	0.04 ± 0.011^{c}
KL-9	21.12 ± 1.25^{g}	5.86 ± 0.16^{b}	775.6 ± 6.36^{c}	185.62 ± 5.11^{b}	1.24 ± 0.07cd	0.58 ± 0.08^{d}	2.36 ± 0.12c	$.039\pm0.004^{c}$

The values are mean ± SD (Standard deviation) of (n=3) observations. The values in each column with a different superscript are significantly different ($p<0.05$).

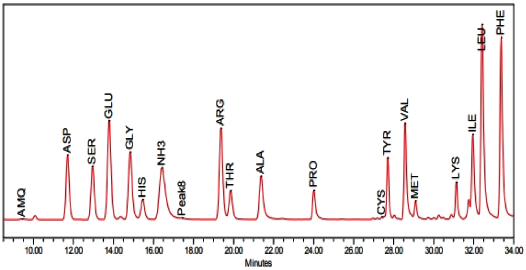

Figure 2. Amino acid chromatogram of J-87 Groundnut variety

10.96), (0.94-1.71), (2.36 - 4.37), and (0.58-1.28) mg/100g, respectively. The observed values of manganese and copper were found to be lower, whereas iron values were higher,as reported in Nigerian groundnut varieties Shokunbi et al. (2012). However, the values of minor minerals were in line with findings of Phan-Thien et al. (2010) and Chen et al.(2022), except the selenium, the current observed values range (0.039-0.21) mg/100g, which was higher than reported by the same authors, which may be attributed to the different agro-climatic factors and cultivation practices such as use of different fertilizers containing varied mineral composition Hasan et al.(2021).

Conclusion

The study revealed that, among the 8 varieties of groundnut, the J-87 variety was superior in terms of crude protein, amino acids, and 1000 kernel weight. The GJG-31 variety with higher true and bulk density may consume less storage area while transport and storage can be profitable for farmers and industries. The Girnar-4 variety, which was developed as a high oleic variety, contains a higher fat and energy content than others, hence can be useful for the development of high-energy food products. In addition, another high oleic variety, Ginar-5 has the lowest fat content among all varieties, thereby suitable for the development of groundnut-based food products with extended shelf life.

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