

PHYSICAL, CHEMICAL AND NUTRITIONAL EVALUATION OF *Arachis hypogaea* L. SEEDS AND ITS OIL

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ABSTRACT

Peanut is an important crop grown worldwide. High yielding Indian peanut varieties namely SB-11 (Boria), JL-24 (Disco), TLG-45 (Latur), grown under local soil and climatic conditions, were compared for their chemical composition and nutritional quality. Due to the insufficiency of the scientific information available, study aims at generating systematic and segregated data on the proposed peanut varieties. SB-11 variety contained maximum protein (42.09%) whereas, JL-24 exhibited highest oil content (47.00%) and sensory acceptability. Mineral compounds were present in significant and comparable amounts using ICP- AES in all the varieties. Functional properties like water holding capacity (2.90g/g), oil binding capacity (1.50g/g) was recorded highest for SB-11 and water solubility index (40%) for JL-24 variety, which facilitates its incorporation in various food products. TLG-45 variety was estimated to have highest total flavonoid (0.51mg/g), DPPH (1.81mg/g) and ABTS (0.24mg/g) radical scavenging activity, whereas SB-11 with highest total polyphenol content of 2.05 mg/g. Difference in the fatty acid composition of oil from peanut varieties was analysed by GCMS. Acid value, iodine value, saponification value, peroxide value, low absorbance and no measurable aflatoxin in all varieties substantiated that they are excellent for human nutrition, especially during malnourishment, incorporation for food enrichment or functional food development. This study can thus be helpful to researchers and industries globally, indicating use of these studied varieties for export, applications in food and oil industries.

Keywords: peanuts; functional properties; physico-chemical composition; antioxidant; fatty acid composition; GC-MS

INTRODUCTION

Peanut (*Arachis hypogaea* L.) or “groundnuts” are the edible seeds of a legume. Peanut belongs to the family fabaceae of bean/legume. India is the second largest producer of peanut in world, with total production of approximately 7.131 million tons per year after China’s 13.42 million tons (Arya *et al.*, 2016; USDA, 2016). Peanut consumption all over the world varies in large proportions hence the commercial products too are variant and generally localized. Peanuts are consumed around the world as raw and in variety of products. Peanuts are valued for their high value oil content. Apart from oil, by-products of peanut contains many other functional compounds like proteins, fibers, vitamins, minerals, antioxidants etc, (USDA, 2015). Literature has revealed that peanuts are excellent source of compounds like resveratrol, phenolic acids (Ma *et al.*, 2014), flavonoids and phytosterols (Chukwumah *et al.*, 2009) that block the absorption of cholesterol from diet. Peanuts contain all the 20 amino acids in variable proportions and is the biggest source of the protein called “arginine” (USDA 2015). These bioactive compounds have been known for their disease preventive properties and are believed to promote longevity (Arya *et al.*, 2016). Apart from the above health benefits; peanuts are rich in monounsaturated fatty acids (MUFAs), polyunsaturated fatty acids (PUFAs) (Veličkovska & Mitrev, 2016). Additional beneficial nutrients indigenous to peanuts include vitamin E, L-arginine, soluble and insoluble fibre, as well as water and lipid-soluble natural phenolic antioxidant. These nutrients act synergistically with the numerous protective bioactives, making peanuts a desirable nutrient-dense plant-based food (Zhang *et al.*, 2011).

In India, about 50% of all childhood deaths are attributed to malnutrition (Sharma *et al.*, 2014). Protein deficiency is the main cause of malnutrition. Vitamin and mineral deficiencies also affect children’s survival and development. Beside all the above facts, systematic and scientific database on different peanut varieties and peanut based products of Indian origin is missing. Hence in the present research efforts were to perform a detailed characterization, comparison and nutritional assessment of Indian peanut varieties namely SB-11, JL-24 and TLG-45 which are locally called as *Boria*, *Disco* and *Latur* respectively.

MATERIAL AND METHODS

Materials

Fresh peanut varieties namely SB-11, JL-24 and TLG-45 belonging from different states of India, were purchased from Agricultural Produce Market Committee (APMC), Mumbai, India, where they are transported for distribution throughout India. Folin-Ciocalteu reagent, sodium carbonate anhydrous, sodium hydroxide was purchased from SD Fine Chemicals, Mumbai, India. Vanilline, petroleum ether was purchased from HiMedia, Mumbai, India. HCl, gallic acid, sodium acetate, potassium chloride, sodium sulphate, potassium per sulphate, were purchased from SD Fine Chemicals, Mumbai, India. 2, 2-azinobis (3-ethylbenzothiazoline-6-sulphonic acid) diammonium salt (ABTS), 1, 1-diphenyl-2-picrylhydrazyl (DPPH), trolox, catechin were obtained from Sigma–Aldrich, India. Hexane, methanol and water of HPLC grade were purchased from Merck whereas, ethanol and conc. sulphuric acid from SD Fine Chemicals. All other chemicals and reagents used in the present study were of analytical grade. The standards of esters were obtained from Sigma Aldrich (USA).

Chemical composition

Peanut varieties were subjected to proximate analysis such as moisture, fat, protein, ash by AOAC Method, (AOAC, 1995) and total carbohydrates content was calculated using following formula:
Total carbohydrate (% dry weight) = {100 - moisture (%) - protein content (% dry weight) - fat (% dry weight) – ash (% dry weight)}

Sample preparation

Peanuts were stored under cool and dry condition prior to analysis. Soxhlet extraction was carried out using petroleum ether as solvent. 25 g of peanuts of each variety were finely crushed and tied in a cellulose thimble. The apparatus was run for 6 h and solvent was eliminated by distillation. Defatted samples were dried and stored at -20°C until analysis.

Fat extraction

Fat extraction from peanut varieties for chemical analysis of oil was done using a mechanical oil press equipment (Adeeko & Ajibola, 1990).

Sensory analysis

Sensory analysis of raw peanut varieties and a control of branded supermarket peanut sample (Satyam) of which variety was unknown was carried out according to the method of Lawless and Heymann (2010) using 5-point rating scale in laboratory at ambient conditions. Semi-trained twelve panellists were selected between age group of 23 to 30 years. Sensory panellists were asked to give score between 1-5, for all peanut varieties in comparison with control for different parameters like colour, aroma, texture, taste and overall acceptability.

Preparation of extract

Defatted powders of all three peanut varieties (1 g) were extracted for 3 hour with 10 ml of methanol/water (80/20) solvent on an orbital shaker set at 180 rpm (30 ± 10°C). The sample suspension was centrifuged at 8,000 rpm for 15 minutes at 10°C, the supernatant was collected, filtered and was stored at -20°C. Analysis was completed within two days.

Determination of total phenolic content

The total phenolic content (TPC) was measured by Folin-Ciocalteu method as explained by Hussain *et al.* (2012). Gallic acid was used as a standard for total phenolics. 0.2 ml methanolic extracts were added with 1 ml of Folin-Ciocalteu reagent (diluted in a ratio of 1:10 with distilled water) and 0.8 ml sodium bicarbonate (7.5%) was added to this mixture. This mixture was allowed to stand in dark for 30 min at room temperature and absorbance was measured at 765 nm using Shimadzu UV-180 spectrophotometer. The standard curve was linear between 0 and 250 µg/ml gallic acid. Results were represented as mg of GAE/g wet basis.

Determination of total flavonoid content

The total flavonoid content (TFC) was measured by vanillin-HCL method as explained by Rebecca *et al.* (2010). Methanol extracts (0.5 ml) were dispensed into 2.5 ml of vanillin reagent (8% HCl in methanol/ 4% vanillin in methanol, 1:1, v/v) and were incubated for 20 minutes at room temperature. The absorbance was taken at 500 nm on a Shimadzu UV-180 spectrophotometer. The standard curve was linear between 0 and 250 µg/ml catechin. The flavonoids were represented as mg of CE/g wet basis.

DPPH free radical-scavenging assay

The ability to scavenge DPPH free radicals was determined based on the method of Sonawane and Arya, (2015) with little modification in DPPH concentration. 0.1mM of DPPH prepared in methanol was diluted to set the absorbance at 0.7 (±0.02) at 517 nm. 3.9 ml of diluted DPPH was added to 0.1 ml of sample extract in test tube and it was vigorously shaken and kept in dark room for incubation (15 min) and absorbance was measured at 517 nm using Shimadzu UV-180 spectrophotometer. The standard curve was linear between 0 and 250 µg/ml Trolox. Results are expressed in mg of TE/g on wet basis. The percent scavenging was calculated by following formula;
Scavenging % = 100 (Ablank - Asample/Ablank)
Where, Ablank is the absorbance of the DPPH solution and Asample is the absorbance of the extract solution.

ABTS Assay free radical-scavenging assay

Antioxidant activity was measured using the modified ABTS method of Re *et al.* (1999). The ABTS reagent was prepared freshly and used within 2 days. The reagent was made by mixing 7mM ABTS + 2.45 mM potassium persulfate and incubated for 16 hours at 37°C. The ABTS cations diluted with ethanol to set O.D at 0.7 (±0.02) at 734 nm (1:30 v/v). 3.9 ml (absorbance of 0.700±0.02) was added to the 0.1 ml extract of sample and mixed thoroughly and absorbance was measured at 734 nm immediately after 6 min. The standard curve was linear between 0 and 50 µg/ml Trolox. Results were expressed in mg of TE/g wet basis.

Estimation of functional properties

Water binding capacity

The water binding capacity (WBC) of peanut was analysed using protocol by Adeleke and Odedeji, (2010). Defatted peanut flour sample – 1g was taken in a

centrifuge tube and 15 ml distilled water was added to the tube and vortexed for 2 min to form a suspended mixture. This mixture was then centrifuged at 4000 rpm at 20°C for 20 min. The supernatant was then discarded and the difference in weight between dry flour and wet pellet was taken as water binding capacity (Nicholls *et al.*, 1995).

Water binding capacity (g/g) = (Weight of sediment)/(Weight of sample)

Oil binding capacity

The oil binding capacity (OBC) of flours was analysed using protocol by Adeleke and Odedeji, (2010). Defatted peanut sample – 1 g was taken in a centrifuge tube and 15 ml of oil was added to the tube and vortexed for 2 min to form a suspended mixture. This mixture was then centrifuged at 4000 rpm at 20°C for 20 min. The supernatant was then discarded and the difference in weight between dry flour and oil pellet was taken as oil binding capacity (Nicholls *et al.*, 1995).

Oil Binding Capacity (g/g) = (Weight of sediment)/(Weight of sample)

Water soluble index

The water soluble index (WSI) of flours was analysed using protocol described by Kaur and Singh, (2005). Defatted peanut sample (2.5 g) was dispersed in 30 ml of distilled water, using a glass rod, and cooked at 90°C for 15 min in a water bath. The cooked paste was cooled to room temperature and transferred to centrifuge tubes, and then centrifuged at 3000g for 10 min. The supernatant was decanted for determination of its solid content into a pre weighed evaporating dish and the sediment was weighed. The weight of dry solids was recovered by evaporating the supernatant overnight at 110°C. Triplicate determinations were carried out. WSI were calculated by the equation:

Water soluble index (%) = (Weight of dissolved solids in supernatant)/(Weight of sample) 100

Foaming capacity (FC)

Foaming capacity was determined by Yu *et al.* (2007). 1% defatted sample was prepared in de-ionised water and adjusted to pH 7.4 with 1.0 N NaOH and 1.0 N HCl. 100 ml (V1) of peanut flour concentrate was blended using a high speed blender for 3 min and then poured into 250 ml graduated cylinder and the volume of foam (VF) was immediately recorded. Foaming capacity was calculated using following equation:

Foaming capacity = VF/V1

Chemical analysis of oil

Iodine value

Iodine value was estimated as per titre metric method of Pearson (1981). Oil sample – 2 g was weighed in a 250 ml dry stopper bottle and 10 ml carbon tetrachloride was added to it. 20 ml of Wij's solution was added and then mixture was allowed to stand for 30 min in the dark. 15 ml of 10% potassium iodide and 100 ml of distilled water was added to the solution and then titrated with 0.1M sodium thiosulphate solution using starch as an indicator before the end point. Along with oil samples blank was also prepared. Iodine value was calculated using following formula:

Iodine value (Wij's) = [(V2-V1)1.269]/(weight of sample (g))

Where, V2= titre value for blank

V1= titre value for sample

Acid value

Titre metric method of Pearson (1981) was used for acid value determination. Oil sample – 5g, 75 ml hot neutral alcohol was added in a conical flask with few drops of phenolphthalein as an indicator. Mixture was titrated with 0.1 M NaOH with continuous shaking until solution turns pink. Acid value was calculated using the formula:

Acid value = (V(5.6))/(Weight of sample)

Where, V= titration end point value

Peroxide value

Peroxide value was determined as per AOAC (Helrich, 1984). Oil sample – 2 g and 1 g of potassium iodide were mixed with 20 ml of solvent mixture i.e. glacial acetic acid and chloroform (3:2 v/v) in a beaker. This was then placed in a boiling water bath for 30 seconds. The content was poured in a flask containing 20 ml (5%) iodide solution. The beaker was rinsed with 25ml distilled water and mixture in the flask was titrated with 0.002 N sodium thiosulphate using starch as

an indicator. Along with oil samples blank was also prepared. Peroxide value was obtained using following formula:

$$\text{Peroxide value} = (2(V_1 - V_2) \text{ mEq/kg}) / (\text{weight of sample})$$

Where, V_2 = blank titre value

V_1 = sample titre value

Saponification value

Saponification value was determined according to **Pearson (1981)**. Oil- 2 g was weighed into a conical flask and 25 ml of 0.5 N alcoholic potassium hydroxide was added and this solution was refluxed for 1h, cooled and titrated with 0.5 N HCl using phenolphthalein as indicator. A blank was prepared alongside and value was calculated using following formula:

$$\text{Saponification value} = (56.1N (A-B)) / (\text{Weight of sample})$$

Where, N= Normality of HCl

A= Volume of HCl for blank

B= Volume of HCl for sample

56.1= Equivalent weight of KOH

Fatty acid composition of oil from peanut varieties by GC-MS

Fatty acid methyl esters (FAMES) were prepared from cold pressed oil by modified method of **Tarmizi et al, (2013)** and **Mishra et al, (2014)**. Oil sample – 20 mg was dissolved in 1 ml HPLC grade hexane. To this mixture 1ml of HPLC grade methanol and 300 µl H₂SO₄ were added for *trans* esterification reaction which was then incubated at 70°C for 1 hour in a heating oven. After the reaction, samples were allowed to cool to room temperature. 1ml of HPLC grade water was added to the mixture and the samples were mixed for 30 seconds using vortex. Samples were allowed separate and the upper organic layer was collected, 0.5 g sodium sulphate was added to it to absorb remaining moisture and was filtered through 0.2 µm syringe filter. These samples were analysed for fatty acid profiling using Gas Chromatography (GC), model Agilent Technologies 7890 equipped with Mass Spectrometer (MS) Jeol model AccuTOF GCV. Separation was performed on a capillary column HP5 capillary column (30m × 0.25mm id., film thickness 0.25 micron). The carrier gas was helium with flow rate of 1 ml/min. The oven temperature was held for 10 min at 100°C and subsequently increased to 280°C at 6°C/min. A sample volume of 1 µl in hexane was injected

using a split mode, with the split ratio of 10:1. The mass spectrometer was set to scan in the range of m/z 35–600 with electron impact (EI) mode of ionization.

Mineral and heavy metal analysis of peanut varieties by ICP-AES

Mineral composition of peanut varieties was determined using Inductively Coupled Plasma- Atomic Emission Spectroscopy (ICP-AES) with make of SPECTRO Analytical Instruments GmbH, Germany and Model ARCOS, Simultaneous ICP Spectrometer. Ash of sample was obtained by AOAC Method, (**AOAC, 1995**). Obtained ash samples were dissolved in aqua regia while heating on hot plate. Dissolved samples were diluted using de-ionized water and were analysed in ICP-AES (**Özcan & Seven, 2003**).

Aflatoxin analysis

AgraStrip Total Aflatoxin Test (4 ppb cut off) kit according to **Luis and Kemerait (2015)** was used for aflatoxin estimation, which is validated screening method for determination of total aflatoxin at 4 ppb cut off level. Tests were performed in duplicate for conformation.

Statistical analysis

Statistical analysis was performed by analysis of variance (ANOVA) using IBM SPSS 24. All data were expressed as mean from triplicate samples ± standard deviation. Duncan test was used and differences were considered statistically significant at $p < 0.05$ level.

RESULTS AND DISCUSSION

Proximate analysis

Proximate analysis includes evaluation of moisture, ash, crude lipid, total protein content and total carbohydrate content of three Indian peanut varieties. It is inferred from Table 1 that peanuts had 36-42% protein and therefore are a good source of protein. Peanuts are characterized by high oil and protein contents and low carbohydrates and ash. Knowledge of these components is important in the end products of the industry (**Ahmed & Young, 1982**).

Table 1 Proximate analysis of Indian peanut varieties

Variety	Moisture %	Oil %	Ash %	Fibre %	Protein %	Carbs %
<i>SB-11</i>	5.80 ± 0.07 ^a	41.53 ± 0.08 ^b	3.22 ± 0.05 ^b	6.11 ± 0.23 ^c	42.09 ± 0.12 ^c	1.37 ± 0.03 ^b
<i>JL-24</i>	5.92 ± 0.05 ^a	47.00 ± 0.11 ^a	3.80 ± 0.08 ^c	3.72 ± 0.03 ^a	38.61 ± 0.07 ^b	1.81 ± 0.05 ^a
<i>TLG-45</i>	7.08 ± 0.09 ^b	46.10 ± 0.21 ^a	2.48 ± 0.03 ^a	3.83 ± 0.04 ^{ab}	36.89 ± 0.06 ^a	2.85 ± 0.05 ^c

All the values are means ± standard deviations (n = 3). Values within a given column followed by the same superscript letters are not significantly different ($p > 0.05$) according to ANOVA and Duncan's studentised range test; carbs – carbohydrates

The highest protein (42.09%) and fibre (6.11%) contents were observed in SB-11 variety followed by JL-24 (38.61%, 3.72%) and TLG-45 (36.89%, 3.83%) respectively. The differences in the protein content was observed among varieties which could be due to the size variation of kernel. Our observations are in accordance with **Prathiba and Reddy, (1994)** who reported correlation between kernel size and its nutritional composition where, protein content was indirectly proportional to kernel size whereas oil content was independent of kernel size. However, no significant difference in fibre content was observed among JL-24 and TLG-45 varieties, dietary fibre consumption contributes to an increase in faecal bulk thus increased rate of intestinal transit. Oil (47%) and ash (3.80%) content were highest for JL-24 variety. The discrepancy range of oil percentage (41.53- 47.00%) was analogous to that of other species of wild peanuts as previously reported by **Stalker et al. (1989)**, although the studied species and environmental conditions were different. Carbohydrate and moisture content was highest for TLG-45 i.e. 2.85% and 7.08% respectively. Ash percentages were 2.48-3.80%, and they exhibited significant differences among TLG-45 and other two varieties. Highest crude protein content (47.00%) and the least oil content (41.53%) was observed in SB-11 which is ideal for products which require more protein and less oil like bread, nufu (peanut tofu), biscuits, etc. This will prove substantial in reducing malnutrition especially in young and growing children due to protein deficiency. Substantial genetic variability exists for chemical composition and nutritional traits which could be utilised for various food preparations and selection for breeding purpose.

Sensory analysis of raw peanut varieties



Figure 1 Indian peanut varieties

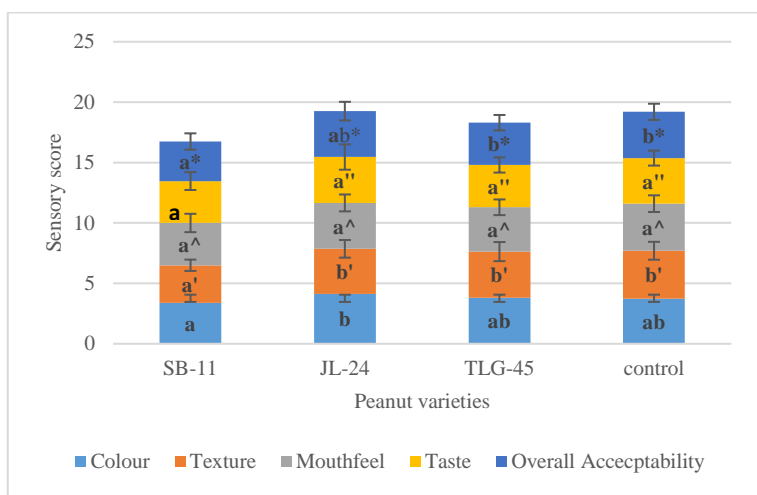


Figure 2 Sensory analysis of raw peanut varieties

Note: The bars on the columns represent standard deviation and the letters on the same column with different superscripts indicate significant difference (p<0.05)

Sensory analysis of raw peanut varieties namely SB-11, JL-24 and TLG-45 was carried out according to the method of Lawless and Heymann (2010) and were compared to super market peanut sample of which variety was unknown (Control). Disco variety showed maximum acceptance in terms of all parameters viz., colour, texture, mouthfeel, taste and overall acceptability compared to SB-11, TLG-45 and control sample (Fig 2). Lowest sensory scores were obtained by SB-11, which could be due to the smallest kernel size and comparatively dull colour (Fig 1) making it less appealing to the panellists. Bigger kernel size and bright reddish pink colour of TLG-45 variety was very appealing however, JL-24 had highest score for taste among other varieties. The redness and hue angle of peanut skin are correlated with total polyphenol content and antioxidant capacity indicating that the hue angle of the peanut skin may be used as a biomarker of total polyphenol content (Chukwumah et al., 2009). No significant difference in the texture and mouthfeel of TLG-45 and SB-11 was observed when compared to control. In peanuts the taste of bitterness and the tactile sensation of astringency is primarily due to the polyphenol and flavonoids (Francisco & Resurreccion, 2012), which are known health promoting bioactives (Oliveira et al., 2014). Sensory acceptability of peanuts is influenced by these bioactives and can also reveal a lot about its nutritional constituents.

Functional properties of peanut varieties

Table 2 Functional properties and biochemical constituents of Indian peanut varieties

Variety	SB-11	JL-24	TLG-45
Functional properties			
WHC (g/g)	2.90 ± 0.67 ^a	2.88 ± 0.13 ^a	2.76 ± 0.08 ^a
OBC (g/g)	1.50 ± 0.10 ^a	1.16 ± 0.05 ^b	1.33 ± 0.05 ^c
WSI (%)	19.33 ± 0.57 ^a	40.00 ± 1.73 ^b	35.00 ± 1.00 ^c
FC	1.06 ± 0.03 ^{ab}	1.03 ± 0.01 ^a	1.10 ± 0.02 ^b
Biochemical constituents			
TPC (mg/g)	2.05 ± 0.11 ^a	1.81 ± 0.26 ^a	1.88 ± 0.22 ^a
TFC (mg/g)	0.24 ± 0.06 ^a	0.25 ± 0.02 ^a	0.51 ± 0.08 ^b
DPPH (mg/g)	1.46 ± 0.02 ^a	1.03 ± 0.02 ^b	1.81 ± 0.07 ^c
ABTS (mg/g)	0.21 ± 0.01 ^a	0.22 ± 0.00 ^{bc}	0.24 ± 0.02 ^c

TPC- total polyphenol content, TFC- total flavonoid content, DPPH- 1-diphenyl-2-picrylhydrazyl radical scavenging activity, ABTS- 2-azinobis (3-ethylbenzothiazoline-6-sulphonic acid) diammonium salt scavenging activity
 All the values are Means ± standard deviations (n = 3). Values within a given column followed by the same superscript letters are not significantly different (p > 0.05) according to ANOVA and Duncan's studentised range test.

Determination of functional properties like WHC, OBC, WSI and FC is necessary for product formulation and in food processing. These properties are affected by the intrinsic factors of protein such as molecular structure and size, and many environmental factors including the method of protein separation, pH, ionic strength, and presence of other components in the food system. Peanuts were found to have high fibre content which is the reason for its higher water

holding capacity (Table 2). Although no significant difference was observed in WHC of all the varieties under study, OBC was highest for SB-11(1.50g/g) followed by TLG-45 (1.33g/g) and JL-24 (1.16g/g). Proteins rich foods with high oil and water binding are desirable for use in meats, sausages, breads, and cakes, while proteins with high emulsifying and foaming capacity are good for salad dressing, sausages, bologna, soups, confectionery, frozen desserts and cakes (Yu et al., 2007). Peanuts are good source of protein which is the reason for low oil binding capacity (Prinyawiwatkul et al., 1993; Wu et al., 2009). Water solubility index was highest for JL-24 > TLG-45 > SB-11. The formation of foam is analogous to the formation of emulsion. In the case of foam, water molecules surround air droplets, and air is the non-polar phase. Theoretically, the amphipathic character of protein makes them the good foaming agents that work at air-water interface to prevent bubble coalescence. Data in Table 2 suggest that defatted peanut flour is not a good foaming agent, with a maximum FC of only 1.1 for TLG-45 and minimum (1.03) for JL-24. Therefore, defatted peanut flours may not be suitable in food system that requires foaming such as cake and ice cream. Functional properties are the intrinsic physiochemical characteristics which may affect the behaviour of food systems during processing, product formulation and storage (Menon et al., 2015). Many foods in India are made up of wheat flour so peanut flour can be incorporated in such foods to add functional properties to it.

Bioactive constituents of peanut varieties

Analysis of bioactive constituents of peanut such as total polyphenol content, total flavonoids, DPPH and ABTS scavenging capacity was performed (Table 2). Phenolics and flavonoids are an important constituent of peanut quality because of their contribution to the taste, colour and nutritional properties (Francisco & Resurreccion, 2012). Peanuts are rich in antioxidants, and the composition of antioxidants in the methanolic extract is complex (Wang et al., 2007). Total phenolic content was found highest in SB-11(2.05 mg/g) followed by TLG-45 (1.88 mg/g) and JL-24 (1.81 mg/g) respectively. Polyphenols help in chelating metal ions such as copper and iron which act as pro-oxidants. Thus we can say polyphenols are secondary antioxidants. TLG-45 had high levels of DPPH radical scavenging activity (1.81 mg/g) followed by SB-11 and JL-24. Similar trend was also observed for ABTS scavenging activity with no significant difference among JL-24 and TLG-45. As polyphenols and antioxidants protect cell constituents against oxidative damage and, therefore, limit the risk of various degenerative diseases associated with oxidative stress. Lipid soluble polyphenols and antioxidants are expelled with the oil. This is the reason that whole peanuts will have higher DPPH scavenging activity compared to defatted peanut flour. 0.51 mg/g of total flavonoid was found in TLG-45 variety which is highest among all varieties and is attributed to its reddish skin colour. There was no significant difference found in total flavonoid contents among SB-11(0.24mg/g) and JL-24 (0.25mg/g). Total flavonoid content has a strong correlation with total proanthocyanidins and hence can be used as indicator for proanthocyanidin content of peanuts (Chukwumah et al., 2009). It is known that there is reduction in flavonoid during processing as flavonoids are heat labile (Odriozola-Serrano et al., 2008), therefore total flavonoids in whole raw peanuts will be more than defatted or heat treated peanuts.

Mineral composition of Indian peanut varieties

Study of mineral composition is of interest due to the pro-oxidant activity and health benefits associated with minerals (Parcerisa et al., 1995). Mineral content of Indian peanut varieties are given in the table (Table 3), significant differences were observed between mineral compositions of varieties. All varieties were found rich in Na, K, Ca, P, Fe, Zn, Cu, Mg and Mn. TLG-45 variety was observed to have highest levels of Na, K, P, Zn, Cu and Mg compared to SB-11 and JL-24. Ca and Mg levels were high in SB-11 variety whereas JL-24 was richest in Fe content, which are very close to the RDA and are in accordance with the results reported by (Gyu-Seong, 1993). Heavy metals like Pb and Ni were found in TLG-45 variety which are slightly exceeding the FSSAI permissible limits of 2.5 ppm and 5 ppm respectively. Heavy metals are usually absorbed from soil by crops and due to contamination during post-harvest practices and amount of absorption depends on factors like pH of soil and type of heavy metals present (Ali et al., 2013). Heavy metal contaminants may also get incorporated due to the equipments used and poor crop harvesting practices (Godfray et al., 2010) which could be the reason for its presence in varieties under study. Cr was found to be 0.75 µg/g in SB-11, no traces of Cd and Se were found in any of the variety. JL-24 was also nil for Pb and other heavy metals i.e. Cr was found to be within the permissible limits. This study shows that mineral composition varies from variety to variety and different geographical conditions as they are grown in different states of India. The mineral elements examined were substantial in reducing malnutrition especially in young and growing children. Thus Indian peanut varieties under study are mineral rich and are excellent for human nutrition.

Table 3 Mineral and heavy metal analysis of peanut varieties using ICP-AES (mg/100g)

Element	SB-11	JL-24	TLG-45	RDA
Copper(Cu)	1.83 ± 0.01 ^a	1.40 ± 0.01 ^b	1.85 ± 0.03 ^a	0.9 mg
Zinc(Zn)	7.20 ± 0.01 ^a	5.78 ± 0.06 ^b	8.09 ± 0.01 ^c	11-8 mg
Iron(Fe)	8.27 ± 0.05 ^a	11.73 ± 0.07 ^b	9.09 ± 0.03 ^c	18-8 mg
Sodium(Na)	79.45 ± 0.34 ^a	62.85 ± 1.10 ^b	295.10 ± 2.93 ^c	2300 mg
Manganese(Mn)	3.88 ± 0.01 ^a	3.67 ± 0.04 ^b	4.24 ± 0.03 ^c	1.8-2.3 mg
Potassium(K)	1373.15 ± 3.67 ^a	1293.23 ± 11.24 ^b	1511.45 ± 16.47 ^c	4.7g
Calcium(Ca)	167.23 ± 1.17 ^a	131.37 ± 0.59 ^b	150.35 ± 1.75 ^c	1000 mg
Magnesium(Mg)	589.12 ± 4.37 ^a	530.94 ± 1.34 ^b	507.45 ± 4.99 ^c	310-400mg
Phosphorus(P)	794.78 ± 0.92 ^a	704.8 ± 0.86 ^b	829.57 ± 3.35 ^c	700 mg
Selenium(Se)	ND	ND	ND	0.05mg
Lead(Pb) (µg/g)	1.80 ± 0.09 ^a	ND	5.00 ± 0.25 ^b	2.5 µg/g *
Cadmium(Cd) (µg/g)	ND	ND	ND	1.5 µg/g *
Cromium(Cr) (µg/g)	0.75 ± 0.00 ^a	0.73 ± 0.03 ^a	ND	5 µg/g *

All the values are Means ± standard deviations (n = 3). Values within a given row followed by the same superscript letters are not significantly different (p > 0.05) according to ANOVA and Duncan's studentised range test.

Note: * FSSAI permissible limits for heavy metals
ND: Not detected

Physico-chemical properties of oil extracted from peanut varieties

Indian daily diet constitute vegetable oil as a major component. Demand for any oil in the market is based on its functionality, economy and acceptability. Three Indian peanut varieties analysed above show that the JL-24 variety has highest oil content of 47% followed by TLG-45 and SB-11(Table 4), hence are suitable for commercial oil production. TLG-45 variety showed highest absorbance at 470nm by Spectrometric analysis. Chemical analysis revealed that the iodine value, peroxide value and saponification values were highest for JL-24, whereas acid value was highest for TLG-45. **Kirk and Sawyer (1991)** indicated that high iodine value denotes high degree of unsaturation of oil due to oxidation and degree of heat treatment during oil processing. Peroxide values for all varieties were between 0.13- 0.26 mEqKg⁻¹ which was less than the standard peroxide value (10 mEqKg⁻¹) for deterioration of vegetable oil, indicating slow oxidation of these oils. Peroxide values between 20 and 40 mEqKg⁻¹ results in rancid taste (**Akubugwo & Ugbogu, 2007**). Acid values are used to measure the extent to which glyceride has been decomposed in the oil by lipase and other factors such as light and heat (**Demian MJ, 1990**). Acid value is indicator of condition and edibility of oil. Locally produced oils have higher saponification values compared to refined oils. According to **Denniston et al, (2004)** high saponification values indicate presence of greater number of ester bonds, suggesting that fat molecules were intact. The study shows that oil from all three Indian peanut varieties have high shelf life, nutritional value and industrial applications.

Table 4 Physico-chemical properties of oil extracted from peanut varieties

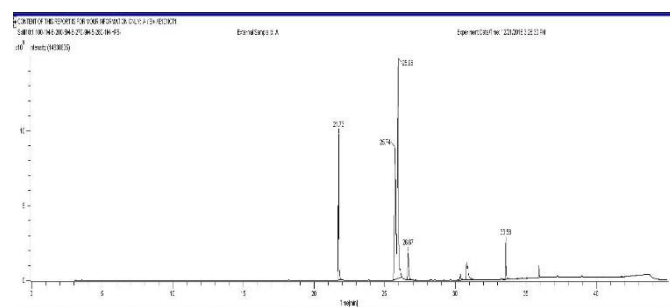
Parameters	SB-11	JL-24	TLG-45
Colour	Bright yellow	Light yellow	Pale yellow
Odour	Agreeable	Agreeable	Agreeable
Absorbance (470nm)	0.15 ± 0.00 ^a	0.14 ± 0.00 ^a	0.12 ± 0.01 ^b
Iodine value (wij's)	4.61 ± 0.26 ^a	6.34 ± 0.25 ^b	4.86 ± 0.07 ^a
Acid value (%)	1.93 ± 0.06 ^a	1.79 ± 0.22 ^a	2.01 ± 0.19 ^a
Peroxide value (mEqKg ⁻¹)	0.23 ± 0.05 ^{ab}	0.26 ± 0.05 ^b	0.13 ± 0.05 ^c
Saponification value	191.67 ± 4.28 ^a	368.38 ± 4.28 ^b	199.15 ± 5.61 ^c

All the values are Means ± standard deviations (n = 3). Values within a given row followed by the same superscript letters are not significantly different (p > 0.05) according to ANOVA and Duncan's studentised range test.

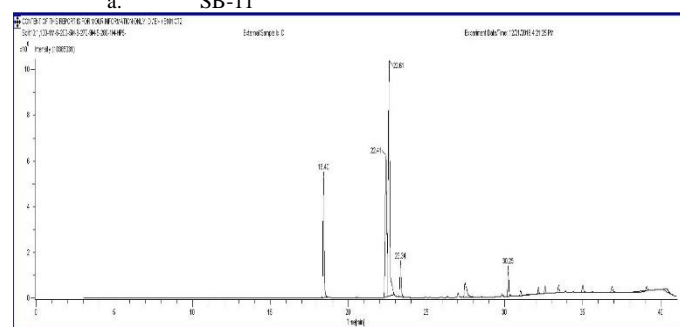
Fatty acid composition of oil from peanut varieties by GCMS

Table 5 Fatty acid composition of oil from peanut varieties by GC-MS

Fatty acids	SB-11 (g/100g)	JL-24 (g/100g)	TLG-45 (g/100g)
Saturated			
Palmitic acid	17	16.79	11.12
Stearic acid	4.66	5.04	4.16
Behenic acid	3.7	3.25	3.63
Unsaturated			
Linoleic acid	28.46	25.75	18.12
Oleic acid	44.54	44.37	50.21
Other	1.63	4.79	12.76



a. SB-11



b. JL-24

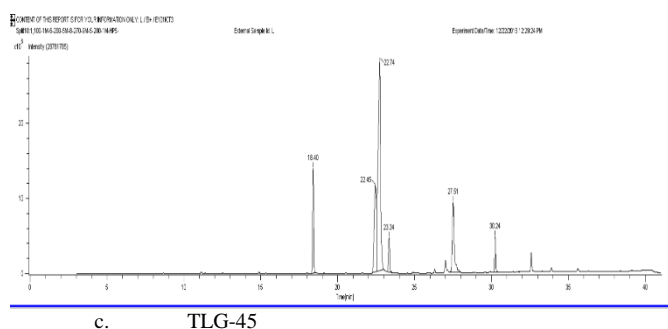


Figure 3 GCMS total ion chromatograms of fatty acid composition of Peanut varieties (a) SB-11, (b) JL-24, (c) TLG-45

GCMS analysis was used to study the fatty acid composition of the oil from peanut varieties. Five major peaks were observed in the total ion chromatogram of all three peanut varieties (Fig 3). Each FAME peak was identified and quantified by referring to the library match software (NIST MS search 2.0) the obtained fatty acid compositions are shown in Table 5 and corresponding chromatograms are shown in Fig 3. GCMS analysis confirmed the presence of

three saturated (palmitic acid, stearic acid and behenic acid) and two unsaturated (linoleic and oleic acid) FAMES in all three varieties having similar impact spectra. The determined fatty acid composition were in accordance with the reported composition of the peanut oil although there are reports of presence of arachidic, eicosenoic and lignoceric fatty acids (Nelson *et al.*, 2000) in traces which could not be detected in studied Indian varieties. Oleic and linoleic acids were the major components of peanut oil from all varieties. All varieties showed lower linoleic and higher oleic acid concentrations. Oleic was predominant in TLG-45 with 50.21%. Similar fatty acid composition was observed for SB-11 and JL-24 variety except linoleic acid percentage. Whereas palmitic, oleic, stearic and behenic acid did not exhibit substantial difference among SB-11 and JL-24. However wide variation of palmitic (11.12%), linoleic (18.12%) and oleic acid (50.21%) concentrations were found in TLG-45 variety. This differences among varieties investigated in this work were probably due to variation in environment, genotype and growing location because all samples of species were cultivated in the same year and growing season (Brown *et al.*, 1975). However, incorporation of peanut oil into food products or incorporation of oil-containing peanut meals could alter shelf life, nutrition value and flavour of the food. Behenic acid concentration was least in all varieties (around 3%). Savage and Keenan (Savage & Keenan, 1994) reported considerable compositional and quantitative changes in the fatty acids and lipids of peanut during various stages of growth and maturity.

Aflatoxin analysis of peanut varieties

Samples	Observation	Result	Inference
JL-24	1. Test line (faint) 2. Control line	Negative	Two lines are visible, this indicates the sample contains total aflatoxin less than 4 ppb.
SB-11	1. Test line (present) 2. Control line	Negative	Two lines are visible, this indicates the sample contains total aflatoxin less than 4 ppb.
TLG-45	1. Test line (present) 2. Control line	Negative	Two lines are visible, this indicates the sample contains total aflatoxin less than 4 ppb.

Aflatoxin contamination in food grains is now well recognized as a public health hazard (Goldblatt, 1971) as they are highly toxic and carcinogenic secondary metabolites of concern in food safety (Achar *et al.*, 2009). Peanuts are frequently contaminated by the fungal species *Aspergillus flavus*, which can produce aflatoxin. This infection can occur during transportation or storage of peanuts. Infection and aflatoxin concentration in peanut can be related to the occurrence of soil moisture stress during pod-filling when soil temperatures are near optimal for *A. flavus*. In similar environments these associations could be supportive to predict the risk of aflatoxin contamination in peanuts (Craufurd *et al.*, 2006). On estimation of peanut varieties for aflatoxin, a visible line in test and control zones of the strip indicated that total aflatoxin content in all varieties is less than 4 ppb (negative) for JL-24, SB-11 and TLG-45 variety (Table 6), thus were regarded as safe for consumption. The maximum level of total aflatoxin in foodstuffs in European community is 4ppb (Commission Regulation (EC) No 1525/98). It is intriguing that certain varieties of peanuts support low toxin production, whereas other varieties support maximal production. This difference is possibly related to certain basic biochemical characters such as protein (Nagarajan & Bhat, 1972) or possibly vitamin E (Detroy *et al.*, 1971) besides cultivar practices.

CONCLUSION

It can be inferred from the above study that these Indian peanuts varieties namely SB-11, JL-24 and TLG-45 are a great source of nutrition. They can be abundantly utilized especially in a country like India which is one of the leading producers of peanut but ironically also has largest counts of malnourished population. All peanut varieties were found rich in oil, protein, minerals and various bioactive compounds. Highest crude protein, polyphenol content and the least oil content of SB-11 makes it ideal variety for consumption as food or ingredient. This will prove substantial in alleviating malnutrition due to protein deficiency especially in young and growing children. JL-24 with its highest oil content and sensory acceptability, can be efficiently utilized for oil extraction as well as in food combinations. Moreover chemical analysis of oil and higher ratios of unsaturated fatty acids to the saturated fatty acids revealed its good quality hence can be used

in salad, cooking, frying etc. TLG-45 variety can be concluded superior among other varieties attributed to its mineral rich composition, highest TFC, DPPH and ABTS radical scavenging activity. All varieties exhibited functional properties like water holding capacity, besides excellent oil binding capacity and water solubility index of SB-11 and JL-24 respectively. These functional and beneficial components that exhibit wide biological and practical applications that are of great interest to the food industry. There is also a greater need of spreading awareness that peanut can prevent undesired supplementations through non dietary sources on regular consumption in Indians, particularly. Overall we and concluded that each variety under study exhibited its own peculiar superiority in terms of its properties and nutrition, hence depending upon the application presented study can assist in selection of suitable peanut variety and also indicating the use of these varieties for export and other oil extraction usages.

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