Nutritional composition and antioxidant activity of Spanish and Virginia groundnuts (*Arachis hypogaea* L.): a comparative study

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Abstract Kernels of sixty groundnut genotypes comprising thirty each of Spanish and Virginia groups were characterized and compared for the content of oil, protein, phenols and antioxidant activity along with their fatty acid and sugars profiles. The antioxidant activity for Virginia genotypes was ranged from 12.5 to 16.5 μ M Trolox equivalent activity for Spanish genotypes ranged from 6.8–15.2 μ M. Amongst Virginia types, the highest oleic acid/linoleic acid (O/L) ratio of 2.38 was observed for NRCG 12312 while from Spanish group the highest O/L ratio of 1.24 was observed for NRCG 12731. The sucrose content for Virginia genotypes ranged from 38.5 to 69.0 mg/g while it was 27.9 to 53.3 mg/g for Spanish genotypes. Average myo-inositol content was higher for Spanish genotypes (0.8–2.1 mg/g) compared to Virginia (0.4–1.8 mg/g) while the reverse was true for stachyose content (Spanish: 3.5–7.9 mg/g; Virginia: 4.6–10.3 mg/g). Thus, Virginia genotypes could be preferred to Spanish genotypes for better oil stability and antioxidant activity.

Keywords Ion chromatography · Antioxidant · Oleic acid · myo-inositol · Peanut · Sugars

Introduction

Groundnut or peanut (*Arachis hypogaea* L.) kernels make an important contribution to the diet in many countries, and its widespread acceptability is attributed to its economic value to the industry and nutritional benefits to consumers. Groundnut kernels are a good source of protein, oil and fatty acids for human nutrition. The fatty acid composition of the oil plays an important role in determining shelf-life, nutrition, and flavor of food products (Gaydou et al. 1983). Groundnut oil is rich in monounsaturated (MUFA) and polyunsaturated fatty acids (PUFA) (Mercer et al. 1990). Substitution of diets rich in saturated fats with oils low in saturated fats, but high in MUFA and PUFA (like groundnut oil), can reduce an individual's risk of cardiovascular disease by leading to lower low-density lipoprotein cholesterol, lower serum triglycerides, and maintained high-density lipoprotein cholesterol levels in human blood plasma (Kris-Etherton et al. 1999). A higher intake of PUFA from groundnut products may improve insulin sensitivity and reduce the risk of developing type-2 diabetes in women (Jiang et al. 2002); such effects may be more pronounced in case of high-oleic groundnuts due to the higher content of MUFA (O'Byrne et al. 1997). Besides good quality fatty acid profiles, other beneficial functional constituents including vitamin E, L-arginine, myo-inositol, soluble and insoluble fiber, phytosterols, as well as water- and lipid-soluble phenolic antioxidants make the groundnut a desirable plant food (Clements and Darnell 1980; Isanga and Zhang 2007; Kris-Etherton et al. 2008). Therapeutic potential of myo-inositol in the treatment of diabetic neuropathy has been discussed by various researchers (Salway et al. 1978; Clements and Darnell 1980; Reviewed by Croze and Soulage 2013). They suggested that increased oral/dietary intake of myo-inositol significantly improve nerve function of diabetic patient. Groundnut kernels contain a range of

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antioxidative phytochemicals including several phenolic acids, flavonoids and stilbenes (e.g. resveratrol), which have health benefitting effects through apparent anti-inflammatory, antimicrobial and anticancer activities (Kris-Etherton et al. 1999; Griel et al. 2004). Growing knowledge about nutritional and functional components in routine foods may provide the basis for the calculation and prescription of diets with known natural compounds.

Groundnut is broadly categorized into four habit groups viz., Runner, Valencia, Spanish and Virginia. Each habit groups has distinct size, flavor, and nutritional composition. Virginia groundnuts have large kernels and hence are preferred for roasting, whereas Spanish groundnuts having small kernels are mostly used for confections. Although the information on oil content and fatty acid profiles of the groundnut varieties of different habit groups are available, however a compiled nutritional database is still missing. Further there is little or no information available on antioxidant activity and sugar profiles of these habit groups. Thus, the present investigation was aimed at characterization of the kernel of sixty groundnut genotypes comprising thirty each of Spanish and Virginia groups, for their oil, protein, sugar, and phenol contents along with their fatty acid profile and antioxidant activity.

Material and methods

Experimental material

Total sixty groundnut genotypes comprising thirty each of Spanish and Virginia (Tables 1 and 2) were grown under standard recommended procedures at the research farm of Directorate of Groundnut Research, Junagadh, Gujarat, India during Kharif-2013. After post harvest curing, the kernel samples were stored at 10 °C until used. Sampling was made by selecting sound and mature kernels from the produce. For statistical analysis, each subsample was considered as replication to calculate standard deviation for each genotype.

Determination of oil, protein content and fatty acid profile

The samples were ground to fine meal and used for various quality traits. Oil and protein content was determined by NIR (Dickey John, Instalab 700). For preparation of methyl esters, the protocol described by Misra and Mathur (1998) was followed. For that, in a 10 ml screw cap test tube, 200 µl oil was mixed with 3 ml hexane kept for 1 h at room temperature with intermittent vortexing. In the same tube, 3 ml of freshly prepared Sodium methoxide (80 mg NaOH in 100 ml methanol) was added and incubated at room temperature for 30 min followed by addition of 3 ml of 0.8 % aqueous sodium chloride and then shaken well. After 5 min, the upper hexane layer

containing the methyl-esters were transferred to another centrifuge tube already containing 100 mg anhydrous sodium sulphate. The hexane layer containing methyl-esters was used for Gas Chromatograph (Netel India Ltd., Model MICHRO 9100) analysis, using 15 % DEGS packed column. The separation conditions maintained for fatty acids analysis in GLC was as follows; Oven temperature: 190 °C, injector temperature: 240 °C, FID temperature: 260 °C and the flow rate of both carrier gas (nitrogen) and fuel gas (hydrogen) were maintained at 30 ml min⁻¹. A reference standard of fatty acid methyl ester (FAME) mixture (Sigma) was analysed under the same operating conditions to determine the peak identity (Fig.1). The FAMES were expressed as relative area percent.

Sugar profiles using ion chromatography

Groundnut kernel samples from each genotype were extracted for oligosaccharide analysis in 80 % ethanol as described by Oupadissakoon et al. (1980). Glucose, fructose, Mannitol, Trehalose, myo-inositol, lactose, sucrose, cellobiose, raffinose and stachyose were used as standards. The concentrations of various components in the standard mixture were adjusted to such levels that a distinct peak for each was obtained in the chromatogram (Fig. 2). Extracted sugars were filtered through membrane (4.5 µm) and an aliquot of 25 µl of samples was injected in the ion chromatograph (Dionex, ICS 3000) equipped with amino trap column, CarboPac PA10 guard column followed by CarboPac PA10 analytical column. Sugars were eluted from column in 150 mM NaOH with a flow rate of 1 ml min⁻¹. Data integration was performed using Chromeleon software supplied with the equipment (Bishi et al. 2015).

Antioxidant activity and total phenols content

Antioxidants and total phenols from kernels were extracted in 80:20 methanol:water. The concentration of phenolics in extracts was measured using Folin-Ciocalteu assay described by Bishi et al. (2015). One ml extract was transferred to a test tube and then alcohol was evaporated till dryness. The residue was dissolved in 1.0 ml water. The Folin and Ciocalteu reagent, 0.5 ml (1:1 with water), was added to each test tube, mixed, and allowed to stand for 3 min. Subsequently, 2 ml, 20 % Na₂CO₃, was added, mixed thoroughly and then placed in a boiling water bath for one minute and cooled in ice water and the colour was read at 650 nm. Catechol (0–25 µg) was used as the standard.

ABTS^{•+} radical-scavenging activity of groundnut kernel extracts was determined according to method described by Arnao et al. (2001) with some modifications. The standard curve was linear between 1 and 10 µM Trolox. Results are expressed in µM Trolox equivalents (TE)/g peanut.

Table 1 Quality traits of Spanish groundnut genotypes

	Genotype NRCG	Oil %	Protein %	P.A. %	S.A. %	O.A. %	L.A. %	O/L ratio	Antioxi. ($\mu\text{M TEg}^{-1}$)	Phenol (mg g^{-1})	myo-ino (mg g^{-1})	Glu. (mg g^{-1})	Suc. (mg g^{-1})	Raffi. (mg g^{-1})	Stach. (mg g^{-1})
1	3648	48.5 d-h	30.9 cd	12.3 g	2.3 e-h	45.9 b	39.4 m	1.16 c	7.2 jk	1.53 r	1.37 g	0.25 jk	35.46 i	0.30 kl	3.90 i
2	6213	45.4 k	34.1 a	13.5 e	2.3 e-h	41.8 gh	41.5 de	1.01 k-m	7.2 jk	1.95 lm	1.40 g	0.41 c	45.13 bc	0.27 mn	7.81 a
3	10,471	48.7 d-h	29.8 d-h	14.6 cd	2.4 d-g	42.4 f	40.6 h-j	1.04 hi	10.0 f-h	2.00 kl	2.09 a	0.36 e	46.38 b	0.31 i-k	7.64 a
4	10,564	49.3 c-f	29.6 d-h	14.9 bc	2.5 c-f	43.3 e	39.3 m	1.10 e	9.3 g-i	2.06 jk	2.02 ab	0.41 cd	39.59 h	0.36 h	7.49 a
5	10,569	48.7 d-h	29.6 d-h	14.7 cd	2.6 cd	42.5 f	40.0 kl	1.06 gh	8.2 ij	2.21 ef	1.89 cd	0.26 jk	44.77 c	0.39 gh	7.83 a
6	10,580	50.1 a-c	28.9 f-i	14.6 cd	2.5 c-f	41.3 hi	40.8 f-j	1.01 k-m	10.8 c-f	2.16 f-i	1.26 hi	0.39 d	41.66 ef	0.32 i-k	7.49 a
7	10,620	49.3 c-f	29.4 e-h	14.8 b-d	2.5 c-f	41.0 ij	41.2 e-g	1.00 l-o	7.2 jk	1.96 lm	1.83 d	0.33 fg	44.78 c	0.26 no	6.02 cd
8	10,635	51.1 a	26.7 j	14.7 cd	2.77 bc	41.8 gh	40.5 i-k	1.03 ij	9.1 g-i	2.08 h-k	1.52 f	0.31 gh	39.68 h	0.40 g	7.82 a
9	10,655	46.6 jk	32.4 b	14.6 cd	2.2 g-j	41.3 hi	41.4 d-f	1.00 l-o	13.2 b	3.42 a	1.17 ij	0.40 cd	42.91 de	0.21 p	6.16 cd
10	10,665	49.5 c-e	28.5 hi	14.7 b-d	2.4 d-g	41.3 hi	41.2 e-h	1.00 k-n	15.2 a	3.38 a	1.15 j	0.21 l	44.01 cd	0.45 ef	7.55 a
11	10,672	48.6 d-h	29.8 d-g	14.4 cd	2.4 d-g	41.1 ij	41.9 b-d	0.98 op	10.9 c-f	2.07 i-k	1.81 d	0.25 k	42.72 de	0.36 h	7.73 a
12	10,910	49.3 c-f	29.7 d-h	13.6 e	2.6 c-e	45.0 c	38.4 n	1.17 c	8.5 i	1.82 no	1.15 j	0.31 gh	33.00 j	0.27 no	5.67 de
13	10,911	48.4 d-h	30.7 c-e	13.3 e	1.9 kl	43.9 d	40.4 jk	1.09 ef	10.9 c-f	1.75 op	1.20 ij	0.25 jk	34.81 i	0.32 ij	4.52 h
14	10,943	50.2 a-c	27.9 ij	15.2 ab	3.0 b	43.3 e	38.4 n	1.13 d	10.9 c-f	2.25 de	1.72 e	0.63 a	39.98 gh	0.55 b	7.52 a
15	10,966	49.6 cd	29.8 d-h	14.5 cd	2.3 d-g	41.3 hi	40.7 g-j	1.02 j-l	10.3 e-g	1.89 mn	1.40 g	0.25 jk	27.89 l	0.36 h	7.46 a
16	10,976	48.7 d-h	30.7 c-e	12.2 g	2.5 c-f	46.8 a	38.2 n	1.23 ab	9.8 f-h	2.10 g-j	0.80 n	0.17 n	45.21 bc	0.25 no	4.93 gh
17	10,978	48.2 f-i	30.6 c-e	12.7 fg	2.5 c-f	45.3 c	39.1 m	1.16 c	6.8 k	1.62 qr	0.85 mn	0.18 mn	39.34 h	0.18 q	3.52 i
18	10,982	48.3 e-h	30.7 c-e	13.4 e	2.3 d-g	40.7 jk	43.1 a	0.95 q	11.6 c	2.19 ef	1.96 bc	0.47 b	32.88 j	0.57 a	5.76 de
19	11,044	48.7 d-h	30.6 c-e	14.3 d	2.0 h-k	42.0 fg	41.3 ef	1.02 j-l	8.1 i-k	2.09 g-j	0.98 kl	0.29 hi	29.15 l	0.30 jk	4.93 gh
20	11,183	46.9 j	32.4 b	13.1 ef	2.2 f-h	43.4 e	40.5 i-k	1.07 fg	9.1 g-i	2.16 f-h	1.69 e	0.48 b	39.81 gh	0.51 c	5.15 fg
21	11,273	48.7 d-h	29.7 d-h	14.8 b-d	2.6 c-e	41.3 hi	41.0 e-i	1.01 k-m	10.3 d-g	1.67 pq	1.03 k	0.26 jk	35.28 i	0.43 f	7.86 a
22	11,603	48.6 d-h	30.5 c-e	13.5 e	2.5 d-f	42.4 f	41.6 b-e	1.02 jk	9.3 g-i	1.76 o	1.32 gh	0.34 ef	30.91 k	0.24 o	4.73 gh
23	11,651	45.4 k	33.9 a	13.3 e	3.3 a	43.1 e	39.7 lm	1.09 ef	11.1 c-f	2.31 d	1.20 ij	0.32 fg	53.29 a	0.47 de	7.46 a
24	11,716	50.7 ab	27.8 ij	13.5 e	2.5 c-f	43.3 e	40.4 jk	1.07 fg	11.1 c-f	2.99 b	1.31 gh	0.27 ij	40.75 f-h	0.28 l-n	5.66 de
25	11,717	49.9 bc	28.8 g-i	15.5 a	1.9 i-l	41.0 i-k	41.3 ef	0.99 m-p	11.6 cd	2.08 h-k	0.82 mn	0.32 g	40.59 f-h	0.32 ij	6.76 b
26	11,909	47.2 ij	32.3 b	14.5 cd	1.7 lm	41.4 hi	42.1 b	0.98 n-p	10.9 c-f	2.09 g-j	1.33 gh	0.27 jk	35.04 i	0.33 ij	6.02 cd
27	12,213	47.6 h-j	31.7 bc	14.4 d	2.2 g-i	40.4 k	42.7 a	0.95 q	8.8 hi	2.25 de	0.90 lm	0.20 lm	41.19 fg	0.33 i	6.01 cd
28	12,383	48.3 e-i	29.7 d-h	14.4 cd	2.2 g-i	41.0 i-k	42.1 bc	0.97 p	11.1 c-f	2.17 e-g	0.78 n	0.22 l	39.36 h	0.29 k-m	5.48 ef
29	12,482	48.0 g-i	30.8 cd	13.5 e	1.5 m	46.3 ab	38.4 n	1.21 b	11.3 c-e	2.66 c	1.16 j	0.26 jk	52.06 a	0.49 cd	7.71 a
30	12,731	49.1 c-g	30.2 d-f	13.4 e	1.5 m	46.7 a	37.8 n	1.24 a	10.1 fg	1.65 q	1.50 f	0.32 fg	31.94 jk	0.33 i	6.28 c
	Avg	48.6	30.3	14.0	2.3	42.7	40.5	1.1	10.0	2.1	1.4	0.3	39.7	0.3	6.4
	Min	45.4	26.7	12.2	1.5	40.4	37.8	0.9	6.8	1.5	0.8	0.2	27.9	0.2	3.5
	Max	51.1	34.1	15.5	3.3	46.8	43.1	1.2	15.2	3.4	2.1	0.6	53.3	0.6	7.9

All values are mean of three replications. Mean values with different letters within the same column are statistically different (p -value <0.05)

Where NRCG is prefix with genotype number, Suc: Sucrose, P.A.: Palmitic acid, S.A.: Stearic acid, O.A.: Oleic acid, L.A.: Linoleic acid, O/L ratio: Oleic/Linoleic ratio, Antioxi ($\mu\text{M TEg}^{-1}$): Antioxidant ($\mu\text{mol Trolox Equivalent}$), Glu: Glucose, Suc: Sucrose, myo-ino: *myo*-inositol, Raffi: Raffinose and Stach: Stachyose

Statistical analysis

All parameters were analysed in triplicate. The significance of differences among the means was carried out using Duncan's multiple range tests (DMRT) at $p < 0.05$ using a software PAST v1.89 (Hammer et al. 2001). Mean data for various traits were subjected to principle component analysis (PCA) for identification of genotypes for various traits and correlation study. Number of significant PCs was identified based on "Screenplot" as suggested by Jackson (1993). For PCA analysis data was standardized with square root transformation and PC 1 and PC 2 scores were used to develop a scatter plot of traits.

Results and discussion

Oil content and fatty acid profiles and oleic: linoleic ratio (O/L ratio)

Oil content and fatty acid profiles of Spanish and Virginia genotypes are presented in Tables 1 and 2. Spanish genotypes had higher oil content (48.6 %), palmitic acid (14.0 %) and linoleic acid (40.5 %) than that of Virginia genotypes (47.2, 10.4 and 30.9 %, respectively). However, variation for oil content was higher in Virginia genotypes (ranging from 44.5 to 53.5 %) than the Spanish genotypes (45.4 to 51.1 %).

Table 2 Quality traits of Virginia groundnut genotypes

	Genotype	Oil %	Protein %	P.A. %	S.A. %	O.A. %	L.A. %	O/L ratio	Antioxi. ($\mu\text{M TEg}^{-1}$)	Phenol (mg g^{-1})	<i>myo</i> -Ino (mg g^{-1})	Glu. (mg g^{-1})	Suc. (mg g^{-1})	Raffi. (mg g^{-1})	Stach. (mg g^{-1})
1	254	46.9 g-l	32.2 e-j	10.5 b-h	2.00 f-j	57.5 c	27.2 o	2.11 c	12.5 j	2.87 g-j	1.11 h-k	0.20 c-e	54.65 f-h	0.40 q	7.61 g-i
2	272	46.7 h-m	32.2 e-j	10.4 c-h	2.03 f-j	53.5 kl	31.1 f-h	1.72 n	13.6 ij	3.64 b-f	0.38 l	0.28 a-e	59.29 c	0.75 h-j	7.92 f-h
3	685	50.9 b	26.3 o	11.3 b-d	2.70 a-d	54.3 h-k	29.5 l-n	1.84 g-j	14.8 c-h	4.13 a-c	1.28 e-i	0.44 a-c	48.14 l	0.46 pq	7.50 g-i
4	1898	50.5 bc	28.0 n	11.0 b-f	2.70 a-d	52.5 lm	31.4 e-g	1.67 o	15.8 a-d	4.62 a	1.53 a-f	0.13 e	43.94 m	0.46 pq	8.28 c-f
5	4775	46.3 i-m	32.8 d-h	11.0 b-f	1.80 h-j	53.4 kl	30.6 f-j	1.74 mn	14.6 d-i	3.29 e-i	1.67 ab	0.18 de	59.56 c	0.70 i-k	7.44 hi
6	4917	47.4 f-i	31.1 jk	10.3 c-i	2.10 e-i	57.3 cd	28.7 n	1.99 d	15.7 a-d	4.64 a	1.76 a	0.34 a-e	58.25 cd	0.69 j-l	8.02 e-g
7	5195	47.6 f-i	31.3 i-k	11.0 b-f	2.20 d-h	54.9 g-j	29.7 k-m	1.85 gh	14.8 c-h	3.96 b-d	1.63 a-c	0.31 a-e	54.63 f-h	0.56 no	7.88 f-h
8	9045	47.4 f-i	31.7 f-k	10.6 b-g	1.63 i-k	54.2 i-k	30.5 g-k	1.78 k-m	13.8 hi	3.45 d-h	1.11 h-k	0.24 b-e	53.62 g-i	1.35 b	8.72 cd
9	9047	47.2 g-j	31.8 f-k	11.0 b-f	1.80 h-j	53.5 kl	30.6 f-j	1.75 mn	15.0 c-g	3.25 e-i	1.52 a-f	0.31 a-e	55.63 fg	0.66 k-m	8.66 cd
10	10,059	48.2 e-g	31.6 f-k	11.5 b	1.53 jk	48.7 n	35.5 c	1.37 q	15.0 c-g	2.96 g-j	1.12 h-k	0.38 a-e	56.67 d-f	0.56 no	7.12 ij
11	10,089	49.6 cd	29.0 mn	9.5 g-i	2.17 d-i	61.6 a	26.3 p	2.35 ab	14.2 f-i	2.82 h-j	1.56 a-d	0.48 ab	50.57 jk	0.78 gh	8.23 d-f
12	11,751	47.8 e-h	30.6 kl	11.0 b-f	2.07 e-i	55.5 fg	31.5 ef	1.76 l-n	15.8 a-c	3.84 b-e	0.88 k	0.19 c-e	52.17 ij	0.55 no	4.61 k
13	12,048	53.5 a	22.6 p	11.2 b-e	2.00 f-j	55.3 f-i	30.8 f-i	1.80 kl	16.5 a	3.83 b-e	1.37 c-h	0.34 a-e	38.51 n	0.41 q	6.86 j
14	12,052	44.5 o	34.6 ab	11.4 bc	1.23 k	52.0 m	35.2 c	1.48 p	13.5 ij	3.14 f-i	1.27 f-i	0.24 b-e	67.32 a	0.46 pq	7.38 h-j
15	12,057	44.5 o	34.8 a	13.6 a	1.90 g-j	43.3 p	37.6 b	1.15 r	15.6 a-e	3.24 e-i	1.12 h-k	0.24 b-e	58.46 cd	0.62 l-n	8.34 c-f
16	12,059	45.5 l-o	34.5 ab	9.6 g-i	3.00 a-c	56.0 fg	30.3 h-l	1.85 g-i	14.4 e-i	2.94 g-j	1.15 h-j	0.35 a-e	62.83 b	0.77 g-i	8.35 c-f
17	12,063	46.2 i-n	33.3 b-e	9.5 hi	2.50 c-f	51.8 m	34.4 d	1.50 p	15.4 a-f	4.16 ab	1.23 g-j	0.43 a-d	53.64 g-i	0.59 m-o	7.48 g-i
18	12,066	46.7 h-m	32.7 d-i	9.8 g-i	2.40 d-g	53.9 jk	30.9 f-i	1.74 mn	15.9 a-c	4.04 a-d	1.21 g-j	0.32 a-e	57.75 c-e	1.27 cd	8.77 cd
19	12,083	45.6 l-o	33.9 a-d	9.2 i	2.60 b-e	56.1 ef	29.8 j-m	1.88 fg	14.9 c-h	3.51 c-g	1.48 b-g	0.35 a-e	57.76 c-e	0.75 h-j	7.87 f-h
20	12,107	44.9 no	34.2 a-c	9.2 i	2.30 d-h	55.3 f-i	31.1 f-h	1.78 k-m	14.1 g-i	2.40 jk	0.86 k	0.45 a-c	68.98 a	1.00 f	9.41 b
21	12,111	47.4 f-i	31.9 f-k	8.0 j	2.20 d-h	57.3 cd	31.5 ef	1.82 h-k	14.1 g-i	3.14 f-i	1.58 a-d	0.33 a-e	59.45 c	0.54 o	7.04 ij
22	12,177	45.9 j-o	32.9 d-g	10.1 e-i	1.80 h-j	57.1 ce	30.1 i-l	1.90 ef	14.5 e-i	2.64 i-k	1.54 a-e	0.48 ab	64.62 b	0.44 q	8.21 d-f
23	12,312	49.0 de	29.0 mn	9.8 g-i	3.10 ab	59.9 b	25.1 q	2.38 a	15.2 b-g	3.48 d-h	1.24 g-j	0.45 a-c	49.11 kl	0.65 k-m	8.56 c-e
24	12,447	47.0 g-k	31.5 g-k	9.5 g-i	2.13 e-i	53.5 kl	32.2 e	1.66 o	15.5 a-e	3.42 d-h	1.23 g-j	0.28 a-e	53.07 hi	0.53 op	8.84 c
25	12,455	45.7 k-o	32.8 d-h	9.7 g-i	2.30 d-h	55.4 f-h	30.9 f-i	1.79 kl	14.9 c-h	3.10 f-i	1.28 e-i	0.39 a-e	54.80 f-h	1.08 e	8.33 c-f
26	12,481	45.4 m-o	33.6 a-d	11.5 b	2.50 c-f	45.3 o	39.1 a	1.16 r	14.9 c-h	3.29 e-i	1.36 c-i	0.29 a-e	58.21 cd	0.83 g	8.42 c-f
27	12,499	48.6 d-f	29.7 lm	9.7 g-i	3.00 a-c	56.3 d-f	29.1 mn	1.93 e	15.2 b-g	2.04 k	0.99 jk	0.31 a-e	52.17 ij	1.65 a	10.28 a
28	12,560	46.8 h-m	31.4 h-k	10.2 d-i	2.50 c-f	55.8 fg	29.8 j-m	1.87 fg	16.2 ab	3.25 e-i	1.08 i-k	0.34 a-e	55.88 ef	1.28 c	9.41 b
29	12,806	47.1 g-k	31.6 g-k	9.9 f-i	2.20 d-h	61.5 a	26.4 p	2.33 b	15.4 a-f	2.73 ij	1.20 g-j	0.54 a	53.80 g-i	0.56 no	7.17 ij
30	13,085	46.5 h-m	33.0 c-f	10.1 e-i	3.20 a	55.5 fg	30.7 f-i	1.81 h-l	15.7 a-d	2.93 g-j	1.32 d-i	0.32 a-e	53.19 hi	1.21 d	8.79 cd
	Avg	47.2	31.6	10.4	2.3	54.6	30.9	1.8	14.9	3.4	1.3	0.3	55.6	0.8	8.1
	Min	44.5	22.6	8.0	1.2	43.3	25.1	1.2	12.5	2.0	0.4	0.1	38.5	0.4	4.6
	Max	53.5	34.8	13.6	3.2	61.6	39.1	2.4	16.5	4.6	1.8	0.5	69.0	1.6	10.3

All values are mean of three replications. Mean values with different letters within the same column are statistically different (p -value <0.05)

Where NRCG is prefix with genotype number, Suc: Sucrose, P.A.: Palmitic acid, S.A.: Stearic acid, O.A.: Oleic acid, L.A.: Linoleic acid, O/L ratio: Oleic/Linoleic ratio, Antioxi ($\mu\text{M TEg}^{-1}$): Antioxidant ($\mu\text{mol Trolox Equivalent}$), Glu: Glucose, Suc: Sucrose, *myo*-ino: *myo*-inositol, Raffi: Raffinose and Stach: Stachyose

Virginia genotypes had higher average content of oleic acid (54.6 %). Average O/L ratio of Virginia genotypes was 1.28 folds higher than that of Spanish genotypes. Variation for O/L ratio was also higher in Virginia genotypes, ranging from 1.2 to 2.4 as compared to Spanish genotypes (0.9 to 1.2). Thus Virginia genotypes can be used in breeding programme to increase oleic acid in groundnut. Our results were in agreement with the findings of Asibuo et al. (2008).

Two fatty acids, i.e. oleic and linoleic acid comprise about 80–85 % of the oil content in groundnuts. In the fatty acid synthesis pathway, oleic acid is a precursor to linoleic acid. In general, saturated fatty acids are less

susceptible to oxidative degradation than their less saturated counterparts. Thus, a high oleic to linoleic (O/L) acid ratio in groundnut improves shelf life and flavor. Moreover, oils that have high oleic acid content and food products containing these oils have been shown to be nutritionally beneficial. Oleic acid has been shown to be associated with a reduction in blood pressure (Teres et al. 2008) and serum lipoprotein levels (O'Byrne et al. 1997). High-oleic groundnuts have health benefits over conventional groundnuts because the linoleic (polyunsaturated fat) and palmitic (saturated fat) fatty acids have been naturally replaced by the healthier oleic fatty acid (monounsaturated fat).

Fig. 1 Chromatogram of fatty acid methyl esters separated in gas chromatograph. Peak no. 3 with retention time 7.56 is of Oleic acid

Sugar profiles and protein content

Various sugars i.e. myo-inositol, glucose, sucrose, raffinose and stachyose determined by ion chromatography are presented in Table 1 and 2. Higher average sucrose content was observed for Virginia genotypes (55.6 mg g^{-1}) than that of Spanish genotypes (39.7 mg g^{-1}). The variability for sucrose content was also higher in Virginia genotypes, ranging from 38.5 to 69.0 mg/g than that of Spanish genotypes (27.9 to

53.3 mg g^{-1}). Glucose which is responsible for browning of kernel during roasting was similar in both with an average of 0.3 mg/g . Average myo-inositol content was slightly higher in Spanish genotypes (1.4 mg g^{-1}) as compared to Virginia genotypes (1.3 mg g^{-1}). Higher content of raffinose family oligosaccharides (RFOs) was observed in Virginia genotypes, which was 32.8 % higher than of Spanish genotypes. The RFOs were considered noxious components as they cause flatulence (Bryant et al. 2004). Analysis of various sugars

Fig. 2 Chromatogram of sugar standards separated in ion chromatograph equipped with CarboPac PA10 Guard column, Amino trap column and CarboPac PA10 analytical column using 150 mM NaOH, pH 12.8 as eluent with flow rate of 1 ml min^{-1}

showed that sucrose was the major sugar followed by stachyose and *myo*-inositol. Our results were in conformity with previous reports (Pattee et al. 2000; Bishi et al. 2013). Thus groundnuts were good source of *myo*-inositol and can provide 65 mg *myo*-inositol by adding 50 g groundnuts in diet. Given as a dietary supplements both *myo*- and *D-chiro*-inositol showed insulin-mimetic effects in women with polycystic ovary syndrome, a metabolic and endocrine disorder associated with insulin resistance (Reviewed by Croze and Soulage 2013). The information generated on sugar profiles of these two habit groups can be utilized for developments of confectionary purpose groundnuts.

Virginia genotypes had 31.6 % average protein content with a range of 22.6 to 34.8 %, which was slightly higher than that of Spanish genotypes (30.3 %). Variability for protein content was also higher in Virginia genotypes. Similarly, higher protein content was also reported in raw and roasted peanuts of the Virginia variety (Rosales-Martínez et al. 2014). It is observed that at higher protein contents, the oil content decreases. Sarvamangala et al. (2011) also suggested the existence of a negative correlation between protein and oil content while evaluating 146 recombinant inbred lines of groundnut.

Antioxidant activity and phenol content

Spanish genotypes possessed antioxidant activity ranged from 6.8 to 15.2 $\mu\text{M TEA g}^{-1}$ with an average of 10.0 $\mu\text{M TEA g}^{-1}$, while Virginia genotypes had 12.5 to 16.5 $\mu\text{M TEA g}^{-1}$ (average of 14.9 μM). Although, Virginia genotypes had higher antioxidant activity but variance was higher in Spanish genotypes. Similar to antioxidant activity, Virginia genotypes possessed higher phenol content which was more than two fold higher than that of Spanish genotypes. Similarly higher phenol content was observed in Virginia varieties than that of Spanish varieties (Rosales-Martínez et al. 2014) however, a slightly higher antioxidant activity was observed in Spanish (7.0 in $\mu\text{M TEA g}^{-1}$ kernel) as compared to Virginia (6.0 in $\mu\text{M TEA g}^{-1}$ kernel). Earlier we have reported higher antioxidant activity in 6 out of 7 Spanish genotypes (Bishi et al. 2015). In present investigation we also observed higher antioxidant activity than our earlier report (1.05–6.97). This may be due to extraction of antioxidant compound in the particular solvent system i.e. 80:20 methanol: water. Moreover, our results are also supported by higher phenol content in Virginia genotypes, which contributed to antioxidant activity. The antioxidant activity in peanut seed was attributed to vitamin E in oil or chlorogenic acid, caffeic acid, coumaric acid, ferulic acid, flavonoids and stilbene (resveratrol) in kernel (Yu et al. 2005).

Principal component (PCA) analysis of Spanish and Virginia genotypes

All quality parameters in groundnut genotypes were analysed for PCA to identify desirable traits and interrelationship among them.

Principal component analysis for Spanish genotypes

PC1 and PC2 scores were used to draw the GT-biplot. The proportion of total variation explained by the first five PC axes was about 82 % (Fig. 3). PCA loading for PC1 and PC2 indicated that the variations showed can be explained by all the observed traits. The maximum variations for PC1 were explained by sucrose, phenols and stachyose content whereas for PC2, the variations were explained by palmitic acid, stachyose, phenols and anti-oxidative capacity. Based on GT-biplot analysis, it was observed that oil content has positive association with traits such as stearic acid, myoinositol, raffinose, glucose, sucrose and stachyose. Further it was shown that the oil content has weak association with palmitic acid, phenols and anti-oxidative capacity, whereas a negative association was observed for protein content. A strong positive association was observed between oleic acid and O/L ratio, whereas both have shown a negative association with linoleic acid. The genotypes such as NRCG 10943 and NRCG 10665 were found to be superior for anti-oxidative capacity, phenols, sucrose and oil content, whereas NRCG 12731, NRCG10910 and NRCG12482 were identified for high O/L and oleic acid content.

Principal component analysis for Virginia genotypes

PC1 and PC2 scores were used to draw the GT-biplot. The proportion of total variation explained by the first four PC axes was about 76.2 % (Fig. 4). PCA loading for PC1 and PC2 indicated that the variations can be explained by all the observed traits except for palmitic acid and linoleic acid contents. The maximum variations for PC1 were explained by the contents of oil, O/L ratio, and oleic acid, whereas for PC2, the variations were explained by protein and sucrose content. Based on GT-biplot analysis, it was observed that glucose content has positive association with raffinose, and stachyose, and weak with sucrose. Protein content of the genotypes has negative association with oil and antioxidants, whereas stearic acid, oleic acid and O/L ratio have negative association with palmitic and linoleic acid contents. From the biplot analysis, NRCG 272, NRCG 9045, NRCG 12066 and NRCG 12107 were identified for low oil, and high protein and sucrose content; NRCG 12048 and NRCG 685 showed higher oil, antioxidants and phenols content; NRCG 10089, NRCG 12312

and NRCG 12806 with higher oleic acid content and O/L ratio, and NRCG 11751 was identified for lower content of flatulence contributing raffinose oligosaccharides. Niemenak et al. (2006) classified different cocoa clones according to

their polyphenol and anthocyanin contents using PCA and hierarchical cluster analysis. Nautiyal et al. (2012) also studied the interrelationship among the various physiological traits and Spanish groundnut cultivars.

Oleic acid, LA: Linoleic acid, O/L ratio: Oleic/Linoleic ratio, Ant: Antioxidant, Glu: Glucose, Suc: Sucrose, Raf: Raffinose Stac: Stachyose, Phe: Phenol, MyI: *Myo*-inositol and Pr: Protein

Conclusions

It can be concluded that Virginia groundnut is better in terms of high O/L ratio, sucrose, antioxidants, phenolics and protein content. Thus Virginia groundnut genotypes can be used in groundnut improvement programme for confectionary purpose and designer groundnut with less oil, high protein sucrose, myo-inositol, protein and high antioxidant activity. Information may also be useful for groundnut industries for selecting groundnut genotypes based on consumer preference.

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