Variability in Oil Quality Among Peanut Genotypes in the Florida Breeding Program[1]

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ABSTRACT

The improvement of peanut (*Arachis hypogaea* L.) oil quality has long been an objective of the Florida breeding program, since it influences the shelf-life and nutritional quality of manufactured products. Fatty acid distribution of the peanut genotypes (228 in 1984 and 298 in 1985) from the Gainesville and Marianna locations was determined by gas-liquid chromatography. A wider range in fatty acid composition, especially in oleic and linoleic acids, was found among these genotypes than that reported previously in the literature for the cultivated peanut. Two closely related experimental lines (435-2--1 and 435-2--2) had 80% oleic and 2% linoleic acid, with iodine values of 74. For the Florida breeding lines, iodine values of the oil ranged from 74 to 107 and the oleic/linoleic (O/L) ratios from 0.9 to 35:1. Florunner, by comparison, has an iodine value of 95 and an O/L ratio of slightly less than 2. The oleic acid content of the different experimental lines ranged from 37% to 80%, and the linoleic acid content from 2% to 43%. The magnitude of this variability permits the development of peanut cultivars with a range of oil composition for improved nutritional and industrial purposes. All the oil quality factors were highly significantly affected by genotype, and all but three of the factors were significantly affected by season.

Key Words: *Arachis hypogaea* L., fatty acids, diet, germplasm, peanut breeding, edible oils.

Peanuts (*Arachis hypogaea* L.) are grown worldwide in the tropic and temperate zones primarily for the seed oil, but in the United States peanuts are used mainly for human foods such as peanut butter, roasted seed and confections. The final quality of edible peanuts is due principally to the chemical composition of the oil, protein and carbohydrate fractions of the seed. Since fatty acids make up the major portion of the weight of an oil molecule, the physical and chemical properties of the oil tend to be determined by the properties of the fatty acids which predominate in their makeup. Therefore, it is important, from a practical standpoint, to know the proportion of the different fatty acids which constitute the oil.

During the first National Peanut Research Conference (February 21-22, 1957), a paper was presented by B. B. Higgins (4) of the Georgia Experiment Station, entitled, "Relation of breeding and varieties to quality for specific uses". He wrote, "Until quite recently most chemists have given little consideration to varietal differences in planning and reporting their studies of peanut composition. Peanuts were just peanuts and peanut oil was considered a constant entity until changed by development of some type of rancidity". Unfortunately this statement still holds true to a large extent today, especially in animal and human nutrition studies, despite the fact that wide ranges in oil quality have been reported within peanut and other oil crop species (5, 6).

Although as many as 12 fatty acids have been reported in peanuts, only three are present in amounts exceeding 5%: palmitic, oleic and linoleic (1). These three acids comprise about 90% of the fatty acid composition of the oil, with oleic and linoleic comprising about 80%. The remainder of the fatty acids comprise about 10%, each ranging in concentration from 0.02% to 3.59%.

Reports of studies since 1970 on the genetic variability in fatty acid composition of peanut genotypes have shown that the range of composition of the different acids is greater than recognized previously (2, 14, 15, 16). For example, peanut genotypes are now known with as low as 21% oleic and as high as 43% linoleic acid (14).

Bovi (2) sub-divided 100 peanut genotypes from the Florida breeding program into three maturity groups and into four U.S. market types. She found large variation in oil quality within each market type and/or maturity group, and concluded that it should be possible to select genotypes from within each maturity or market type with oil qualities to suit particular industrial or dietary needs.

Cobb and Johnson (3) pointed out that several factors affect the fatty acid composition of peanut oil: variety, seasonal variation, the part of the seed analyzed and abnormalities such as diseases and insect damage. The production location and/or temperature conditions under which the crop is grown can also affect the fatty acid composition (2, 5, 10, 12). Seed developing in lower temperatures contain a more unsaturated oil because of the increased activity of oleate desaturase, the enzyme responsible for the proportion of oleic to linoleic acid (12). Bovi (2) obtained a negative correlation between iodine value and soil temperature and suggested that the chemical composition of peanut oil could be altered by adjusting the planting date.

This study was designed to examine the variation in oil quality among peanut genotypes, including several commercial cultivars and plant introductions, from the Florida breeding program in 1984 and 1985. The relative effect of genotype and year on the oil quality traits of 32 genotypes was also determined.

Materials and Methods

The fatty acid composition of a total of 494 peanut genotypes from the Florida breeding program (1984 and 1985 crops) was determined by gas-liquid chromatography using the saponification-transesterification procedures of Metcalf *et al.* (8). Of the 228 genotypes and analyzed from the 1985 season, 118 were from the Marianna, Florida location and 110 from the Gainesville location. The 298 genotypes from the 1985 crop included 147 from Marianna and 151 from Gainesville. Thirty-two genotypes at the Gainesville location were common to both years. The majority of the genotypes selected for analyses were advanced breeding lines having good yield and marketability po-

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tential. A few cultivars and plant introductions were also included. All of the genotypes had been under experimental observation at the respective locations for several years.

The peanut genotypes were grown in accordance with recommended cultural practices. The seed were planted during the months of April and May and plants were harvested when judged to be mature based on the general condition of the plants as well as the color of the seedcoat and the the inner side of the pod. Irrigation water was applied as needed to the Gainesville location.

Randomly selected samples of unshelled pods were obtained from each genotype and only sound mature seed were included for fatty acid analyses. Data obtained on the individual fatty acid were used to calculate the total of three long-chain saturated acids (C20:0 + C220:0 + C24:0), the polyunsaturated to saturated acid ratio (P/S), the oleic/linoleic acid ratio (O/L), and iodine value.

The 32 common genotypes were analyzed statistically across years to determine the effect of season on the expression of the different oil quality traits. In all but one of the oil quality traits (lignoceric C24:0) the test of non-additivity of the error term was non-significant, indicating that only for the percent lignoceric acid was the transformation of data necessary. The analysis of variance of the transformed data for lignoceric acid however, did not change the relative significance, and therefore the non-transformed data are presented.

Genetic variability, a requisite for varietal improvement, is generally the first concern of plant breeders. Thus, in this paper we have included only the values for the six genotypes having the highest and the six having the lowest levels of the twelve oil quality traits to illustrate the range in variability without making the paper excessively long.

Results and Discussion

Genotype variation

The six peanut genotypes having the highest and the six genotypes having the lowest percentages of the saturated fatty acids (palmitic C16:0, stearic C18:0 and arachidic C20:0) are presented in Table 1 along with the percentage for the commercial cultivar, Florunner. Table 2 presents similar results for the two long-chain fatty acids, behenic C22:0 and lignoceric C24:0, and the total for the three long-chain fatty acids (C20:0 + C22:0 + C24:0), as well as the percentages for Florunner.

The range in the percent of the saturated fatty acids found among the peanut genotypes in the Florida program was not widely different from the ranges reported in other lines by other investigators (1, 14, 15). High levels (5-6%) of the long-chain saturated fatty acids, arachidic and behenic, are undesirable as they were suggested as being the responsible toxic element for enhancing atherosclerosis in rabbits fed diets utilitizing peanut oil (9).

In rapeseed, the levels of long-chain fatty acids have been lowered to essentially zero by plant breeding. However, the biochemical changes responsible for the absence of long-chain fatty acid formation are not known (12). The reduction or elimination of the long-chain fatty acids in peanut oil would be a worthwhile objective of peanut breeding programs since it might also increase the polyunsaturated to saturated (P/S) ratio. The American Heart Association and the American Health Foundation have recommended diet modifications to achieve lower serum cholesterol levels in the population. These diet modifications include reducing consumption of saturated fatty acids and thereby increasing the P/S ratio in the diet (13).

The six genotypes having the highest and the six having the lowest levels of concentration of the unsaturated fatty acids (oleic C18:1, linoleic C18:2, and eicosenoic C20:1) are presented in Table 3, along with the data for the Florunner check. In Table 4 the ratios of the polyunsaturated/saturated acids and the oleic/linoleic

Table 1. Variation in oil quality traits (palmitic, stearic and arachidic acids) among selected peanut genotypes from Gainesville and Marianna Florida plantings in 1984 and 1985.

Oil quality trait	Level of concentration of oil quality trait					
	High			Low		
	Lab. no.[a]	Genotype	%	Lab. no.[a]	Genotype	%
Palmitic acid C16:0	1-a-78	574B-6-	12.87	2-a-119	393-7-1-	6.63
	1-a-55	545B-1-1-	12.24	2-a-59	625B-4-1-	7.11
	2-a-21	558A-5-5-	12.22	2-a-151	435-2--2	7.16
	1-a-31	PI459096	12.15	2-a-58	625B-4-1-	7.31
	1-a-2	Dixie Run.	12.11	2-a-8	435-2--1	7.35
	2-a-143	636B-3-1	12.06	2-a-94	639B-7-3-	7.46
	Check[b]	Florunner	10.08			
Stearic acid C18:0	1-g-27	81206	4.88	1-a-69	563B-19-	1.69
	1-a-14	NC-FLA-14	4.72	1-a-86	607B-1-	1.75
	2-a-21	558A-5-5-	4.66	2-g-118	72x39B-3-	1.76
	2-a-124	PI 475849	4.62	2-a-24	563B-2-2-	1.80
	1-a-30	J. Jumbo	4.44	1-a-3	78114	1.80
	2-a-118	V803-1-1-	4.40	1-a-49	479A-5-	1.81
	Check[b]	Florunner	2.35			
Arachidic acid C20:0	2-a-125	PI 475870	2.05	1-a-69	563B-19-	1.03
	2-a-124	PI 475849	1.99	2-a-110	642B-3-2	1.05
	2-g-39	81206	1.98	1-a-86	607B-1-	1.06
	1-g-17	72x93-10-	1.87	2-g-55	76x5-1-2-	1.07
	2-a-59	625B-4-1-	1.87	1-a-49	579A-5-	1.07
	2-a-123	U.S. #29	1.86	1-a-100	647A-5-1-	1.08
	Check[b]	Florunner	1.22			

[a] The first part of the laboratory number refers to the year the crop was grown (1=1984, 2=1985); the second part to location (a=Gainesville, g=Marianna); and the last part of the number is that assigned to the seed sample in the laboratory.

[b] Oil quality data for the Florunner check is the mean of six samples representing both locations in 1984 and in 1985.

Table 2. Variation in oil quality traits (behenic, lignoceric acids and total of three along chain acids) among selected peanut genotypes from Gainesville and Marianna Florida plantings in 1984 and 1985.

Oil quality trait	Level of concentration of oil quality trait					
	High			Low		
	Lab. no.[a]	Genotype	%	Lab. no.[a]	Genotype	%
Behenic acid C22:0	2-g-106	72x83B-7-	4.82	2-a-11	537B-6-	2.30
	1-a-104	602A-4-	4.81	2-a-128	546B-1-4-	2.35
	1-g-18	72x93-10-	4.72	2-g-9	72x78-1-1-	2.39
	1-a-23	PI 468206	4.58	2-a-26	570A-1-1-	2.42
	1-g-90	81206	4.58	2-g-147	72x78-2-2-	2.44
	2-a-34	602A-4-	4.52	1-a-30	J. Jumbo	2.44
	Check[b]	Florunner	2.98			
Lignoceric acid C24:0	1-a-69	563B-19-	2.46	1-a-30	J. Jumbo	1.05
	2-a-79	636B-1-2-	2.41	2-a-26	570A-1-1-	1.12
	2-g-106	72x83B-7-	2.33	2-a-21	558A-5-5-	1.15
	2-a-125	PI 475870	2.28	2-a-118	803-1-1-	1.16
	1-a-18	Makulla Red	2.25	2-a-11	537B-6-	1.17
	2-g-118	72x39B-3-	2.21	2-a-22	560A-1-2-	1.21
	Check[b]	Florunner	1.75			
Total of 3 long chain acids C20:0+ C22:0+ C24:0	2-a-125	PI 475870	8.64	2-a-11	537B-6-	4.76
	2-g-106	72x83B-7-	8.63	2-a-26	570A-1-1-	4.92
	1-g-18	72x93-10-	8.61	2-a-108	641B-4-1-	4.93
	1-g-90	81206	8.20	2-g-9	72x78-1-1-	4.97
	2-g-84	72x93-9-	7.98	2-a-109	641B-5-2-	4.99
	1-a-104	602A-4-	7.96	2-a-22	560A-1-2-	4.99
	Check[b]	Florunner	5.95			

[a] The first part of the laboratory number refers to the year the crop was grown (1=1984, 2=1985); the second part to location (a=Gainesville, g=Marianna); and the last part of the number is that assigned to the seed sample in the laboratory.

[b] Oil quality data for the Florunner check is the mean of six samples representing both locations in 1984 and in 1985.

ratio, and the iodine values are presented. The dilemma facing peanut breeders can be visualized from these two tables since cultivars must satisfy both the requirement of the manufacturer, which is stability of the processed product, and the consumer demand of an increased P/S ratio. In Table 4 the two breeding lines, 435-2--1 and 435-2--2, have higher levels of oleic acid than that previously reported for peanuts. The oleic/linoleic (O/L) ratio of near 35 for these lines is much higher than the ratio of 1.0 to 4.0 usually reported for peanut, whereas the polyunsaturated to saturated (P/S) ratio for these lines was the lowest among the genotypes. The interrelationships of the peanut oil quality traits is very evident in Table 4 where it may be noted that the six genotypes with the lowest P/S ratio are the same genotypes with the lowest iodine value. The fact that the Florunner cultivar generally scores close to midway between the highest and lowest genotypes in its level of oil quality traits may partly explain its acceptability by both processors and consumers.

Table 3. Variation in oil quality traits (oleic, linoleic and eicosenoic acids) among selected peanut genotypes from Gainesville and Marianna Florida plantings in 1984 and 1985.

Oil quality trait	Level of concentration of oil quality trait					
	High			Low		
	Lab. no.[a]	Genotype	%	Lab. no.[a]	Genotype	%
Oleic acid C18:1	2-a-8	435-2--1	79.91	2-a-72	631B-16-1-	36.72
	2-a-151	435-2--2	79.71	2-g-35	76x4A-3-4-	36.78
	2-a-119	393-7-1-	66.52	2-a-25	567A-2-1-	37.04
	1-a-14	NC-FLA-14	65.34	2-a-46	607B-2-4-	37.13
	1-a-73	427BV-18	63.40	2-g-103	76x16-4-1-	37.20
	1-g-90	81206	63.21	2-g-5	570A-3-2-	38.21
	Check[b]	Florunner	51.07			
Linoleic acid C18:2	2-g-103	76x16-4-1-	43.14	2-a-8	435-2--1	2.14
	2-g-35	76x4A-3-4-	42.68	2-a-151	435-2--2	2.29
	2-a-72	631B-16-1-	42.30	1-g-90	81206	15.28
	2-g-14	76x4A-3-4-	42.26	1-a-14	NC-FLA-14	15.44
	2-a-46	607B-2-4-	41.40	2-a-119	393-7-1-	16.66
	2-a-25	567A-2-1-	41.34	1-g-8	76x5-5-2-	18.59
	Check[b]	Florunner	29.21			
Eicosenoic acid C20:1	1-a-69	563B-19-	1.90	2-g-71	72x93-10-	0.34
	2-a-8	435-2--1	1.81	1-a-31	PI 459096	0.75
	2-g-141	72x93-6-1-	1.80	2-a-21	558A-5-5-	0.77
	2-a-142	639A-16-1-	1.73	1-a-30	J. Jumbo	0.83
	2-a-151	435-2--2	1.72	2-a-22	560A-1-2-	0.84
	1-a-34	639B-5-1-	1.71	1-a-2	Dixie Run.	0.84
	Check[b]	Florunner	1.35			

[a] The first part of the laboratory number refers to the year the crop was grown (1=1984, 2=1985); the second part to location (a=Gainesville, g=Marianna); and the last part of the number is that assigned to the seed sample in the laboratory.

[b] Oil quality data for the Florunner check is the mean of six samples representing both locations in 1984 and in 1985.

New findings in nutrition and changing trends in peanut marketing project a brighter future for the utilization of peanut cultivars with widely different nutritional and chemical quality traits. For example, recent research has indicated that the high levels of the monounsaturated oleic acid, as present in olive oil, is as effective as the polyunsaturated linoleic acid in lowering the blood plasma cholesterol (7). The oleic acid levels in the two experimental peanut lines 435-2--1 (79.91%) and 435-2--2 (79.71%) are comparable to the oleic acid level in olive oil.

Table 4. Variation in oil quality traits P/S and O/L ratios and iodine value) among selected peanut genotypes from Gainesville and Marianna Florida plantings in 1984 and 1985.

Oil quality trait	Level of concentration of oil quality trait					
	High			Low		
	Lab. no.[a]	Genotype	Ratio	Lab. no.[a]	Genotype	Ratio
Polyunsatured to saturated acid ratio P/S	2-g-103	76x16-4-1-	2.333	2-a-8	435-2--1	0.138
	2-g-14	76x4A-3-4-	2.227	2-a-151	435-2--2	0.141
	1-a-86	607B-1-	2.198	1-g-27	81206	0.755
	2-g-145	72x112-4-	2.196	1-a-14	NC-FL 14	0.848
	2-g-140	72x38-1-3-	2.188	2-a-90	639A-1-9-	1.024
	2-g-131	72x38-8-2-	2.158	2-g-81	72x94-7-1	1.024
	Check[b]	Florunner	1.59			
Oleic/Linoleic acid ratio O/L	2-a-8	435-2--1	37.34	2-g-35	76x4A-3-4-	0.861
	2-a-151	435-2--2	34.81	2-g-103	76x16-4-1-	0.862
	1-a-14	NC-FLA-14	4.23	2-a-72	631B-16-1-	0.868
	1-g-90	81206	4.14	2-a-25	567A-2-1-	0.895
	2-a-119	393-7-1-	3.99	2-a-46	607B-2-4-	0.897
	1-g-8	76x5-5-2-	3.37	2-g-5	570A-3-2-	0.931
	Check[b]	Florunner	1.77			
Iodine value	2-g-103	76x16-4-1-	107.64	2-a-151	435-2--2	73.87
	2-g-14	76x4A-3-4	106.46	2-a-8	435-2--1	73.93
	2-a-72	631B-1-6-	105.61	1-g-90	81206	81.84
	1-a-86	607B-1-	105.48	1-a-14	NC-FLA 14	83.73
	2-g-140	72x38-1-3-	105.23	2-a-90	639A-1-9-	86.52
	1-g-40	74x36-6-1-	105.19	2-g-80	72x94-7-1-	86.58
	Check[b]	Florunner	95.58			

[a] The first part of the laboratory number refers to the year the crop was grown (1=1984, 2=1985); the second part to location (a=Gainesville, g=Marianna); and the last part of the number is that assigned to the seed sample in the laboratory.

[b] Oil quality data for the Florunner check is the mean of six samples representing both locations in 1984 and 1985.

The high oleic, low linoleic levels in these two 435 peanut lines may have occurred as a result of a natural mutation. Changes of this magnitude were induced by artificial irradiation of peanuts by Sharma *et al.* (11) who produced 61% oleic acid in mutants from a parental line with 39% oleic acid.

The two 435 genotypes were derived from a seed sample received in 1959 from W. K. Bailey, former Leader, Peanut Investigations, USDA, ARS, CRD, Beltsville, Maryland. The original seed stock was a Florispan derivative, but because of its variation in seed characteristics from Florispan there is the possibility of a spanish outcross. In seven earlier years (1968-1974) of oil quality tests, the 435 parental stock had 50.8 $\mp$ 1.3% oleic and 26.2 $\mp$ 1.2% linoleic acid in its oil composition. The iodine value of the oil of 435 in these seven early years was 91.3 $\mp$ 1.3.

There are other crop plants where major genes at one locus change the relative amounts of oleic and linoleic. For example, in safflower high linoleic is dominant, but two different alleles give either 75% or 45% oleic in homozygous recessives (12). Since oleate is the precursor of both long-chain and polyunsaturated fatty acids, the differences in relative amounts of these fatty acids are presumed to be the result of differences in the relative rates of synthesis and metabolism of oleate. The genetic constitution of the embryo determines proportions of the different fatty acids synthesized, and there is no maternal effect (12).

The iodine value (IV) is a measure of oil chemical stability, with oils having higher IV being more unsaturated and chemically less stable. Iodine values among the Florida peanut genotypes (Table 4) ranged from

levels comparable to olive oil (78-86) to those similar to corn (103-130) and cottonseed (103-115) oil. Worthington and Miller (17) found that corn oil containing 60% linoleic acid was superior to peanut oil with 32% linoleic acid in lowering the ratio of low density lipoproteins to high density lipoproteins (LDL/HDL) in growing rats. Since the linoleic acid content of corn oil ranges from 34 to 61% (5, 6), it would be of interest to compare the animal response to peanut and corn oil having similar levels of linoleic acid, for example in the area of 40% linoleic.

Year variation

All of the components of peanut oil quality in this study were highly affected by genotype (Tables 5 and 6). Year had a significant effect on all but three of the oil quality traits, the long-chain lignoceric acid (C24:0), eicosenoic acid (C20:1), and the total of the three long-chain saturated acids (C20:0 + C22:0 + C24:0). The effect of year on the oil quality traits obtained in this research is similar to that reported by other investigators (1, 2, 3, 10).

Table 5. Analysis of variance of the fatty acid composition of 32 peanut genotypes from 1984 and 1985 experimental plantings at Gainesville, Florida.

		Mean squares with level of significance[a]							
		Fatty acid							
Variable	Df	C16:0	C18:0	C18:1	C18:2	C20:0	C20:1	C22:0	C24:0
Year	1	9.242**	1.809**	95.893**	61.564**	0.495**	0.003NS	0.706**	0.024NS
Genotype	31	1.873**	0.573**	74.239**	59.813**	0.055**	0.062**	0.341**	0.092**
Error	31	0.260	0.100	5.066	4.123	0.008	0.009	0.040	0.013
Coefficient of variation	(%)	5.17	11.83	4.81	6.18	6.65	7.19	5.78	6.42
		Fatty acid composition (%)							
1984 mean		10.24	2.51	45.53	33.82	1.29	1.31	3.55	1.76
1985 mean		9.48	2.85	47.98	31.85	1.47	1.32	3.34	1.72
Grand mean		9.86	2.68	46.75	32.83	1.38	1.31	3.44	1.74
Range									
High genotype		11.42	3.94	61.60	39.93	1.82	1.68	4.67	2.14
Low genotype		8.00	2.07	38.95	20.94	1.15	0.92	2.64	1.37

[a] NS, *, **, Analysis of variance component is non-significant and significant at the .05 and .01 levels of probability, respectively.

Summary

A wider range in fatty acid composition, especially in oleic and linoleic acids, was found among peanut genotypes in the Florida breeding program than that reported previously in the literature for the cultivated peanut. Two closely related experimental lines (435-2--1 and 435-2--2) had 80% oleic and 2% linoleic acid, with iodine values of 74. For the Florida breeding lines, iodine values of the oil ranged from 74 to 107 and the oleic/linoleic (O/L) ratios from 0.9 to 35:1. Florunner, by comparison, has an iodine value of 95 and an O/L ratio of slightly less than 2. The oleic acid content of the different experimental lines ranged from 35% to 80%, and the linoleic acid content from 2% to 43%. This variability permits the development of peanut cultivars with a wider range of oil composition for improved nutritional and industrial purposes.

Table 6. Analysis of variance of the oleic/linoleic (O/L) and polyunsaturated/saturated (P/S) ratios, iodine values and total long chain fatty acids (C20:0, C22:0, C24:0) of 32 peanut genotypes from 1984 and 1985 plantings at Gainesville, Florida.

		Mean squares with level of significance[a]			
Variable	Df	O/L Ratio	P/S Ratio	Iodine Value	Tot. Long Chain acids (%) 20:0+22:0+24:0
Year	1	0.503**	0.056*	26.368**	0.089NS
Genotype	31	0.479**	0.122**	39.030**	0.735**
Error	31	0.045	0.010	2.876	0.110
Coefficient of variation	(%)	14.06	6.07	1.73	5.06
1984 mean		1.42	1.64	98.76	6.60
1985 mean		1.60	1.58	97.48	6.53
Grand mean		1.51	1.61	98.12	6.57
Range					
High genotype		2.98	1.96	104.42	8.13
Low genotype		0.99	1.18	90.22	5.36

[a] NS, *, **, Analysis of variance component is non-significant and significant at the .05 and .01 levels of probability, respectively.

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