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EVALUATION OF NUTRITIONAL QUALITY OF GROUNDNUT (*Arachis hypogaea* L.) FROM GHANA

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ABSTRACT

Groundnut is the most important legume in Ghana. The crop is grown in all the agro-ecologies in the country; from the dry savannah regions to the moist forest areas. Several food preparations incorporate groundnut to improve the protein level, taste and flavour. Despite the importance of the crop, the chemical compositions of the varieties grown by farmers have not been analyzed according to their nutritional quality. Oil, fatty acids, protein, oleic/linoleic (O/L) acid ratio, iodine value and free soluble sugars were studied in 20 groundnut varieties grown in Ghana to determine their nutritional quality and to inform end-users which variety to choose for maximum benefit. Results indicated a significant difference ($p<0.05$) in oil content among the varieties. Oil content ranged from 33.60 to 54.95%. Mean oil content of the subspecies *hypogaea* (49.7%) was higher than in subspecies *fastigiata* (47.3%). The major fatty acids were oleic and linoleic which accounted for 77.89% of the total fatty acids. The subspecies *hypogaea* had significantly higher ($p<0.01$) content of oleic acid (55.9%) than the subspecies *fastigiata* (43.3%). The sum of three fatty acids oleic, linoleic and palmitic acid constitute 89.35% of the total fatty acids of the seeds. The mean O/L ratio ranged from 1.14 to 3.66; the mean for subspecies *hypogaea* was 2.59 as compared to 1.28 for subspecies *fastigiata*. There was high correlation between oleic and O/L acid ratio ($r^2=0.983$) and negative correlation between oleic acid and linoleic acid ($r^2=-0.996$). The iodine value ranged from 85.77 to 98.43% and total soluble sugars from 9.20 to 13.30%. Protein of defatted portion ranged from 39.65 to 53.45%. Subspecies *fastigiata* had higher mean protein content than subspecies *hypogaea*. Generally, there were significant variations in the parameters measured in the groundnut varieties. Five varieties with O/L ratio more than 2.0 were identified and their oils would be further tested for their stability.

Key words: Groundnut, oil, oleic, linoleic, protein

INTRODUCTION

Groundnut is a major annual oilseed crop and a good source of protein. Oil and protein content, fatty acid and amino acid composition, taste and flavour are important quality traits. Groundnut protein is increasingly becoming important as food and feed sources, especially in developing countries where protein from animal sources is not within the means of majority of the populace. Vegetable oils are in high demand due to diseases associated with fat from animal origin. The seed has several uses including as a whole seed or processed to make groundnut butter, oil, and other products. The groundnut cake has several uses in feed and infant food formulations [1].

The oil content of groundnut differs in both quantity and the relative proportion of fatty acids. Twelve fatty acids have been reported in groundnut but eight major fatty acids constitute 98% of fatty acids in groundnut [2, 3]. Differences in the fatty acid composition have been attributed to several factors, including genotype, the level of maturity of the seed, season, year and geographical area of production [4].

Oleic acid, a monounsaturated fatty acid, and linoleic acid, a polyunsaturated acid, constitute approximately 80% of the total fatty acid composition of groundnut [5]. Due to the high proportion of oleic and linoleic acids in groundnut seed, the chemistry and quality of groundnut oil depend on their relative proportions. Oils with higher proportion of unsaturated fatty acids can be heated to high temperatures without smoking, leading to faster cooking time and absorption of less oil [6]. Oils with high content of monounsaturated fatty acid (oleic acid) are less susceptible to oxidative changes during refining and storage. Nutritionally, a high content of linoleic acid is preferable because it is an essential fatty acid and has been known to lower total blood cholesterol and low-density lipo-protein levels [7]. However, linoleic acid has two double bonds and is more susceptible to oxidative rancidity than oleic acid and the saturated fatty acids [8]. Oxygen reacts with the double bonds of unsaturated fatty acids to form products characterized by undesirable flavour and odour.

A study by Psaltopoulou *et al*. [9] showed that diets containing high levels of monounsaturated fatty acids were as effective in lowering serum cholesterol levels as were low-fat diets. Oleic/linoleic (O/L) acid ratio and iodine value are indications of the quantity of unsaturated fatty acids present in a fat and have been used to predict the shelf life of fat and oils [10]. Groundnuts with high O/L ratio and low iodine value have high level of monounsaturated fatty acids, product stability and long shelf life.

Reddy [11] indicated that the seed of groundnut contains 25 to 32% protein and the cake, the residue after oil extraction, 46-60% protein. The defatted meal after oil extraction is an ingredient in livestock feeds, added to several food preparations like bread, biscuits, cookies and cereal based preparations for infants to improve the diets of malnourished people in developing countries.

Sugars in groundnut seed play an important role as precursors in the production of the typical roasted groundnut flavour. Seed sugars provide a source of carbon for the production of flavour compounds [12]. Sucrose, upon hydrolysis, produces fructose and glucose, which

upon heating can react with some specific amino acids to form flavour components [13]. The flavour of the roasted groundnut plays an important role in its acceptance by consumers and other users. Flavour also plays an important role in the acceptability of groundnut products such as peanut butter. Newell *et al.* [14] noted that free amino acid and free sugars are important precursors of groundnut flavour.

Groundnut is an important legume in Ghana with an annual production of 450,000 tons (t) in 2003 [15]. Groundnut is grown in all the agro-ecologies in Ghana, from the dry savannah regions to the moist forest areas and eaten with boiled maize to reduce the impact of hunger during the lean season when most foodstuffs are in short supply. Groundnut is also used for various infant foods such as stews, soups and cereal mixtures, improving their nutritional quality and taste. Extracting oil from groundnut provides an income for women and their dependants in the small-scale cottage industry. The flour received after oil extraction is used to formulate the diet for animals and human beings [1].

The chemical composition of groundnut seeds has been evaluated in some countries. However, studies on the chemical composition of groundnut cultivars grown in Ghana have not been conducted. Therefore, the main objective of this study was to determine the protein, oil, fatty acids, O/L ratio, iodine value and soluble sugar content in groundnut cultivars grown in Ghana and to inform industrialists and manufacturers of the right varieties to choose for their products.

MATERIALS AND METHODS

Characterisation of groundnut cultivars

Twenty groundnut varieties were collected from the Crops Research Institute (under the Council for Scientific and Industrial Research), Fumesua, Ghana and planted in May 2004 to determine their subspecies. The varieties were grouped into two subspecies according to their branching patterns, presence or absence of flowers on main stem, flower arrangement on leaf axils, namely: (1) *hypogaea* (Virginia market types) and (2) *fastigiata* (Spanish and Valencia market types). Cultivars with flowers on the main stem, sequential branching and flowering were grouped into subspecies *fastigiata* and those without flowers on the main stem, alternative branching patterns and alternate flowering were grouped into *hypogaea* subspecies category [16]. Sound mature kernels were handpicked after drying and sent to International Crops Research Institute for the Semi Arid Tropics (ICRISAT) in Patancheru, India for analyses of protein, soluble sugars, oil, and fatty acids. The cultivars and their subspecies are shown in Table 1.

Oil content

Oil content was determined using a commercial nuclear magnetic resonance spectrometer as described by Jambunathan *et al.* [17]. All readings were taken on oven–dried (110 degrees Celsius [^{o}C], 16 hours [h]) samples and the values were expressed on a uniform 5% seed moisture content basis.

Fatty acid composition

Fatty acid methyl esters (FAME) were estimated using the method of Mercer *et al.* [18]. From the fatty acid estimation, the following quality parameters were determined as described by Mozingo *et al*. [19]:

i. Iodine value (IV) = (% Oleic acid) (0.8601)+(% Linoleic acid) (1.7321)+ (% Eicosenoic acid) (0.7854)

ii. Oleic acid (O)/Linoleic acid (L) ratio = % Oleic / % Linoleic acid

iii. Total saturated fatty acids (%) (TSF) = % Palmitic acid +% Lignoceric acid

iv. Polyunsaturated (P)/Saturated (S) ratio = % Linoleic acid/ TSF

v. Total long chain saturated fatty acids (%) (TLCF) = % Arachidic acid + % Behenic acid + % Lignoceric acid

Protein and total soluble sugars

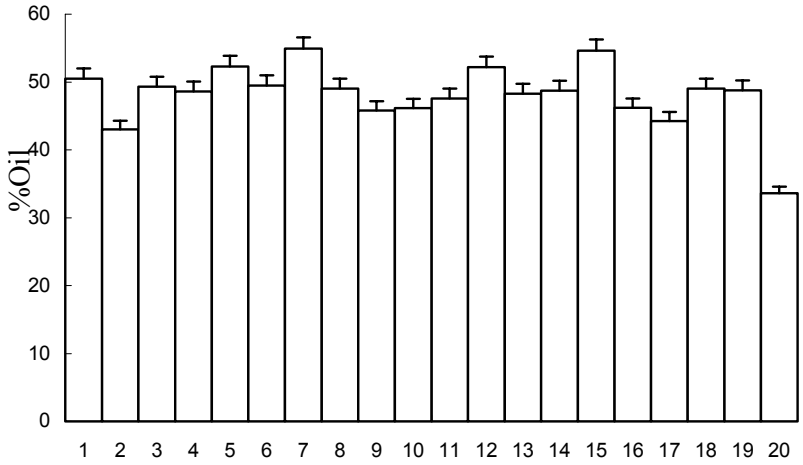
The protein content was determined with a Technicon Autoanalyser (Pulse Instrumentation Ltd, Saskatoon, SK) [20]. Total soluble sugar content was analyzed according to the method described by Dubois *et al.* [21]. All analyses were conducted in duplicate and the average between the two readings taken. Analyses of variance (ANOVA) and correlation were carried out with GenStat statistical package (version 5).

RESULTS

Oil, Protein, and Total soluble sugars

Significant differences ($p<0.01$) were observed among the 20 cultivars for oil (Fig. 1), protein, and total soluble sugars (Table 2). Oil content ranged from 33.6 to 54.95%. Five varieties had oil content higher than 50%. Broni fufuo, a Spanish variety had unusually low oil content compared with the other varieties. Groundnut varieties belonging to subspecies *hypogaea* had slightly more oil than the *fastigiata* varieties.

Figure 1. Oil content of 20 groundnut varieties. Identity numbers correspond with the variety numbers in Table 1.



Protein of defatted portion ranged from 39.65 to 53.45%. The protein content of defatted flour of the subspecies (ssp) *fastigiata* was slightly higher than of the ssp hypogaea. The mean protein content of defatted flour of ssp *hypogaea* was 43.45% and ssp *fastigiata* 48.63%. Variation in total soluble sugars ranged from 9.20 to 13.30%.

Significant differences ($p<0.01$) were observed among the individual fatty acids for the 20 groundnut varieties (Table 3 and 4). Spanish varieties generally had lower oleic acid than the Virginia varieties. The range of the groundnut oil for Virginia varieties was from 44.85 to 63.55%; and that of the Spanish was from 40.85 to 46.40%. The Virginia varieties on average had 29% more oleic acid compared to the Spanish varieties.

The linoleic acid content varied between 17.35 and 36.0%. The Spanish varieties generally had higher linoleic acid than the Virginia varieties. Oleic and linoleic acids together accounted for 77.9% of the total fatty acids in the 20 groundnut varieties analyzed. The values of O/L acid ratio of all the groundnut varieties exceeded 1.0. They varied between 1.14 and 3.66. The Virginia varieties generally had higher O/L ratio ranging from 1.43 to 3.66 with an average of 2.59. The Spanish varieties ranged from 1.14 to 1.51 and had a mean of 1.28.

The iodine value ranged from 85.77 to 98.43. Overall, the Spanish varieties had higher values for iodine compared to the Virginia varieties.

Significant variations ($p<0.01$) in palmitic, stearic, arachidic, eicosenoic, behenic and lignoceric acids were observed among the 20 varieties (Table 5). The content of palmitic acid varied between 9.05 and 12.85%. Stearic acid ranged from 1.75 to 3.65% and had a mean

value of 2.93%. The content of arachidic acid ranged from 1.05 t0 1.70% and that of eicosenoic acid from 0.77 to 1.50%. Behenic acid ranged from 3.10 to 4.40% and lignoceric acid from 1.15 to 1.95%. The sum of the means of oleic, linoleic and palmitic acid was 89.35%.

Correlation coefficients among the fatty acids are presented in Table 6. The correlation of palmitic acid content and that of oleic acid and O/L ratio were significant ($p<0.01$) and negative. However, there was a significant positive correlation between palmitic acid and linoleic acid and between oleic acid and O/L ratio. In addition, correlations between linoleic acid and O/L ratio, stearic and eicosenoic acid, and oleic and linoleic acid were significant and negative.

Total saturated fatty acids in the varieties ranged from 17.85 to 22.80%. The Virginia varieties generally had lower saturated fatty acids than the Spanish varieties. The ratio of polyunsaturated fatty acid to saturated fatty acids ranged from 0.97 to 1.61% and the long chain fatty acids from 5.80 to 7.70 %.

DISCUSSION

The oil content of the cultivars was in line with the observation of Dubois *et al.* [21] who reported oil content of groundnut ranged from 44 to 56%. Five varieties had oil contents higher than 50%. These particular varieties should be considered for further testing in different locations and seasons to determine the stability of the trait due to oil content being influenced by locations, seasons and growing conditions [4]. However, there was a variety, Broni fufuo which had an exceptionally low oil content of 33.60%. The variety with low oil content could be used for products which require less fat and oil. The slightly higher oil content observed in ssp *hypogaea* are in conformity with the results of Dwivedi *et al.* [23] who observed that, Virginia cultivars had higher oil content than Valencia and Spanish lines.

The oleic and linoleic acid content of the groundnut varieties analyzed accounted for 75.30 to 81.05% of the total fatty acids. The results are consistent with the findings of Ahmed and Young {5} who found that oleic and linoleic acids constituted approximately 80% of the total fatty acid composition of groundnut. The levels of oleic and linoleic acids follow the range observed by Treadwell *et al*. [24]. They found 36 to 67% oleic acid and 15 to 43% linoleic acid in the groundnut varieties they analysed. The levels of oleic acid found in the varieties were generally high. High level of oleic acid implies high oil stability and better shelf life of groundnut seeds and products because oleic acid is a monounsaturated fatty acid, being less prone to oxidative rancidity [25]. Unsaturated fatty acids have also been found to reduce plasma cholesterol levels [9]. Varieties with high oleic acids could be used for products to improve their shelf life and their nutritional quality.

Oleic acid, linoleic acid and palmitic acids constituted on average 89.35% of the total fatty acid content of all the varieties analysed. The results are consistent with the findings of Ahmed and Young [5] and Dwivedi *et al*. [23], who found the percentage of the three fatty acids to be about 90% in groundnut. The oleic/linoleic acid ratio for the 20 varieties ranged from 1.14 to 3.66. O/L ratio is considered to be a measure of oil stability. Groundnut varieties

with higher O/L ratios have been found to exhibit increased oil stability and increased shelf life of products [8]. The O/L ratio have been found to increase with groundnut maturity and affected by cultivar and environmental factors [26]. Most of the varieties had appreciable level of O/L ratio since values more than 1.0 are preferred in export markets.

The iodine value ranged from 85.77 to 98.43 in the groundnut varieties. The Spanish varieties generally had higher iodine values than the Virginia varieties. Iodine value is an indication of the quantity of unsaturated fatty acids present in a fat and has been used to predict the shelf life of fat and oils [10]. High values depict high content of polyunsaturated fatty acid in the product. The shelf life or stability of groundnut oil is measured by the number of days before the onset of oxidative rancidity, a process that involves the whole groundnut seed, groundnut oil or groundnut product by exposure to heat and air [8].

Protein of defatted portion ranged from 39.65 to 53.45%. This agrees with the findings of Reddy [11] and Savage and Keenan [22], who observed a protein content of 46-60% in groundnut residue after oil extraction. The high protein content of the cultivars is important because most people in Ghana cannot afford protein from animal origin. Several tons of soybean meal is imported into Ghana for the poultry and livestock industry every year [27]. Using groundnut meal in animal feeds can reduce the overdependence on soybean meal and therefore save the scarce foreign exchange spent in importing soybean meal. Kamaloo and Kowoka had high protein content, and may be ideal for meal preparation. Dagomba and Nkate kokko have high O/L ratios and would be ideal for products that would be utilised over a long period of time, since their products may have longer shelf life.

Free sugar content, ranging from 9.2 to 13.3mg/100g in defatted seeds, was lower than the sugar content in hirsuta lines analyzed by Newell *et al*.[13], ranging from 141-179µmol/g. Soluble sugars are important for the sweet taste in peanuts. Pattee *et al.* [28] found that groundnut varieties with high sweet taste intensities had high free sugar content compared to those varieties with lower intensities. Free soluble sugars have also been associated with the flavour of groundnut. Koehler *et al.* [12] indicated that free soluble sugars provide carbon for the production of flavour compounds. Oupadissakoon and Young [29] observed a strong correlation (r^2=0.928) between roasted groundnut flavour and amino acids and free sugar content of raw seed. Since sweet taste and flavour play an important role in groundnut acceptance by consumers, groundnut varieties with higher content of free sugars should be grown in Ghana.

Varieties belonging to ssp *hypogaea* generally had lower mean total saturated fatty acid (19.22%) as compared to (22.07%) ssp *fastigiata*. Subspecies *fastigiata* had higher level of polyunsaturated/saturated fatty acid ratio (1.55) and longer chain fatty acid (6.86%) as compared with 1.22 and 5.47% by subspecies *hypogaea*, respectively.

Highly significant negative correlation between oleic acid and linoleic acid observed in this study is in agreement with previous studies [4, 18]. This indicates that the selection of high oleic acid varieties will bring about corresponding increase in O/L ratio and lower levels of linoleic acid. The relationship between palmitic acid and linoleic acid was positive as observed in an earlier study [30].

CONCLUSION

The study has identified groundnut varieties with various quality attributes which can be selected from according to the product to be made. If long shelf life is required in groundnut products, it may be beneficial to choose Dagomba, Nkate kokoo and Sinkazie because of their high oleic/linoleic acid ratios. When products with high protein meal are required, Kamalloo, Kowoka and Afu may be useful. Groundnut products which are produced manly for their flavour and taste may use Sinkazie and F-mix because of their high soluble sugar content. Five varieties with O/L ratio more than 2.0 were identified and their oils would be further tested for their stability. Subspecies *hypogaea* has better oil content and O/L ratio but their long duration on the field makes them unpopular among farmers because of the erratic rainfall pattern. Farmers with irrigation facilities should be encouraged to plant these particular varieties.

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Table 1: Groundnut varieties and their subspecies

Variety	Subspecies
1. Dagomba	Hypogeae
2. F-Mix	„
3 Nkatepa	„
4. Manipinta	„
5. Sinkazie	„
6. Kumawu early	„
7. Nkate kokoo	„
8. Baasare	Fastigiata
9.Broni nkatee	„
10. Afu	„
11. Nkoranza local	„
12. Atebubu local	„
13. Aprewa	„
14. Kintampo local	„
15. Shitaochi	„
16. Broni	„
17.Kamaloo	„
18. Kofi Nsarko	„
19. Kowoka	„
20. Broni fufuo	„

Table 2: Percentage of protein and total soluble sugars in defatted flour

Variety	Subspecies	Protein (%)	Total soluble sugar (%)
1. Dagomba	Hypogeae	46.20	9.20
2. F-Mix	„	43.45	13.05
3 Nkatepa	„	44.90	12.30
4. Manipinta	„	50.15	11.50
5. Sinkazie	„	39.65	13.30
6. Kumawu early	„	46.95	11.30
7. Nkate kokoo	„	45.80	10.15
8. Baasare	Fastigiata	51.05	9.65
9.Broni nkatee	„	51.40	10.50
10. Afu	„	51.45	9.30
11. Nkoranza local	„	49.15	10.90
12. Atebubu local	„	44.25	10.50
13. Aprewa	„	48.10	9.20
14. Kintampo local	„	48.30	9.30
15. Shitaochi	„	44.20	9.60
16. Broni	„	49.25	12.50
17.Kamaloo	„	53.45	10.15
18. Kofi Nsarko	„	43.60	12.20
19. Kowoka	„	52.10	9.30
20. Broni fufuo	„	45.95	12.40
Mean		47.5	10.8
SED		0.58	0.26
Cv(%)		1.2	2.9

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Table 3: Percent of major fatty acids (oleic and linoleic), oleic/linoleic acid ratio and iodine value of the 20 groundnut Ghanaian varieties

Variety	Subspecies	Oleic	Linoleic	O/L ratio	Iodine value
1. Dagomba	Hypogeae	63.55	17.35	3.66	85.77
2. F-Mix	„	51.95	27.55	1.89	93.58
3 Nkatepa	„	55.35	24.65	2.25	91.29
4. Manipinta	„	55.35	24.30	2.79	90.76
5. Sinkazie	„	57.50	21.80	2.64	88.08
6. Kumawu early	„	44.85	31.45	1.43	93.67
7. Nkate kokoo	„	62.90	18.15	3.47	86.44
8. Baasare	Fastigiata	43.85	34.10	1.29	97.51
9.Broni nkatee	„	40.85	36.00	1.14	98.43
10. Afu	„	43.25	33.55	1.29	96.02
11. Nkoranza local	„	42.25	34.05	1.24	96.00
12. Atebubu local	„	43.60	33.05	1.32	95.38
13. Aprewa	„	42.65	34.55	1.23	97.21
14. Kintampo local	„	43.40	33.35	1.30	95.71
15. Shitaochi	„	46.40	30.75	1.51	93.77
16. Broni	„	44.00	32.75	1.34	95.51
17.Kamaloo	„	42.80	34.60	1.24	97.53
18. Kofi Nsarko	„	43.30	33.65	1.29	96.23
19. Kowoka	„	43.25	34.05	1.27	96.81
20. Broni fufuo	„	42.65	34.40	1.24	97.17
Mean		47.69	30.20	1.72	94.14
Cv(%)		0.7	1.0	1.91	0.38
SED		0.33	0.29	0.03	0.35

Table 4: Percentage of minor fatty acids of the 20 groundnut Ghanaian varieties

Variety	Botanic Group	Palmitic	Stearic	Arachidic	Eicosenoic	Behenic	Lignoceric
1. Dagomba	Hypogaea	9.05	2.95	1.35	1.35	3.90	1.65
2. F-Mix	„	10.65	1.75	1.05	1.50	3.70	1.75
3 Nkatepa	„	10.20	2.25	1.25	1.25	3.35	1.75
4. Manipinta	„	9.45	2.45	1.40	1.35	3.65	1.70
5. Sinkazie	„	10.25	2.90	1.55	1.10	3.55	1.40
6. Kumawu early	„	12.25	3.55	1.65	0.80	3.90	1.45
7. Nkate kokoo	„	9.20	2.85	1.55	1.15	3.10	1.15
8. Baasare	Fastigiata	11.75	2.60	1.45	0.93	3.80	1.50
9.Broni nkatee	„	12.05	2.50	1.40	1.20	4.40	1.60
10. Afu	„	12.15	2.95	1.50	0.91	4.15	1.50
11.Nkoranza local	„	12.85	3.15	1.45	0.88	3.95	1.35
12. Atebubu local	„	12.40	3.55	1.65	0.81	3.75	1.30
13. Aprewa	„	12.40	2.85	1.50	0.87	3.80	1.40
14.Kintampo local	„	12.60	3.65	1.55	0.78	3.20	1.30
15. Shitaochi	„	12.30	3.65	1.70	0.77	3.35	1.30
16. Broni	„	11.65	2.90	1.40	1.20	4.35	1.95
17.Kamaloo	„	11.95	2.75	1.40	1.00	3.90	1.55
18. Kofi Nsarko	„	11.95	3.40	1.60	0.90	3.90	1.35
19. Kowoka	„	11.75	3.20	1.65	0.81	3.85	1.45
20. Broni fufuo	„	12.20	2.65	1.50	1.15	4.00	1.50
Mean		11.45	2.93	1.48	1.03	3.73	1.50
Cv(%)		2.6	1.1	5.7	3.6	2.6	5.1
SED		0.12	0.21	0.05	0.4	0.1	0.08

Table 5: Total saturated fatty acids, polyunsaturated /saturated ratio and long chain fatty acids

Variety	Botanical group	Total saturated fatty acid	Polyunsaturated/ saturated ratio	Long chain saturated fatty acid
1. Dagomba	Hypogaea	17.90	0.97	5.90
2. F-Mix	„	18.90	1.46	6.50
3 Nkatepa	„	18.80	1.31	6.35
4. Manipinta	„	18.65	1.30	6.75
5. Sinkazie	„	19.65	1.11	6.50
6. Kumawu early	„	22.80	1.38	7.00
7. Nkate kokoo	„	17.85	1.02	5.80
8. Baasare	Fastigiata	21.10	1.62	6.75
9.Broni nkatee	„	21.95	1.64	7.40
10. Afu	„	22.25	1.51	7.15
11. Nkoranza local	„	22.75	1.50	6.75
12. Atebubu local	„	22.65	1.50	6.70
13. Aprewa	„	21.95	1.57	6.70
14. Kintampo local	„	22.30	1.50	6.05
15. Shitaochi	„	22.30	1.38	6.35
16. Bron	„	22.25	1.47	7.70
17.Kamaloo	„	21.55	1.61	6.85
18. Kofi Nsarko	„	22.20	1.52	6.85
19. Kowoka	„	21.90	1.56	6.95
20. Broni fufuo	„	21.85	1.57	7.00
Mean		21.08	1.42	6.7
SED		0.14	0.15	0.30
CV(%)		1.41	1.89	3.74

Table 6: Linear correlations between the fatty acids and oleic/linoleic acid ratio

	Palmitic	Stearic	Oleic	Linoleic	Arachidic	Eicosenoic	Behenic	Lignoceric	O/L
Palmitic	0.458	-0.946**	0.926**	0.388	-0.731**	0.560**	-0.244	-0.918**	
Stearic		-0.299	0.233	0.844**	-0.806**	-0.119	-0.474	-0.215	
Oleic			-0.996**	-0.288	0.599**	-0.728**	0.068	0.983**	
Linoleic				0.238	-0.562**	0.729**	-0.053	-0.984**	
Arachidic					0.788**	-0.010	0.576**	-0.220	
Eicosenoic						-0.010	0.576**	0.548**	
Behenic							0.307	-0.730**	
Lignoceric								0.018	

** Significant at $p<0.01$

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