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Oil Quality Characteristics and Headspace Volatiles of Newly Released Groundnut (*Arachis hypogaea* L) Cultivars*

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Abstract: Several groundnut (*Arachis hypogaea* L) cultivars developed by the International Crops Research Institute for the Semi-arid Tropics (ICRISAT), and one local cultivar for use as a control were grown in the post-rainy and rainy seasons at Patancheru, India. Free and bound lipids were extracted and their fatty acid compositions determined. Acid, peroxide, iodine and saponification values were determined. Flavour quality was evaluated using headspace analysis. The quantity of total lipids was significantly higher in the cultivars grown in the rainy season than those grown in the post-rainy season and was higher in the ICRISAT cultivars than in the control in both seasons. Oleic (O) to linoleic (L) acid ratio was lowest in the chloroform–methanol extract and highest in water-saturated butanol extract. One ICRISAT line, ICGS 21, showed the highest O/L ratio in all lipid fractions in both seasons. Among the flavour components, *n*-methyl pyrrole, associated with an objectionable musty flavour, was present in very high concentration in all the cultivars.

Key words: fatty acids, oleic acid, linoleic acid, bound lipids, acid value, peroxide value, iodine value, saponification value, headspace analysis, flavour profile.

INTRODUCTION

Groundnut (*Arachis hypogaea* L) is an important source of edible oil for millions of people living in the semi-arid tropical regions. Oil quality and its stability is therefore very important for the consumers. The fatty acid composition of groundnut oil is well documented (Treadwell *et al* 1983). The effects of variety, location, and their interaction on fatty acid composition have been investigated (Brown *et al* 1975; Mozingo and Steele 1982). Flavour quality is also important for the consumer acceptability of groundnut products. A simple rapid headspace analysis technique has been developed to screen groundnut for potential flavour defects (Young and Hovis 1990). In India, groundnut is grown both in the rainy (June–October) and in the post-rainy (October–April) seasons. The chemical composition and protein quality of selected groundnut cultivars developed by the International Crops Research Institute for the Semi-arid Tropics (ICRISAT) and grown in the rainy and post-rainy seasons have been reported (Jambunathan *et al* 1992). The purpose of this study was to investigate the oil quality characteristics and flavour quality of groundnut cultivars developed by ICRISAT and released for commercial cultivation in India. Results obtained on groundnut cultivars grown in the rainy and post-rainy seasons were compared with a local cultivar.

MATERIALS AND METHODS

Materials

Four released groundnut cultivars, ICGS 1 (ICGV

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87119), ICGS 5 (ICGV 87121), ICGS 11 (ICGV 87123), ICGS 44 (ICGV 87128), and a breeding line, ICGS 21 (ICGV 87124), were grown during the 1985–1986 post-rainy and 1988 rainy seasons at ICRISAT Centre, Patancheru, India. Another cultivar, Kadiri 3 (Robut 33-1), which has been cultivated in India for several years, was also grown as a control. After harvest, seed samples were stored at 4°C before analysing them for the composition of lipid fractions, fatty acid composition, and oil quality parameters. In both seasons, groundnut cultivars were grown on Alfisols with 60 kg P_2O_5 ha^{-1} as a basal fertiliser dose under irrigated conditions. During the 1985–1986 post-rainy season, the temperature ranged from 17·5 to 31·9°C with a mean of 24·7°C. Relative humidity ranged from 31·8 to 77·9% with a mean of 54·9%, and there were 140 mm of rainfall. During the 1988 rainy season, the temperature ranged from 21·8 to 29·7°C with a mean of 25·8°C. Relative humidity ranged from 63·6 to 91·8% with a mean of 77·6%, and there were 778 mm of rainfall.

To evaluate the flavour quality, seven groundnut cultivars, ICGS 1, ICGS 5, ICGS 11, ICGS 37 (ICGV 87187), ICGS 44, ICGS 76 (ICGV 87141), and ICG (FDRS) 10 (ICGV 87160), were grown during the 1990 rainy season. The groundnut cultivars were grown on Alfisols with 60 kg P_2O_5 ha^{-1} as a basal fertiliser dose under irrigated conditions. During this season, the temperature ranged from 21·6 to 29·6°C with a mean of 25·6°C. Relative humidity ranged from 63·7 to 92·1% with a mean of 77·9%, and there were 577 mm of rainfall. After harvest, seed samples were stored at 4°C before analysis.

METHODS

Free and bound lipids

Whole groundnut kernels (35 g) were ground in a Krups blender (Robert Krups, Solingen, Germany) for 30 s. Free lipids from the meal were extracted overnight with *n*-hexane in a Soxhlet apparatus. Most of the hexane was evaporated on a hot sand bath in a fume hood and the residual hexane was evaporated at 105°C in a forced draught oven for 30 min. The oil percentage, denoted as hexane (first extract), was calculated (AOCS 1980). The remaining groundnut meal after the first hexane extraction was air-dried and ground to a homogeneous sample in a mortar with a pestle. Oil was re-extracted from this sample using *n*-hexane as described above and the extracted oil percentage, denoted as hexane (second extract), was calculated. This fraction probably represents bound lipids though it was extracted by hexane. Bound lipids were extracted according to Chowdhury and Juliano (1980) with the following modifications. The residue was air-dried, processed as described above, and extracted with chloroform–methanol (2:1 v) in a rotary shaker for 8 h at 25°C. The chloroform–methanol extract was evaporated to determine the extracted bound lipids. The remaining residue was further extracted with water-saturated butanol in a rotary shaker for 24 h at 25°C. The quantity of bound lipids extracted by this solvent was calculated by evaporating the solvent. The fatty acid methyl esters of different lipid fractions were prepared according to Metcalfe *et al* (1966).

Oil quality parameters

Oil quality characteristics such as acid value, iodine value, saponification value, and peroxide value were determined on hexane-extracted oil following the standard procedures (AOCS 1980). Analyses were carried out on cultivars obtained only from the 1988 rainy season.

Fatty acid composition

The fatty acid composition was determined on each of the lipid fractions according to Mercer *et al* (1990) with the following modifications. A Shimadzu GC-9A model gas chromatograph (Shimadzu Corporation, Tokyo, Japan) fitted with a flame ionisation detector and a glass column (2·1 m × 3 mm id) packed with Altech CS-10 W-AW (80–100 mesh) (Altech Associates Inc, USA) was used. The carrier gas helium was maintained at a flow rate of 50 ml min^{-1}. The injector port and the detector port were maintained at 260°C. The column temperature was held at 190°C for 4 min initially, and programmed to increase from 190 to 250°C at 10°C min^{-1} and held at 250°C for 2 min. Peak areas were quantified using a mixture of reference fatty acid methyl esters (Nuchek 21A, Nuchek Prep Inc, USA) as the standard.

Headspace volatiles composition

Flavour quality of the raw groundnuts was evaluated according to Young and Hovis (1990) with the following modifications. A gas chromatograph, Shimadzu GC-9A, fitted with a flame ionisation detector and a glass column (1 m × 2 mm id) packed with Porapak P (80–100 mesh) (Altech Associates Inc, USA) was used. Flow of the carrier gas helium was adjusted to about 65 ml min^{-1} so that hexanal eluted at 5·00 ± 0·03 min. The column temperature was programmed to increase from 105 to 225°C at 15°C min^{-1} and held at 225°C for 0·5 min. The injector and detector temperatures were maintained at 240°C. Threshold values for the reference standards, acetone, 2-methyl propanal and *N*-methyl pyrrole, corresponding to musty after-taste, fruity, and musty flavour, were measured as peak areas. The peaks were identified using the reference standards. The areas of peaks obtained using a Shimadzu CR-3A integrator were reported after dividing them by 10^4.

TABLE 1
Free and bound lipids composition of groundnut cultivars grown in rainy and post-rainy seasons, ICRISAT Centre[a]

Cultivar	*Season*[b]	*Hexane (first extract)* ($g\ kg^{-1}$)	*Hexane (second extract)* ($g\ kg^{-1}$)	*Chloroform–methanol extract* ($g\ kg^{-1}$)	*Water-saturated butanol extract* ($g\ kg^{-1}$)	*Total lipids* ($g\ kg^{-1}$)
ICGS 1	PR	473·3	2·1	16·3	28·5	520·2
	R	492·7	4·4	15·8	16·6	529·7
ICGS 5	PR	469·5	1·8	15·2	29·0	515·5
	R	493·1	4·0	17·7	17·4	532·2
ICGS 11	PR	468·6	1·5	15·3	28·3	513·7
	R	488·8	4·3	16·9	17·6	527·6
ICGS 21	PR	500·0	2·8	15·9	28·0	546·7
	R	507·4	3·2	17·4	19·2	547·2
ICGS 44	PR	480·8	1·6	14·0	20·7	517·1
	R	494·5	4·0	17·6	18·6	534·7
Control,	PR	449·7	1·9	17·8	22·1	491·5
Kadiri 3	R	480·2	3·3	20·0	18·9	522·4
SE±	PR	6·74	0·19	0·52	1·50	7·20
	R	3·61	0·21	0·56	0·41	3·44

[a] Means of three determinations. [b] PR—post-rainy season 1985–1986; R—rainy season 1988.

Statistical calculations using the Duncan's multiple range test (SAS 1985) were carried out on data obtained from triplicate determinations of each of the oil quality parameters that have been reported.

RESULTS AND DISCUSSION

Total lipids content

The proportion of different lipids extracted from groundnut kernels by sequential extraction using the solvents hexane (first extract), hexane (second extract), chloroform–methanol, and water-saturated butanol is given in Table 1. A large proportion of lipids ranging from 449·7 to 507·4 g kg^{-1} was extracted by the first hexane extract. However, a very small proportion varying from 1·5 to 4·4 g kg^{-1} of lipid from the sample was not extracted by this procedure even though the extraction was carried out for about 18 h. This fraction became soluble in hexane only on re-extracting the ground residue obtained after the first extraction. The percentage of lipid fraction extracted by chloroform–methanol was less than 20·0 g kg^{-1} while water-saturated butanol extracted between 16·6 and 29·0 g kg^{-1}. Hexane extracts free lipids consisting primarily of neutral glycerides while polar solvents like chloroform–methanol and water-saturated butanol extract bound lipids consisting of phospholipids, glycolipids, and other complex lipids (St Angelo and Ory 1975).

The proportion of lipid in the first hexane extract was significantly ($P < 0·01$) higher in the cultivars grown in the rainy season than in the post-rainy season. It was significantly ($P < 0·01$) higher in ICRISAT cultivars than in the control in both the seasons. Among the cultivars, ICGS 21 contained a significantly ($P < 0·01$) higher proportion of free lipids content in both the seasons. The percentage of lipids in the second hexane and chloroform–methanol extract was higher in the rainy than in the post-rainy season. The percentage of lipids in water-saturated butanol extract was significantly ($P < 0·01$) higher in the post-rainy season than in the rainy season.

Oil quality parameters

The oil quality characteristics of the groundnut cultivars grown during the 1988 rainy season are shown in Table 2. Acid, iodine, and peroxide values of oil influence the oxidative stability of oil. The acid value representing free fatty acids content in the six cultivars ranged from 0·10 to 0·15 and was well below the maximum acceptable value (4 mg KOH g^{-1} oil) recommended by Codex Alimentarius Commission (1969). The iodine value indicating the degree of unsaturation ranged from 91·4 to 98·9. The saponification value, which is related inversely to the molecular weight, ranged from 172·5 to 183·9 and was below the recommended value. The peroxide value (meq kg^{-1}), which is a measure of products of lipids oxidation, ranged from 6·1 (Kadiri 3) to 9·4 (ICGS 44) and was below the maximum acceptable level of

TABLE 2
Oil quality parameters of groundnut cultivars grown in rainy season 1988, ICRISAT Centre[a]

Cultivar	*Acid value*	*Peroxide value*	*Iodine value*	*Saponification value*
ICGS 1	0·10	7·9	96·8	182·8
ICGS 5	0·15	6·6	97·5	183·9
ICGS 11	0·11	6·5	95·5	175·4
ICGS 21	0·14	7·3	93·2	180·9
ICGS 44	0·15	9·4	98·9	183·4
Control, Kadiri 3	0·14	6·1	91·4	172·5
SE±	0·009	0·49	1·15	1·94
Recommended value[b]	4·0	10	80–106	187–196

[a] Means of three determinations.
[b] Codex Alimentarius Commission (1969).

TABLE 3
Fatty acid composition of hexane (first) extract of groundnut cultivars grown in rainy and post-rainy seasons, ICRISAT Centre[a]

Cultivars	*Season*[b]	*Fatty acids (g kg^{-1})*								*O/L ratio*
		Palmitic	*Stearic*	*Oleic*	*Linoleic*	*Arachidic*	*Eicosenoic*	*Behenic*	*Lignoceric*	
ICGS 1	PR	122·0	23·2	369·1	407·3	14·2	14·1	32·0	18·1	0·91
	R	129·4	22·3	376·3	393·2	14·2	14·0	32·4	18·1	0·96
ICGS 5	PR	120·2	21·1	375·2	408·1	13·0	14·1	31·2	17·1	0·92
	R	126·1	22·0	376·3	396·2	14·1	14·0	33·2	18·1	0·95
ICGS 11	PR	122·3	23·0	370·2	408·2	14·1	14·0	30·2	18·0	0·91
	R	126·0	21·1	376·4	398·2	14·0	14·2	32·1	18·0	0·95
ICGS 21	PR	114·2	28·0	433·3	353·1	14·2	13·0	29·2	15·0	1·23
	R	116·1	27·1	452·3	335·2	14·1	13·1	29·0	13·1	1·35
ICGS 44	PR	120·2	27·0	390·8	386·1	15·0	13·9	30·2	16·8	1·01
	R	126·1	22·2	378·1	394·0	14·2	14·1	33·2	18·1	0·96
Control,	PR	122·3	29·0	392·2	381·3	15·0	14·1	28·0	18·1	1·03
Kadiri 3	R	133·0	23·2	375·2	391·2	14·1	14·1	32·2	17·0	0·96
SE±	PR	1·27	1·31	9·86	8·96	0·30	0·18	0·58	0·49	0·050
	R	2·30	0·87	12·65	9·95	0·03	0·17	0·63	0·81	0·064

[a] Means of three determinations.
[b] PR—post-rainy season 1985–1986; R—rainy season 1988.

10 meq kg^{-1} for raw groundnut oil (Narasimhan *et al* 1986). Groundnut cultivars varied in their tendency to develop oxidative rancidity as shown by the peroxide values. In comparison with ICRISAT cultivars, the control groundnut cultivar, Kadiri 3, showed lower peroxide, iodine, and saponification values.

Fatty acid composition of lipid fractions

Hexane (first) extract
The fatty acid composition of hexane-extracted lipid is given in Table 3. A high percentage of oleic (O) acid, low percentage of linoleic (L) acid, high O/L ratio, and low iodine value are desirable for better oil stability or longer shelf-life of the groundnut product (Mozingo *et al* 1988). ICGS 21 showed the highest oleic acid and lowest linoleic acid values among the six cultivars. ICGS 21 showed O/L ratios of 1·23 during the post-rainy and 1·35 during the rainy season which were significantly ($P < 0·01$) higher than the others. The O/L ratios of other ICRISAT cultivars were either similar to or slightly lower than that of the control. Results from these analyses indicate that there is a need to screen and identify other agronomically superior cultivars having improved O/L ratios. Kadiri 3 showed an O/L ratio of 1·03 during the post-rainy and 0·96 during the rainy

TABLE 4

Fatty acid composition of hexane (second) extract of groundnut cultivars grown in rainy and post-rainy seasons, ICRISAT Centre[a]

Cultivar	*Season*[b]	*Fatty acids* ($g\ kg^{-1}$)													*O/L ratio*
		Caprylic	*Capric*	*Lauric*	*Myristic*	*Myristoleic*	*Palmitic*	*Stearic*	*Oleic*	*Linoleic*	*Arachidic*	*Eicosenoic*	*Behenic*	*Lignoceric*	
ICGS 1	PR	69·2	66·0	25·0	308·2	36·0	99·1	27·0	156·3	176·2	7·0	6·0	14·0	10·0	0·89
	R	9·0	26·9	43·1	38·0	43·0	163·8	27·1	255·9	280·0	21·0	35·1	43·1	14·0	0·91
ICGS 5	PR	72·4	69·3	28·9	267·8	42·8	96·7	29·9	172·4	179·5	9·5	6·4	13·2	11·7	0·96
	R	10·0	25·9	38·1	33·3	32·7	152·1	23·0	258·2	307·6	23·0	32·1	44·0	20·0	0·84
ICGS 11	PR	54·1	54·0	22·9	253·3	40·0	94·7	32·1	198·0	208·9	9·0	9·1	12·9	11·0	0·95
	R	11·0	28·8	45·2	38·1	28·0	142·9	26·0	296·0	294·0	19·1	24·9	31·0	15·0	1·01
ICGS 21	PR	45·5	54·1	19·0	206·7	21·0	99·4	36·1	259·0	210·4	9·1	7·8	19·8	12·1	1·23
	R	12·4	32·3	53·2	43·1	33·1	146·0	28·1	294·4	266·2	15·0	25·1	29·0	20·1	1·10
ICGS 44	PR	73·2	87·5	31·1	246·1	45·2	98·4	31·8	171·0	170·9	9·5	7·0	15·1	13·2	1·00
	R	10·1	45·9	70·2	69·1	38·0	171·7	30·0	204·0	252·9	20·1	34·0	43·2	10·8	0·81
Control,	PR	74·1	87·0	30·1	297·2	56·2	84·0	32·1	153·6	146·5	8·1	6·0	14·1	10·0	1·05
Kadiri 3	R	13·1	39·1	55·3	48·4	28·0	138·5	28·1	214·0	250·2	27·0	37·0	93·2	28·1	0·86
SE±	PR	4·90	6·11	1·92	15·04	4·74	2·39	1·22	16·13	9·92	0·40	0·50	1·04	0·51	0·048
	R	0·63	3·21	4·67	5·26	2·34	5·25	0·97	15·83	9·36	1·64	2·11	9·58	2·50	0·042

[a] Means of three determinations.
[b] PR—post-rainy season 1985–1986; R—rainy season 1988.

seasons. The mean O/L ratios and the mean oleic acid contents of six cultivars were similar in the post-rainy and rainy seasons.

Hexane (second) extract

The fatty acid composition of the lipid fraction obtained on second extract of hexane is given in Table 4. Interestingly, this fraction contained considerable amounts of caprylic, capric, lauric, myristic and myristoleic acids. An earlier report by Iverson *et al* (1963) also indicated the presence of trace amounts of these fatty acids. Considerable variation was noticed in the concentration of these medium chain fatty acids during the rainy and post-rainy seasons. Caprylic, capric, and myristic acids were significantly ($P < 0·01$) higher in the post-rainy season compared with those in the rainy season and the high concentration of myristic acid in the post-rainy season is noteworthy. It must be emphasised that this hexane-extractable fraction constitutes only 0·2–0·4 % of groundnut. The authors have no explanation as to why these fatty acids were not initially extracted with the hexane. A stronger interaction between starch–lipid or protein–lipid components could have possibly been ruptured on regrinding the residue. Higher concentrations of medium chain fatty acids in groundnut than the present distribution may be desirable as these are reported to be absorbed better (Babayan 1981). In the hexane (second) extract the mean O/L ratios did not vary significantly between the rainy and post-rainy seasons. However, ICGS 21 showed a higher O/L ratio than the control and other ICRISAT cultivars.

Chloroform–methanol extract

The fatty acid composition of the chloroform–methanol extract showed a much higher concentration of palmitic acid (range 221·1–256·2 g kg^{-1}) than those exhibited (range 114·2–133·0 g kg^{-1}) in the hexane (first) extract (Table 5). Arachidic acid was present in a negligible amount while behenic acid was in a much lower concentration than the hexane (first) extract. Arachidic, behenic and lignoceric acids have been implicated in the elevated atherogenic effect of groundnut oil (Kritchevsky *et al* 1971). Therefore, it would be desirable to investigate the fatty acid composition of bound lipids to understand the overall implications of groundnut lipids on nutritional quality. Linoleic acid was significantly ($P < 0·01$) higher in the post-rainy season than in the rainy season. The mean O/L ratios of cultivars grown in the rainy season were significantly ($P < 0·01$) higher than in the cultivars grown in the post-rainy season. ICGS 1 had the lowest amount of oleic acid and highest amount of linoleic acid during the post-rainy season and ICGS 21 had the highest amount of oleic acid and lowest amount of linoleic acid during the rainy season. The high values of SE for oleic and linoleic acids reflect the wide range in the concentration of these acids in the six cultivars.

Water-saturated butanol extract

The fatty acid composition of the water-saturated butanol extract showed the presence of a higher concentration of lauric acid in the post-rainy season (Table 6). Among the three major lipid extracts, water-saturated butanol had the lowest concentration of linoleic acid in both seasons. Significant amounts of palmitic acid were present in the water-saturated butanol extracts belonging to the rainy season. ICGS 21 had the highest amount of oleic acid and lowest amount of linoleic acid during the rainy season and the high SE

TABLE 5
Fatty acid composition of chloroform–methanol extract of groundnut cultivars grown in rainy and post-rainy seasons, ICRISAT Centre[a]

Cultivar	Season[b]	Fatty acids (g kg^{-1})											O/L ratio
		Lauric	Myristic	Myristoleic	Palmitic	Stearic	Oleic	Linoleic	Arachidic	Eicosenoic	Behenic	Lignoceric	
ICGS 1	PR	ND[c]	1·1	3·0	245·0	37·1	300·6	385·2	0·3	4·0	6·6	17·0	0·78
	R	1·3	1·1	0·4	246·0	31·0	320·1	372·1	ND	4·2	6·3	17·1	0·86
ICGS 5	PR	ND	1·0	3·1	240·0	31·0	334·0	367·0	0·3	3·5	5·5	14·5	0·91
	R	ND	1·0	4·1	249·7	31·0	321·1	360·9	1·0	4·2	6·9	19·9	0·89
ICGS 11	PR	ND	1·1	2·0	245·1	34·9	320·2	372·1	0·4	4·1	6·1	13·8	0·86
	R	1·1	2·0	1·1	251·8	32·0	316·1	361·1	1·1	4·7	7·1	21·9	0·88
ICGS 21	PR	ND	1·0	3·1	229·2	36·0	370·0	336·0	0·3	4·1	6·0	14·2	1·10
	R	1·0	1·0	1·1	221·1	36·8	444·1	268·1	2·0	4·8	6·1	13·9	1·66
ICGS 44	PR	ND	1·1	1·9	235·8	34·0	333·8	371·0	0·3	4·1	6·1	11·8	0·90
	R	1·1	2·0	1·9	256·2	32·1	319·1	347·1	2·0	5·1	7·3	25·9	0·92
Control, Kadiri 3	PR	ND	2·2	2·0	249·7	32·0	340·1	355·9	0·2	2·9	4·8	10·0	0·96
	R	1·3	7·8	3·8	253·0	33·6	343·4	318·9	2·6	5·1	8·9	21·6	1·08
SE±	PR	NA[d]	0·19	0·25	3·03	0·95	9·37	6·89	0·03	0·20	0·25	0·98	0·048
	R	0·06	1·08	0·63	5·22	0·90	20·42	15·87	0·33	0·17	0·41	1·70	0·127

[a] Means of three determinations.
[b] PR—post-rainy season 1985–1986; R—rainy season 1988.
[c] ND—not detected.
[d] NA—not applicable.

TABLE 6
Fatty acid composition of water-saturated butanol extract of groundnut cultivars grown in rainy and post-rainy seasons, ICRISAT Centre[a]

Cultivar	Season[b]	Fatty acids (g kg^{-1})										O/L ratio
		Capric	Lauric	Myristic	Myristoleic	Palmitic	Stearic	Oleic	Linoleic	Behenic	Lignoceric	
ICGS 1	PR	ND[c]	19·0	10·6	ND	241·2	52·6	331·3	318·8	14·1	12·1	1·04
	R	6·0	6·1	7·1	11·2	247·2	44·1	322·2	330·0	11·1	15·0	0·98
ICGS 5	PR	ND	15·4	9·4	14·1	228·2	55·2	355·3	301·1	12·1	9·0	1·18
	R	7·2	4·1	12·3	11·1	254·4	44·1	313·3	329·2	9·0	15·3	0·95
ICGS 11	PR	ND	9·6	8·1	11·3	229·4	51·2	344·1	321·0	12·1	13·1	1·07
	R	8·1	6·0	10·0	ND	261·7	49·1	317·0	322·2	9·8	16·0	0·98
ICGS 21	PR	ND	25·4	7·1	6·2	211·3	50·4	403·1	273·3	12·0	11·1	1·48
	R	7·2	4·1	11·3	12·1	223·4	56·1	428·4	236·2	10·1	11·1	1·81
ICGS 44	PR	ND	ND	12·8	8·0	224·2	46·8	357·1	328·0	10·9	12·0	1·09
	R	6·1	4·2	9·1	8·1	266·3	47·1	315·3	311·4	10·1	22·3	1·01
Control, Kadiri 3	PR	ND	30·9	8·7	6·9	225·6	53·2	337·4	306·4	18·9	11·8	1·10
	R	1·4	12·9	13·8	ND	264·2	54·8	338·7	287·4	11·7	14·9	1·18
SE±	PR	NA[d]	4·51	0·83	1·94	3·93	1·17	10·50	8·04	1·19	0·57	0·066
	R	0·97	1·39	0·97	2·28	6·56	2·12	18·24	14·73	0·39	1·48	0·135

[a] Means of three determinations.
[b] PR—post-rainy season 1985–1986; R—rainy season 1988.
[c] ND—not detected.
[d] NA—not applicable.

values reflect the wide range in the concentration of these acids. The mean O/L ratios between the rainy and post-rainy seasons were similar and ICGS 21 showed a higher O/L ratio than the control during both the seasons.

The chloroform–methanol extract exhibited the lowest O/L ratio for all the cultivars while the water-saturated butanol extract exhibited the highest O/L ratios for all the cultivars. When O/L ratios of lipid fractions are compared, ICGS 21 exhibited the highest O/L ratio and was significantly ($P < 0·01$) higher than

TABLE 7

Concentrations of headspace volatile components of groundnut cultivars grown in 1990 rainy season, ICRISAT Centre[a]

Cultivar	*Methanethiol*	*Acetone pentane dimethyl sulphide*	*2-Methyl propanal*	*2-Butanone*	*2-Methyl and 3-methyl butanal*	*Pentanal*	N-*methyl pyrrole*	*Hexanal*
ICGS 1	22·3	67·1	63·0	7·5	62·3	20·6	113·4	13·1
ICGS 5	23·6	66·1	69·2	7·9	82·0	17·3	82·8	10·6
ICGS 11	21·3	51·9	56·7	6·9	68·5	15·4	83·7	9·5
ICGS 37	21·3	55·1	54·3	6·3	57·6	15·7	92·6	10·0
ICGS 44	21·6	76·9	44·5	7·5	51·9	17·6	79·0	11·3
ICGS 76	25·1	48·4	72·7	6·6	90·9	12·2	98·7	8·2
ICG (FDRS) 10	26·5	59·5	45·8	6·4	86·2	17·7	153·7	10·7
SE±	0·77	3·76	4·13	0·25	5·72	0·98	9·90	0·57

[a] Means of three determinations, expressed as peak area values divided by 10^4.

all the cultivars in each of the lipid fractions in both the 1985–1986 post-rainy and 1988 rainy seasons. The variations in the oleic acid content in the three major lipid fractions across the six genotypes were not significant in both seasons while linoleic acid content varied significantly in all the lipid fractions except in the water-saturated butanol extract.

Headspace volatiles composition

The headspace volatiles responsible for abusive drying (methanethiol), musty after-taste (acetone, pentane, and dimethyl sulphide), fruity (2-methyl propanal), degree of roast (2-butanone), ageing (2-methyl butanal and 3-methyl butanal), tongue or throat burn (pentanal), musty (*n*-methyl pyrrole) and beany (hexanal) flavours were determined according to Young and Hovis (1990) (Table 7). The musty after-taste, fruity, and musty flavours were identified as the major headspace volatile components in raw groundnuts and their threshold levels were reported by Young and Hovis (1990). In the present investigation the peak area for the musty after-taste ranged from 48·4 (ICGS 76) to 76·9 (ICGS 44) whereas its recommended threshold value is 75·1. The peak area for fruity flavour ranged from 44·5 (ICGS 44) to 72·7 (ICGS 76) and the recommended threshold value is 46·6. The peak area for musty flavour ranged from 79·0 (ICGS 44) to 153·7 (ICG (FDRS) 10) whereas its recommended threshold value is 36·2. Therefore, among the three flavour compounds, the compound associated with musty flavour (*n*-methyl pyrrole) was present in much higher concentration in these groundnut cultivars. The sum of peak areas responsible for the musty after-taste, fruity, and musty flavours was higher in ICGS 1 and ICG (FDRS) 10 as compared with other cultivars. However, in view of the higher concentration of defective flavour components in these groundnut cultivars, there is a need to screen more groundnut cultivars to ascertain the level of these components.

CONCLUSIONS

The quantity of oil extracted from groundnut kernels using traditional expellers in rural parts of India is less than those obtained using solvents such as hexane, which is commonly used in solvent extraction plants. The results in this paper show that even after extraction with hexane, about 4–5% of lipids remain unextracted in the cake. This information is important while calculating nutritional and calorific implications of groundnut as predictions are usually made based on consumption pattern. For this, the data obtained on the hexane-extracted oil fraction are used and these do not reflect the total lipids contents as reported here. To the authors' knowledge, there are no available reports on flavour profile of groundnut cultivars grown in India. Therefore, further confirmation will be required to understand the variety, location, and other influences on flavour components of groundnut.

Among the six groundnut cultivars, ICGS 21 maintained a higher O/L ratio in all the different lipids fractions in the post-rainy and rainy seasons. It is interesting that ICGS 21 exhibited the highest 100-seed mass and oil content in both 1985–1986 post-rainy and 1988 rainy seasons (Jambunathan *et al* 1992). It also showed the highest values for true digestibility, biological value, net protein utilisation and utilisable protein among all the groundnut cultivars of 1985–1986 post-rainy season. Significant differences were observed in the fatty acid profiles of free and bound lipid fractions of the groundnut cultivars. It may therefore be necessary to evaluate the bound lipid fractions also to obtain a clearer picture of lipid quantity and quality of groundnut cultivars. The flavour profile showed that there is a need

to improve the flavour quality in these groundnut cultivars.

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