ELSEVIER

Food Chemistry 53 (1995) 7–14
Elsevier Science Limited
Printed in Great Britain
0308-8146/95/$9.50

Fatty acid composition of Caribbean-grown peanuts (*Arachis hypogaea* L.) at three maturity stages

Margaret J. Hinds*

Department of Food Science, Alabama A & M University, Normal, Alabama, USA and Department of Chemical Engineering, The University of the West Indies, St Augustine, Trinidad

(Received 9 June 1994; accepted 1 August 1994)

Fatty acid contents of peanut seeds (cultivar NC2) at three stages of maturity harvested between 1985 and 1987 from two soil types in St Vincent, Eastern Caribbean, were determined by gas–liquid chromatography. Oil from mature NC2 seeds grown in St Vincent contained more oleic and less linoleic acid than oil from mature NC2 seeds grown in North Carolina and Jamaica. With respect to soil types in St Vincent, seeds grown on volcanic clay loam contained more stearic, long-chain and total saturated fatty acids but less linoleic and total unsaturated acids than samples from volcanic sandy loam. As seeds progressed from intermediate through nearly-mature to mature stages, palmitic and linoleic acids (%) decreased while oleic acid increased. Also, irrespective of soil type and year, oleic acid (%) in the oil of mature seeds was 57·4 ± 0·77, suggesting that this value may be a useful index of seed maturity for the NC2 peanut cultivar grown in St Vincent.

INTRODUCTION

The quality and flavor of edible peanuts and peanut products can be affected by the fatty acid composition of the lipid. The eight major fatty acids in peanuts are palmitic (hexadecanoic, 16:0), stearic (octadecanoic, 18:0), oleic (*cis*-9-octadecenoic, 18:1), linoleic (*cis*-9-, *cis* 12-octadecadienoic, 18:2), arachidic (eicosanoic, 20:0), eicosenoic (*cis*-11-eicosenoic, 20:1), behenic (docosanoic, 22:0) and lignoceric (tetracosanoic, 24:0) acids. Palmitic, stearic, oleic and linoleic acids make up about 96% of peanut triacylglycerols (Ahmed & Young, 1982).

Fatty acid composition of peanut seeds from various maturity classes and varieties grown worldwide have been extensively studied (Worthington, 1969; Worthington & Hammons, 1971; Young *et al.*, 1972; Cobb & Johnson, 1973; Sanders *et al.*, 1982; Court *et al.*, 1984; Mozingo *et al.*, 1985, 1988*a*,*b*; Knauft *et al.*, 1986; Raheja *et al.*, 1987; Lynd & Ansman, 1989; Wallerstein *et al.*, 1989; Branch *et al.*, 1990; Kim & Hung, 1991; Hashim *et al.*, 1993; Grosso *et al.*, 1994). Conflicting trends have been observed for changes in fatty acid profiles as seeds mature. Increase in oleic and decreases in palmitic, linoleic, arachidic, eicosenoic, behenic and lignoceric acids with seed maturity have been observed (Worthington, 1969; Young *et al.*, 1972; Cobb & Johnson, 1973; Sanders *et al.*, 1982), whereas decrease in oleic and increase in linoleic acids have been reported (Lynd & Ansman, 1989; Hashim *et al.*, 1993). In two reports (Mozingo *et al.*, 1985, 1988*a*), stearic, oleic and arachidic increased while the other fatty acids decreased. Kim and Hung (1991) noted increase in stearic and oleic acids and no change in palmitic acid, whereas Knauft *et al.* (1986) observed no changes in fatty acid composition of seeds due to maturity. Strong negative correlation between oleic and linoleic acids have been reported (Worthington & Hammons, 1971; Raheja *et al.*, 1987; Wallerstein *et al.*, 1989; Branch *et al.*, 1990; Mercer *et al.*, 1990; Dwivedi *et al.*, 1993*a*, 1993*b*). However, differences in climatic conditions resulted in variations in the oleic/linoleic acid ratio for a given genotype.

The peanut has been identified as a suitable crop for the small farm systems of the Caribbean. During 1985 to 1989, peanuts produced by CARICOM countries totalled 4000–5000 metric tonnes/year (CARDI, 1985; FAO, 1986, 1990). The NC2 cultivar has been grown extensively in CARICOM countries since 1982 (CARDI, 1983, 1985; Singh, 1985, 1989; Anon., 1986; Miller, 1988; Chinnan, 1989, 1990, 1993). However, the seed composition of this variety in a tropical insular environment has not been fully investigated. Miller (1988) reported briefly on the fatty acid composition of mature NC2 seeds harvested in Jamaica in 1985. St Vincent is one of the main peanut-growing islands in the Eastern Caribbean, and it differs from Jamaica by being volcanic in origin and exposed to higher temperatures.

*Present address: Human Environment & Family Science Dept., North Carolina A&T State University, 102 Benbow Hall, Greensboro NC 27411, USA.

There are approximately 350 peanut farmers in St. Vincent and total annual peanut production is 500-800 metric tonnes (St Vincent Marketing Corporation, 1985–1991). Hinds and Singh (1994) observed the oleic acid content of composite seed samples (the collection of seeds at various maturity stages harvested on a given day) of the NC2 cultivar grown in St Vincent. At optimum harvest dates, oleic acid (%) in oil of the composite seed samples peaked significantly (P = 0·05) at a value of 55·8 ± 0·59.

Arising from the indeterminate fruiting habit of the peanut and lack of reliable objective maturity indices for Caribbean-grown peanuts, there has been a high incidence of immature pods among peanuts marketed in the Caribbean (Singh, 1985). Knowledge about the fatty acid profile of the seeds at various maturity stages could assist in establishing criteria for the quality of marketed pods. This study focused on determining the fatty acid composition of seeds at three maturity stages of the NC2 cultivar grown in St Vincent.

MATERIALS AND METHODS

Collection and preparation of samples

Peanuts (cultivar NC2) were collected during a 3-year period (1985–1987) from two farms with different soil types — volcanic clay (VC) and volcanic sandy (VS) — on which peanuts are commonly grown in St Vincent. The distribution profile of the components of these soil types from their surfaces to 0·9-m depths have been established (ICTA, 1958). The proportions of very coarse (2·0–1·0 mm), medium (1·0–0·2 mm) and fine (0·2–0·02 mm) sands are 1–0%, 30–21% and 21–11%, respectively, for the VC soil and 2–1%, 39–38% and 20–19%, respectively, for the VS soil (ICTA, 1958). For this study, the farms were prepared, planted and maintained by peanut farmers using standard cultural practices (Hinds *et al.*, 1992). On each farm, plots were laid out in a randomized complete block design. Pods were harvested manually from one growing season per year at intervals of 3, 4 or 7 days between 99 and 141 days after planting (DAP). On each sampling day, three replicates of 100 plants each from three different plots on the farm were harvested. All pods were collected to obtain composite samples. The latter were cleaned with tap water and blotted dry with paper towels.

Each composite sample of (green) pods was thoroughly mixed and subdivided. One subdivision was categorized into intermediate, nearly-mature, mature and over-mature stages based on their external features (Hinds *et al.*, 1992). The three maturity stages of pods discussed in this study are intermediate, nearly-mature and mature, because they comprise the mixture of pods marketed in St Vincent. The external features of the pods at these maturity stages were as follows: thick and soft shell with non-defined external lines (intermediate); firm shell with reticulations on the majority of the external surface, except for near the beak where the shell was either smooth or slightly soft (nearly-mature); and very firm shell with reticulations clearly defined all over its external surface (mature). For a given maturity stage, pods harvested on different days from the same year (growing season) and soil type were combined, thus making a total of 18 treatments (maturity stages). Pods were neither cured nor dried but were stored at –10°C immediately after being grouped into maturity stages.

Preparation and gas chromatographic analysis of fatty acid methyl esters

Fatty acid analyses were carried out during 1988 and 1989. Frozen pods were shelled and deskinned manually. Each treatment of chilled seeds obtained was ground separately into a paste, which was stored at –10°C for 1–6 months. The paste was partially thawed at 10°C one day prior to analysis. The fatty acid methyl esters (FAME) were prepared, separated, identified and quantified using essentially the procedures of Quality methods QM-8, QM-18 and QM-25 (APRES, 1983). Total lipid was extracted by blending 75 g of paste from each treatment with chloroform/ methanol (2 : 1, v/v). Subsamples of lipid, obtained by evaporating the extract under nitrogen, were esterified with 14% boron–trifluoride–methanol/toluene/methanol 5 : 4 : 11, v/v/v) using 25 ml of solution per 300 mg of lipid. Replicates of 0·1 μl of the final ester solutions were injected into a Varian Model 3700 gas chromatograph with flame ionization detector attached to a Perkin Elmer 7500 data station with Perkin Elmer 7500 printer plotter. A coiled glass column (1·82 m by 2 mm i.d.) packed with 10% SP-2330 on 80/100 mesh Chromosorb W AW (Supelco Inc., Bellefonte, PA, USA) was used. The injector and detector temperatures were 250 and 350°C, respectively. The oven temperature was maintained at 200°C for 4 min, then increased at the rate of 7°C/min to a maximum temperature of 242°C. The gas flow rates per minute were 20, 30 and 300 ml for nitrogen (carrier gas), hydrogen and air, respectively. The FAME were identified by their retention times relative to the composite peanut standard 21A (Nu Chek-Prep, Elysian, MN, USA). Weights (%) of the eight FAME present in standard 21A were reported by the manufacturer. Standard 21A (0·1 μl) was injected after every nine experimental samples, and areas under the eight peaks (from standard 21A) corresponding to the eight FAME were calculated and computed as weight (%) by the Perkin Elmer data station. Ratios of the reported standard values to the observed values for the eight FAME in standard 21A were calculated. When a ratio of one was not obtained, the number obtained was used as a correction factor. Corrected values for weights (%) of experimental FAME were obtained by multiplying the observed experimental FAME values by the appropriate correction factors (APRES, 1983). Iodine values (IV) were calculated from the formula of Cocks and Van Rede (1966):

$$IV = (0{\cdot}8601 \times \% \text{ oleic}) + (1{\cdot}7321 \times \% \text{ linoleic}) + (0{\cdot}7854 \times \% \text{ eicosenoic}).$$

Statistical analysis

The Statistical Analysis System (SAS) Institute, Inc. computer package was used for all analyses (SAS, 1985). A factorial arrangement of treatments (maturity stages) and replicates/treatment was used to evaluate their effects on each fatty acid parameter. Year and soil type were nested within each treatment. The effects of location within farm were not considered because (i) preliminary experiments conducted in 1985 did not show significant differences among samples in a particular maturity class due to locations within farm, and (ii) there were insufficient numbers of intermediate pods. ANOVA was obtained by the general linear models (GLM) procedure. Significant differences between means (P = 0·05) were determined by the Tukey's studentized range (HSD) test.

RESULTS AND DISCUSSION

Mature seeds

Weights (%) of the eight major fatty acids in the oil from mature seeds are presented in Table 1. The three major fatty acids (palmitic, oleic and linoleic) accounted for approximately 86–93% of the oil. With respect to soil types, oil from VC soil samples generally contained more stearic acid and less linoleic acid than that from VS. However, there were no overall significant differences in palmitic and oleic acids (%) in oil between the two soil types.

The proportions of the fatty acids in the samples grown in St Vincent were within the ranges reported for peanuts in general by previous researchers (Worthington and Holley, 1967; Worthington *et al.*, 1972; Cobb & Johnson, 1973; Brown *et al.*, 1975; Sanders *et al.*, 1982; Norden *et al.*, 1987). Yet, when the fatty acid compositions of the oils (in this study) were compared with those of NC2 peanuts grown in North Carolina between 1975 and 1976 (Treadwell *et al.*, 1983), it was observed that the latter had less palmitic (9·18%), stearic (2·39%), oleic (48·04%) and arachidic (1·39%) acids but more linoleic (32·78%) and behenic (3·06%) acids. However, NC2 peanuts grown in North Carolina between 1982 and 1984 (Mozingo *et al.*, 1988*b*) had fatty acid compositions that were closer to those in this study: only linoleic acid (%) was greater than the St Vincent value, while levels of oleic and arachidic acids were less. Oil from mature NC2 peanuts grown in Jamaica in 1985 also had a fatty acid composition that was different from that of the St Vincent samples: it

Table 1. Weights (%) of fatty acids in oil of mature seeds of peanuts (cultivar NC2) grown in St Vincent from 1985 to 1987

Fatty acid parameter	Weights (%) of fatty acids in oil[a]					
	1985		1986		1987	
	VC[b]	VS[c]	VC	VS	VC	VS
C16:0	10·4 ± 0·02 b	10·7 ± 0·67 b	11·7 ± 0·20 a	11·4 ± 0·18 a	10·4 ± 0·02 b	10·4 ± 0·10 b
C18:0	3·8 ± 0·04 ab	3·2 ± 0·64 bc	4·2 ± 0·18 a	3·8 ± 0·50 ab	3·8 ± 0·04 ab	2·6 ± 0·06 c
C18:1	56·4 ± 0·10 c	56·9 ± 0·49 bc	58·6 ± 0·89 a	57·8 ± 0·42 ab	57·4 ± 0·10 bc	57·1 ± 0·07 bc
C18:2	21·0 ± 0·02 abc	21·5 ± 0·74 ab	19·9 ± 0·40 c	20·5 ± 0·95 bc	20·0 ± 0·02 c	22·4 ± 0·07 a
C20:0	1·6 ± 0·01 a	1·7 ± 0·07 a	1·6 ± 0·30 a	1·7 ± 0·03 a	1·6 ± 0·01 a	1·7 ± 0·07 a
C20:1	1·2 ± 0·03 a	1·1 ± 0·05 a	0·7 ± 0·32 b	1·1 ± 0·01 ab	1·2 ± 0·03 a	1·2 ± 0·15 a
C22:0	2·9 ± 0·02 a	2·8 ± 0·05 a	2·8 ± 0·05 a	2·8 ± 0·02 a	2·9 ± 0·02 a	2·9 ± 0·16 a
C24:0	2·7 ± 0·02 a	1·9 ± 0·68 ab	0·8 ± 0·24 c	1·4 ± 0·26 bc	2·7 ± 0·02 a	1·6 ± 0·08 bc
Oleic/linoleic ratio	2·7 ± 0·01 bcd	2·6 ± 0·09 cd	2·9 ± 0·04 a	2·8 ± 0·15 abc	2·9 ± 0·01 ab	2·5 ± 0·01 d
Long-chain saturated	7·2 ± 0·04 a	6·4 ± 0·67 ab	5·2 ± 0·41 bc	5·8 ± 0·20 b	7·2 ± 0·04 a	6·2 ± 0·03 ab
Saturated	21·4 ± 0·08 a	20·3 ± 1·28 ab	21·1 ± 0·49 a	21·0 ± 0·29 a	21·4 ± 0·08 a	19·2 ± 0·17 b
Unsaturated	78·6 ± 0·06 b	79·5 ± 0·95 ab	79·2 ± 1·03 ab	79·4 ± 0·59 ab	78·6 ± 0·06 b	80·8 ± 0·16 a

[a]Means of triplicate determinations × three locations in farm representing averages for harvest dates. Means with different letters (a–d) across rows are significantly different (Tukey's HSD test, P = 0·05).
[b]VC, volcanic clay loam.
[c]VS, volcanic sandy loam.

contained more linoleic (34·00%) and eicosenoic (1·49%) acids but less stearic (1·87%), oleic (47·57%), arachidic (1·32%) and behenic (2·13%) acids (Miller, 1988). It has been shown that a high level of linoleic acid may predispose peanut oil to rancidity (Fore *et al.*, 1953; Holley & Hammons, 1968; Worthington & Hammons, 1977), resulting in unpleasant off-flavors and odors which reduce the quality of the finished product (Clydesdale, 1979). Oils from NC2 peanuts grown in St Vincent with their relatively lower linoleic content and iodine value (IV = 84·9–88·9) may be less susceptible to oxidation than oils (IV = 97·7) from the other NC2 crops (Mozingo *et al.*, 1988*b*) discussed.

Ratios of oleic to linoleic acid (O/L) were greater in the VC soil samples (Table 1) due to the lower linoleic acid (%) in their oils. O/L ratios for the mature NC2 peanuts grown in St Vincent were all greater than those obtained for eight other varieties grown in Oklahoma (Young *et al.*, 1972). O/L ratios from the St Vincent crops were also greater than all but one value of those reported for 10 cultivars which were grown in Georgia, Florida and three locations in Texas (Brown *et al.*, 1975). On comparison with other NC2 crops, the O/L ratios of the samples from St Vincent were greater than those (1·48) grown in North Carolina between 1982 and 1984 (Mozingo *et al.*, 1988*b*) and also greater than those (1·40) grown in Jamaica in 1985 (Miller, 1988). Considerable importance has been ascribed to the role of O/L ratios in oil stability and shelf-life of peanut products (Young *et al.*, 1974; Mozingo *et al.*, 1988*b*; O'Keefe *et al.*, 1993). Oil and products from the NC2 peanuts in this study may be fairly stable since O/L ratios on the upper end of the O/L range of 1–4 for peanuts in general usually indicate greater stability (Holley & Hammons, 1968; Worthington *et al.*, 1972; Young *et al.*, 1972; Brown *et al.*, 1975; Sykes & Michaels, 1986).

Table 1 includes the weights (%) of long-chain saturated, total saturated and total unsaturated fatty acids in the mature seeds. Oil from samples grown on VC soil contained more long-chain and total saturated fatty acids, whereas the VS soil produced more unsaturated oils. Long-chain saturated fatty acids (%) from the peanuts grown in St Vincent were within the range of 4·76–8·64 obtained for 494 peanut genotypes (Norden *et al.*, 1987). However, Miller (1988) and Mozingo *et al.* (1988*b*) reported slightly lower values (4·43 and 5·87, respectively) for long-chain saturated fatty acids from NC2 crops grown in Jamaica and North Carolina, respectively. Total saturated fatty acids from the St Vincent samples were within the range of 13·08–26·39% reported by Norden *et al.* (1987). However, the St Vincent peanuts contained more total saturated fatty acids than NC2 peanuts grown in Jamaica (16·87%; Miller, 1988) and North Carolina (18·99%; Mozingo *et al.*, 1988*b*). Total unsaturated fatty acids (%) in the St Vincent samples were less than those (83·06%) of NC2 peanuts grown in Jamaica in 1985 (Miller, 1988) and also less than values (81·01%) for the same cultivar grown in North Carolina between 1982 and 1984 (Mozingo *et al.*, 1988*b*). This observation also suggests that oil from peanuts grown in St Vincent may be more stable than oil from NC2 peanuts grown in North Carolina.

Variations with maturity

Weights (%) of palmitic acid in oil decreased as seeds passed from intermediate through nearly-mature to mature stages (Table 2). These results agree with findings of Worthington (1969), Sanders (1980), Abdel-Hamid (1982), Court *et al.* (1984) and Mozingo *et al.* (1985, 1988*a*), but disagree with those of Knauft *et al.* (1986) and Kim and Hung (1991). There were significant differences in palmitic acid (%) between soil types and years at all maturity stages (Table 2). Yet, in some instances, palmitic acid levels in mature seeds were not significantly different from those in nearly-mature ones.

Stearic acid (%) increased with maturity of seeds in 1985 and 1986, but decreased in 1987 (Table 3). General increases in stearic acid with maturity of Argentine and Spanhoma varieties (Young *et al.*, 1972) and various cultivars (Mozingo *et al.*, 1985, 1988*b*; Kim & Hung, 1991) have been reported. The results from 1987 agree with those of Sanders (1980) and some observations of Young *et al.* (1972) in which stearic acid decreased with maturity of seeds. For the samples grown in St Vincent, stearic acid levels in the intermediate seeds

Table 2. Weights (%) of palmitic acid in oil of seeds of peanuts (cultivar NC2) at various maturity stages grown in St Vincent from 1985 to 1987

Maturity stage	Weights (%) of palmitic acid in oil[a]					
	1985		1986		1987	
	VC[b]	VS[c]	VC	VS	VC	VS
Mature	10·4 ± 0·02 h	10·7 ± 0·67 fgh	11·7 ± 0·20 cde	11·4 ± 0·18 cdef	10·4 ± 0·02 h	10·4 ± 0·10 gh
Nearly-mature	10·8 ± 0·02 efgh	12·2 ± 0·22 bc	11·9 ± 0·65 bcd	11·3 ± 0·06 defg	10·4 ± 0·01 h	11·8 ± 0·39 bcd
Intermediate	11·4 ± 0·03 cdef	11·5 ± 0·05 cdef	13·3 ± 0·54 a	12·7 ± 0·25 ab	12·3 ± 0·10 bc	12·0 ± 0·06 bcd

[a]Means of triplicate determinations × three locations in farm representing averages for harvest dates. Means with different letters (a–h) across rows and down columns are significantly different (Tukey's HSD test, $P = 0.05$).
[b]VC, volcanic clay loam.
[c]VS, volcanic sandy loam.

Table 3. Weights (%) of stearic acid in oil of seeds of peanuts (cultivar NC2) at various maturity stages grown in St Vincent from 1985 to 1987

Maturity stage	Weights (%) of stearic acid in oil[a]					
	1985		1986		1987	
	VC[b]	VS[c]	VC	VS	VC	VS
Mature	3·8 ± 0·04 abcd	3·2 ± 0·64 cdefg	4·2 ± 0·18 ab	3·8 ± 0·50 abcd	3·8 ± 0·04 abcd	2·6 ± 0·06 gh
Nearly-mature	3·3 ± 0·41 cdefg	2·7 ± 0·11 efg	3·8 ± 0·21 abc	3·5 ± 0·20 bcde	3·7 ± 0·05 abcd	4·2 ± 0·06 ab
Intermediate	3·0 ± 0·03 defg	2·2 ± 0·04 h	2·6 ± 0·61 fgh	3·5 ± 0·24 bcdef	4·4 ± 0·04 a	4·0 ± 0·02 abc

[a]Means of triplicate determinations × three locations in farm representing averages for harvest dates. Means with different letters (a–h) across rows and down columns are significantly different (Tukey's HSD test, $P = 0·05$).
[b]VC, volcanic clay loam.
[c]VS, volcanic sandy loam.

from the various year–soil combinations were significantly different from each other. The amounts by which stearic acid increased or decreased from intermediate to mature stage differed between soil types and also among years for the same soil type, thus resulting in significant differences in stearic acid among mature seeds (Table 1).

Weights (%) of oleic acid in oil increased with maturity of seeds (Table 4). Also, for each year–soil combination, oleic values for intermediate, nearly-mature and mature stages were significantly different from each other. Previous researchers have observed an increase in oleic acid (%) (Young *et al.*, 1972; Pattee *et al.*, 1974; Sanders, 1980; Abdel-Hamid, 1982; Court *et al.*, 1984; Mozingo *et al.*, 1985, 1988*b*; Kim & Hung, 1991) as well as a decrease (Lynd & Ansman, 1989; Hashim *et al.*, 1993) with maturity of seeds. In the present study, some levels of oleic acid in intermediate seeds were significantly ($P = 0·05$) less than others. However, the resulting oleic acid (%) in the oil of mature seeds were consistent irrespective of levels of oleic acid at earlier stages (Table 4). These results suggest that mature NC2 peanuts from crops grown in St. Vincent would probably contain 57·4 ± 0·77% oleic acid in their oils irrespective of soil type and growing season.

Linoleic acid (%) decreased with seed maturity from intermediate through nearly-mature to mature stages (Table 5). Similar trends were observed by Worthington (1969), Young *et al.* (1972), Sanders (1980), Mozingo *et al.*, (1985, 1988b) and Kim and Hung (1991), but different trends were reported by Knauft *et al.*, (1986), Lynd and Ansman (1989) and Hashim *et al.*, (1993). Linoleic levels were different between soil types and years at the three stages of maturity investigated (Table 5). Linoleic acid (%) in intermediate seeds from the St Vincent crops were less than those in mature seeds from North Carolina (Treadwell *et al.*, 1983; Mozingo *et al.*, 1988b). Thus, oil stability of products made from St Vincent-grown peanuts may not be decreased by incorporation of some intermediate and nearly-mature seeds.

O/L ratios increased with maturity of the seeds (Table 6) indicating increased oxidative stability of oil. These results agree with findings of Worthington (1969), Young *et al.*, (1972), Sanders (1980), Mozingo *et al.*, (1985, 1988*a*), and Kim and Hung (1991). For each soil type and year, except for VS soil samples in 1986, O/L values from intermediate, nearly-mature and mature stages were significantly different from each

Table 4. Weights (%) of oleic acid in oil of seeds of peanuts (cultivar NC2) at various maturity stages grown St Vincent from 1985 to 1987

Maturity stage	Weights (%) of palmitic acid in oil[a]					
	1985		1986			1987
	VC[b]	VS[c]	VC	VS	VC	VS
Mature	56·4 ± 0·10 ab	56·9 ± 0·49 ab	58·6 ± 0·89 a	57·8 ± 0·42 a	57·4 ± 0·10 a	57·1 ± 0·07 ab
Nearly-mature	48·8 ± 0·06 f	53·5 ± 0·27 cd	53·0 ± 1·41 cd	53·1 ± 1·93 cd	54·8 ± 0·12 bc	52·3 ± 0·14 de
Intermediate	43·4 ± 0·17 g	49·3 ± 0·06 f	45·6 ± 1·35 g	50·0 ± 1·26 ef	49·5 ± 0·45 f	48·5 ± 0·10 f

[a]Means of triplicate determinations × three locations in farm representing averages for harvest dates. Means with different letters (a–h) across rows and down columns are significantly different (Tukey's HSD test, $p = 0·05$).
[b]VC, volcanic clay loam.
[c]VS, volcanic sandy loam.

Table 5. Weights (%) of linoleic acid in oil of seeds of peanuts (cultivar NC2) at various maturity stages grown in St Vincent from 1985 to 1987

Maturity stage	Weights (%) of linoleic acid in oil[a]					
	1985		1986		1987	
	VC[b]	VS[c]	VC	VS	VC	VS
Mature	21·0 ± 0·02 hi	21·5 ± 0·74 ghi	19·9 ± 0·40 i	20·5 ± 0·95 i	20·0 ± 0·02 i	22·4 ± 0·07 gh
Nearly-mature	29·3 ± 0·21 b	24·8 ± 0·56 e	25·7 ± 1·01 de	26·8 ± 1·11 cd	22·9 ± 0·04 fg	24·2 ± 0·21 ef
Intermediate	32·2 ± 0·11 a	28·4 ± 0·04 bc	30·0 ± 0·79 b	25·5 ± 0·63 de	25·0 ± 0·03 e	26·8 ± 0·17 cd

[a]Means of triplicate determinations × three locations in farm representing averages for harvest dates. Means with different letters (a–h) across rows and down columns are significantly different (Tukey's HSD test, $P = 0·05$).
[b]VC, volcanic clay loam.
[c]VS, volcanic sandy loam.

Table 6. Oleic/linoleic acid ratio in oil of seeds of peanuts (cultivar NC2) at various maturity stages grown in St Vincent from 1985 to 1987

Maturity stage	Oleic/linoleic acid ratio in oil[a]					
	1985		1986		1987	
	VC[b]	VS[c]	VC	VS	VC	VS
Mature	2·7 ± 0·01 bc	2·6 ± 0·09 bc	2·9 ± 0·04 a	2·8 ± 0·15 ab	2·9 ± 0·01 ab	2·5 ± 0·01 cd
Nearly-mature	1·7 ± 0·01 gh	2·2 ± 0·05 e	2·1 ± 0·13 e	2·0 ± 0·15 ef	2·4 ± 0·00 d	2·2 ± 0·02 e
Intermediate	1·3 ± 0·01 i	1·7 ± 0·00 gh	1·5 ± 0·09 hi	2·0 ± 0·10 ef	2·0 ± 0·02 ef	1·8 ± 0·01 fg

[a]Means of triplicate determinations × three locations in farm representing averages for harvest dates. Means with different letters (a–i) across rows and down columns are significantly different (Tukey's HSD test, $P = 0·05$).
[b]VC, volcanic clay loam.
[c]VS, volcanic sandy loam.

other. O/L ratios from intermediate and nearly-mature stages of the St Vincent peanuts were similar to those from mature NC2 peanuts grown in Jamaica (Miller, 1988) and North Carolina (Mozingo *et al.*, 1988*b*). This suggests that, in St Vincent, marketed peanuts containing nearly mature and intermediate stages may not be inferior, in terms of their oil stability, to mature NC2 peanuts from North Carolina and Jamaica. However, the higher moisture contents associated with immature pods may give rise to other undesirable qualities, namely, contamination with mold (Davidson *et al.*, 1982) and changes in phospholipids (Pattee *et al.*, 1982) during storage. Therefore, in addition to tests for oxidative stability of oil and levels of aflatoxin, sensory evaluation would also be necessary to detect off-flavors and assist in determining the usefulness of the intermediate and nearly-mature seeds for human consumption.

CONCLUSION

Oil from mature NC2 seeds grown in St Vincent contained more oleic and less linoleic acid than oil from mature NC2 seeds grown in North Carolina and Jamaica. The linoleic acid (%) and O/L ratios in nearly-mature and intermediate seeds from St Vincent showed similar values to those in mature seeds harvested from North Carolina and Jamaica. These results suggest that the climate and physical properties of the soils in St Vincent may contribute towards an increase in oleic and a decrease in linoleic acid in peanuts. Changes in the major fatty acids (%) with maturity of seeds showed similar trends to those previously reported by some researchers. With respect to soil types in St Vincent, seeds grown on VC soil contained more stearic, long-chain and total saturated acids and less linoleic and total unsaturated acids than samples from VS soil. Both farms on which the peanuts were grown experienced similar climatic conditions. Thus, differences between the physical properties of their soils (e.g. water holding capacity, infiltration rates and soil temperatures) probably influenced the fatty acid composition of the seeds. This relationship will be investigated. However, it should be noted that, irrespective of soil type and year, the oleic acid (%) in the oil of mature seeds was within the small range of 57·4 ± 0·77, suggesting that this value could be a useful index of seed maturity for the NC2 peanut grown in St Vincent.

ACKNOWLEDGEMENTS

This research was funded by the Peanut Collaborative Research Support Program, USAID Grant No. DAN-4048-G-2065-00. The author is grateful to deceased professors B. Singh (Alabama A&M University) and G. M. Sammy (The University of the West Indies) for their contribution to this research.

REFERENCES

Abdel-Hamid, Y. (1982). Changes in chemical composition of peanut during development and ripening. *Riv. Ital. Sostanze Grasse*, **59**, 285–6.

Ahmed, E. M. & Young, C. T. (1982). Composition, quality and flavor of peanuts. In *Peanut Science and Technology*, eds H. E. Pattee & C. T. Young. American Peanut Research and Education Society Inc., Yoakum, TX, USA, pp. 655–88.

Anon. (1986). Peanut production in the Caribbean. *Caribbean Farming*, Feb., 20–1, 25.

APRES (1983). *Quality Methods*. American Peanut Research and Education Society, Stillwater, OK, USA.

Branch, W. D., Nakayama, T. & Chinnan, M. S. (1990). Fatty acid variation among US runner-type peanut cultivars. *J. Amer. Oil Chem. Soc.*, **67**, 591–3.

Brown, D. F., Carter, C. M., Mattil, K. F. & Darroch, J. G. (1975). Effect of variety, growing location and their interaction on the fatty acid composition of peanuts. *J. Food Sci.*, **40**, 1055–7.

CARDI (1983). *Development of Technology for Peanut Production* (1983 Annual Report). Caribbean Agricultural Research and Development Institute, St. Augustine, Trinidad.

CARDI (1985). *Development of Technology for Peanut Production* (Final Report, Dec. 1985). Caribbean Agricultural Research and Development Institute, St Augustine, Trinidad.

Chinnan, M. S. (1989). Postharvest handling systems for the small peanut producer. In *1988/89 Annual Report of Peanut Collaborative Research Support Program*. Peanut CRSP, University of Georgia Experiment Station, Griffin, GA, USA, pp. 273–95.

Chinnan, M. S. (1990). Postharvest handling systems for the small peanut producer. In *1989/90 Annual Report of Peanut Collaborative Research Support Program*. Peanut CRSP, University of Georgia Experiment Station, Griffin, GA, USA, pp. 193–205.

Chinnan, M. S. (1993). Postharvest handling systems for the small peanut producer. In *1993 Annual Report of Peanut Collaborative Research Support Program*. Peanut CRSP, University of Georgia Experiment Station, Griffin, GA, USA, pp. 213–29.

Clydesdale, F. (1979). *Food Science and Nutrition: Current Issues and Answers*. Prentice-Hall Inc., Englewood Cliffs, NJ, USA.

Cobb, W. Y. & Johnson, B. R. (1973). Physiological properties of peanuts. In *Peanuts: Culture and Uses*. American Peanut Research and Education Society, Stillwater, OK, USA, pp. 209–63.

Cocks, L. V. & Van Rede, C. (1966). *Laboratory Handbook for Oil and Fat Analysts*. Academic Press, New York, USA.

Court, W. H., Roy, R. C. & Hendel, J. G. (1984). Effect of harvest date on agronomic and chemical characteristics of Ontario peanuts. *Can. J. Plant Sci.*, **64**, 521–8.

Davidson, Jr, J. I., Whitaker, T. B. & Dickens, J. W. (1982). Grading, cleaning, storage, shelling and marketing of peanuts in the United States. In *Peanut Science and Technology*, eds H. E. Pattee & C. T. Young. American Peanut Research and Education Society Inc., Yoakum, TX, USA, pp. 571–623.

Dwivedi, S. L., Nigam, S. N., Subrahmanyam, P., Jambunathan, R., Nagabhushanam, G. V. S., Reddy, P. M., Raghunath, K. & McDonald, D. (1993*a*). Effect of foliar diseases control by chlorothalonil on pod yield and quality characteristics of confectionery groundnuts (*Arachis hypogaea* L.). *J. Sci. Food Agric.*, **63**, 265–71.

Dwivedi, S. L., Nigam, S. N. Jambunathan, R., Sahrawat, K. L., Nagabhushanam, G. V. S. & Raghunath, K. (1993*b*). Effect of genotypes and environments on oil content and oil quality parameters and their correlation in peanut (*Arachis hypogaea* L.). *Peanut Sci.*, **20**, 84–9.

FAO (1986). *1985 FAO Production Yearbook*, **39**. Food and Agriculture Organization of the United Nations, Rome, Italy.

FAO (1990). *1989 FAO Production Yearbook*, **43**. Food and Agriculture Organization of the United Nations, Rome, Italy.

Fore, S. P., Morris, N. J., Mack, C. H., Freeman, A. F. & Bickford, W. G. (1953). Factors affecting the stability of crude oils of 16 varieties of peanuts. *J. Amer. Oil Chem. Soc.*, **30**, 298–301.

Grosso, N. R., Lamarque, A., Maestri, D. M., Zygadlo, J. A. & Guzman, C. A. (1994). Fatty acid variation of runner peanut (*Arachis hypogaea* L.) among geographic localities from Cordoba (Argentina). *J. Amer. Oil Chem. Soc.*, **71**, 541–2.

Hashim, I. B., Koehler, P. E., Eitenmiller, R. R. & Kvien, C. K. (1993). Fatty acid composition and tocopherol content of drought stressed Florunner peanuts. *Peanut Sci.*, **20**, 21–4.

Hinds, M. J. & Singh, B. (1994). Evaluation of fatty acids in oil as reaping indices for Caribbean-grown groundnut (*Arachis hypogaea*). *J. Agric. Sci.*, **122**, 423–8.

Hinds, M. J., Singh, B. & Anderson, J. C. (1992). Determination of pod and crop maturity for peanuts using percent pod-fill. *Can. J. Plant Sci.*, **72**, 1057–65.

Holley, K. T. & Hammons, R. O. (1968). *Strain and Seasonal Effects on Peanut Characteristics* (Research Bulletin No. 32). College of Agriculture, University of Georgia Experiment Station, Tifton, GA, USA.

ICTA (1958). *Soil and Land Use Surveys (No. 3. St Vincent)*. The Regional Research Centre of the British Caribbean, Imperial College of Tropical Agriculture, Trinidad.

Kim, N.-K. & Hung, Y.-C. (1991). Mechanical properties and chemical composition of peanuts as affected by harvest date and maturity. *J. Food Sci.*, **56**, 1378–81, 1392.

Knauft, D. A., Norden, A. J. & Gorbet, D. W. (1986). The effect of three digging dates on oil quality, yield and grade of five peanut genotypes grown without leafspot control. *Peanut Sci.*, **13**, 82–86.

Lynd, J. Q. & Ansman, T. R. (1989). Effects of P, Ca with four K levels on nodule histology, nitrogenase activity and improved Spanco peanut yields. *J. Plant Nutr.*, **12**(1), 65–84.

Mercer, L. C., Wynne, J. C. & Young, C. T. (1990). Inheritance of fatty acid content in peanut oil. *Peanut Sci.*, **17**, 17–21.

Miller, E. A. (1988). A study on the proximate composition, amino acids and fatty acids of peanuts grown in Jamaica. M.S. thesis, Alabama Agricultural & Mechanical University, Normal, Alabama,USA.

Mozingo, R. W., Coffelt, T. A. & Wynne, J. C. (1985). Effect of seed size on fatty acid composition of peanut cultivars. *Proc. Amer. Peanut Res. Educ. Soc. Inc.*, **17**, 57.

Mozingo, R. W., Coffelt, T. A. & Wynne, J. C. (1988*a*). Market grade effects on fatty acid composition of five peanut cultivars. *Agron. J.*, **80**, 73–5.

Mozingo, R. W., Coffelt, T. A. & Wynne, J. C. (1988*b*). *Quality Evaluations of Virginia-Type Peanut Varieties Released from 1944–1985*. (Southern Cooperative Series Bulletin No. 335). Virginia Agricultural Experiment Station, Blacksburg, VA, USA.

Norden, A. J., Gorbet, D. W., Knauft, D. A. & Young, C. T. (1987). Variability in oil quality among peanut genotypes in the Florida breeding program. *Peanut Sci.*, **14**, 7–11.

O'Keefe, S. F., Wiley, V. A. & Knauft, D. A. (1993). Comparison of oxidative stability of high and normal oleic peanut oils. *J. Amer. Oil Chem. Soc.*, **70**, 489–92.

Pattee, H. E., Johns, E. B., Singleton, J. A. & Sanders, T. H. (1974). Composition changes of peanut fruit parts during maturation. *Peanut Sci.*, **1**, 57–62.

Pattee, H. E., Pearson, J. L., Young, C. T. & Giesbrecht, F. G. (1982). Changes in roasted peanut flavor and other quality factors with seed size and storage time. *J. Food Sci.*, **47**, 455–6, 460.

Raheja, R. K, Batta, S. K., Ahuja, K. L., Labana, K. S. & Singh, M. (1987). Comparison of oil content and fatty acid composition of peanut genotypes differing in growth habit. *Plant Foods Hum. Nutr.*; **37**, 103–8.

Sanders, T. H. (1980). Fatty acid composition of lipid classes in oils from peanuts differing in variety and maturity. *J. Amer. Oil Chem. Soc.*, **57**, 12–15.

Sanders, T. H., Landsen, J. A., Greene, R. L., Drexler, J. S. & Williams, E. J. (1982) . Oil characteristics of peanut fruit separated by a non-destructive maturity classification method. *Peanut Sci.*, **9**, 20–3.

SAS (1985). *Statistical Analysis System User's Guide.* Statistical Analysis System Institute Inc., Cary, NC, USA.

Singh, B. (1985). Peanut utilization in food systems in developing countries. In *1984 Annual Report of Peanut Collaborative Research Support Program.* Peanut CRSP, University of Georgia Experiment Station, Griffin, GA, USA, pp. 266–71.

Singh, B. (1989) . Peanut utilization in food systems in developing countries. In *1988/89 Annual Report of Peanut Collaborative Research Support Program.* Peanut CRSP, University of Georgia Experiment Station, Griffin, Georgia, GA, USA, pp. 265–71.

St Vincent Marketing Corporation (1985–1991) . Records, St Vincent Marketing Corporation, Kingstown, St Vincent.

Sykes, E. E. & Michaels, T. E. (1986). Combining ability of Ontario-grown peanuts (*Arachis hypogaea* L.) for oil, fatty acids and taxonomic characters. *Peanut Sci.*, **13**, 93–7.

Treadwell, K., Young, C. T. & Wynne, J. C. (1983). Evaluation of fatty acid content of forty peanut cultivars. *Oleagineux*, **38**, 381–5.

Wallerstein, I. S., Merin, U. & Rosenthal, I. (1989). Comparison of kernels of three Virginia-type peanut cultivars. *Lebensm. Wiss. Technol.*, **22**, 179–81.

Worthington, R. E. (1969). Developmental changes in peanut lipid fatty acids. In *Proceedings of the 5th National Peanut Research Conference.* Virginia Polytechnic Institute, Blacksburg, VA, USA, p. 87.

Worthington, R. E. & Hammons, R. O. (1971). Genotypic variation in fatty acid composition and stability of *Arachis hypogaea* L. oil. *Oleagineux*, **26**, 695–700.

Worthington, R. E. & Hammons, R. O. (1977). Variability in fatty acid composition among *Arachis* genotypes: a potential source of product improvement. *J. Amer. Oil Chem. Soc.*, **54**, 105–6.

Worthington, R. E. & Holley, K. T. (1967). The linoleic acid content of peanut oil. *J. Amer. Oil Chem. Soc.*, **44**, 515–16.

Worthington, R. E., Hammons, R. O. & Allison, J. R. (1972). Varietal differences and seasonal effects on fatty acid composition and stability of oil from 82 peanut genotypes. *J. Agric. Food Chem.*, **20**, 727–30.

Young, C. T., Mason, M. E., Matlock, R. S. & Waller, G. R. (1972). Effect of maturity on fatty acid composition of eight varieties of peanuts grown at Perkins, OK in 1968. *J. Amer. Oil Chem. Soc.*, **49**, 314–17.

Young, C. T., Worthington, R. E., Hammons, R. O., Matlock, R. S., Waller, G. R. & Morrison, R. D. (1974). Fatty acid composition of Spanish peanut oils as influenced by planting location, soil moisture conditions, variety and season. *J. Amer. Oil Chem. Soc.*, **51**, 312–15.