Seasonal Variation in the Composition of California Avocados

Grant G. Slater,* Solomon Shankman, John S. Shepherd, and Roslyn B. Alfin-Slater

A representative sample of the 1968–1969 California avocado crop was analyzed, using standard techniques, at approximately 8, 12, 16, and 20% fat for the Fuerte variety and at 16 and 20% fat for the Hass variety. In addition to the fat measurement, the content of water, fiber, protein, 7 fatty acids, 11 vitamins, and 17 minerals was determined at each fat level. A serving of Fuerte avocado (80.8 g) was found to have 132 calories. Correlation among the fat, water, protein, and ash in the Fuerte resulted in the following: % water = 89.49 − % fat; % fiber = 3.45 − 0.0735% fat; % protein = 1.483 + 0.052% fat; and % protein = 5.807 − 0.048% water, in the range from 8 to 22% fat. The percent of the Recommended Dietary Allowance (RDA) (1974) for children, provided by one-half of a Fuerte avocado (80.8 g), was found to vary from 1% for calcium to 19% for vitamin E; however, most nutrients were supplied at 6–11% of the RDA for all major age and sex groups.

In 1967 the Nutritional Research Committee of the California Avocado Advisory Board recommended that a representative sample of the whole California avocado crop be analyzed to provide nutritionists with accurate data upon which to base evaluations on the use of avocados. Since about 90% of all California avocados found in the market are the Fuerte and Hass varieties, analysis of these two would be representative of the whole crop. It was decided that samples should be taken from all growing areas within California in order to average variances in the soil, climate, fertilizers, and tree selection, and this was done. Furthermore, not only were the Fuerte and Hass specimens analyzed separately, but the Fuerte avocados were measured at four times during their harvesting period and the Hass twice, so that the nutrient content would be known for the different stages of maturity of the product.

Although new analyses have continued to be made on avocados, recent literature still quotes values reported more than 15 years ago. Thus, the recent Life Science Book "Food and Nutrition" (Sebrell and Haggerty, 1967) used the data in Wooster (1958) which was taken from USDA Circular No. 549 in 1940 by Chatfield and Adams. Improvements in techniques, standards, and food technology indicate the need for this new analysis which attempts to quantitate all the important nutrients found in avocados, from a sample representing the average California avocado.

EXPERIMENTAL SECTION

Sampling. The Calavo Growers of California (1958), from whom the avocados were obtained, have records from each packing house on the ratio of size to fat content, since by law avocados with less than 8% fat cannot be sold; thus, it was possible to select avocados of an approximate oil content by size. The maximum oil content of avocados as commercially marketed is about 20%; therefore, the most typical avocado, the Fuerte, was sampled at 8, 12, 16, and 20% oil while the less common variety, the Hass, was collected at 16 and 20% fat. The packing house records were used to select avocados from each of the five commercial California districts to make a sample representative of the total crop for each of the varieties based on a study by the Giannini Foundation (1968). Collections were made of each variety of fruit for a total of 700 avocados. Boxes of about 24 fruits were shipped to the Shankman Laboratories, Los Angeles, Calif., as soon as picked. In the laboratory 15 of the 24 avocados were randomly selected from each box. A 90° arc segment was cut from the same area in the side of the avocado, the slices were peeled, and all 15 pieces combined, ground, and then refrigerated at 4° until analyzed.

Analysis. Standardized methods as published in the 10th edition of the Official Methods of Analysis of the Association of Official Agricultural Chemists (AOAC) or Methods of Assay of the Association of Vitamin Chemists (AVC), 2nd and 3rd editions, were used in most analyses. Duplicate samples were used except in the case of the microbiological assays of two vitamins (see below), where five concentrations were measured from a single weighing. The ranges of values are those found for similar vitamin assays in the Shankman Laboratories. Water was determined by subjecting the sample to a vacuum at 16° for 16 hr (AOAC, p 346). Fat was extracted with petroleum ether (AOAC, p 352) and a slight modification of the standard method was used in measuring the fiber content (AOAC, p 352). A semi-microdistillation was used for the nitrogen in the determination of protein (AOAC, p 16). Fatty acids were done by gas chromatography after methyl esters were prepared from separated fatty acids, with methanol-BF_3 reagent (AOAC, p 430) and the areas under the peaks were measured by triangulation. The minerals were assayed using a semiquantitative spectrographic method on the ash by Pacific Spectrochemical Laboratories, Los Angeles, Calif.; the spectrographic method may have variability as high as ±50%.

To avoid loss of some of the more labile vitamins, the determination of ascorbic acid (AVC, 1951, p 87) was made within 24 hr of cutting the fruit, and carotene (AOAC, p 758) was measured within 48 hr. Impurities were removed from thiamine using a Decalso column after enzymatic digestion (AOAC, p 765). Enzymatic digestion of the carbohydrates was used in preparing samples of riboflavine and pyridoxine analysis (AVC, 1966, p 212). In the titrimetric assay of niacin (AVC, 1966, p 172) a modified medium was used that contained 2% potassium acetate and 3% dextrose after final dilution instead of sodium acetate, since potassium in the medium is less toxic and permits a longer linear growth of the organisms. The pantothenate, titrimetric method (AVC, 1966, p 201) utilized alkaline phosphatase and chicken liver enzymes. Biotin (AVC, 1966, p 247) was also measured using a titrimetric method. The microbiological method for folic acid (AVC, 1966, p 227) used *Streptococcus fecalis* 8043 and a chicken pancreas enzyme followed by turbidometry. Choline (AVC, 1966, p 415) was assayed by the Lim and Schall procedure. Tocopherol by the Rasmussen and Hjarde

Division of Environmental and Nutritional Science, School of Public Health, University of California, Los Angeles, California 90024 (G.G.S., R.B.A.S.), Shankman Laboratories, Los Angeles, California 90021 (S.S.), and Calavo Growers of California, Los Angeles, California, 90051 (J.S.S.).

Table I. Percent Composition of California Avocados[a]

	Fuerte						Hass			
Component	10/22/68[b]	2/13/69	12/7/68	4/5/68	Av	Serv,[c] g/80.8 g	4/5/68	6/4/68	Av	Serv.,[c] g/80.8 g
Fat (±0.5)[d]	8.3	12.1	17.1	22.8	15.1	12.2	17.6	21.8	19.5	15.8
Water (±0.5)	81.4	76.0	74.2	65.8	74.4	60.1	71.5	68.4	70.0	56.6
Fiber (±0.2)	3.03	2.25	2.28	1.80	2.34	1.89	2.20	2.80	2.50	2.02
Protein (±0.4)	1.95	2.04	2.40	2.66	2.26	1.83	2.40	2.37	2.39	1.93
Ash (±0.15)	1.20	0.95	1.34	1.38	1.22	0.99	1.18	2.10	1.64	1.33
Carbohydrates (by difference)	4.1	6.7	2.7	5.6	4.8	3.9	5.1	3.0	4.1	3.3
Calories per 100 g	99	143	174	237	163		187	213	200	
Calories per 80.8 g	80	115	141	191	132	132	151	172	162	162

[a] Average of two determinations on the ripe edible pulp from a composite sample of 15 avocados. [b] Date fruit arrived at Shankman Laboratories. [c] A serving is one-half an average avocado = 3.75 oz × 76% (edible) = 2.85 oz or 80.8 g. An average California avocado weighs 213 g. [d] Range of similar measurements in Shankman Laboratories.

Table II. Fatty Acids of California Avocados[a]

	Fuerte					Hass		
Component	10/22/68[b]	2/13/69	12/7/68	4/5/68	Av	4/5/68	6/4/68	Av
			As Percent of Total Fatty Acids					
Saturated[c]								
Palmitic	16.5	12.1	10.0	10.6	12.3	16.1	4.1	10.1
Stearic	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1
Subtotal	16.5	12.1	10.0	10.6	12.3	16.2	4.1	10.2
Unsaturated[c]								
Palmitoleic	5.9	1.9	1.3	4.8	3.5	7.4	0.5	4.0
Oleic	71.8	73.9	82.2	72.5	75.1	63.5	93.3	78.4
Linoleic	6.0	10.5	6.6	11.2	8.6	12.2	2.2	7.2
Linolenic[d]	0.0	0.7	0.1	0.8	0.4	0.8	0.0	0.4
Arachidonic	0.1	0.1	0.0	0.0	0.1	0.0	0.0	0.0
Subtotal	83.7	87.1	90.2	89.3	87.7	83.9	96.0	90.0
Total	100.2	99.2	100.2	99.9	100.0	100.1	100.1	100.2
Ratio unsat./sat.[e]	5.1	7.2	9.0	8.4	7.4	5.2	23.4	14.3
Ratio P/S[f]	0.36	0.93	0.67	1.13	0.73	0.80	0.53	0.75
			As Percent of Pulp[g]					
Saturated								
Palmitic	1.34	1.44	1.68	2.36	1.71	2.77	0.85	1.81
Stearic	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.01
Unsaturated								
Palmitoleic	0.48	0.23	0.22	1.07	0.50	1.27	0.11	0.69
Oleic	5.81	8.79	13.81	16.17	11.15	10.93	19.40	15.16
Linoleic	0.48	1.25	1.11	2.49	1.33	2.10	0.46	1.28
Linolenic	0.00	0.08	0.01	0.18	0.07	0.14	0.00	0.07
Arachidonic	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00

[a] Average of two determinations on the ripe fruit from a composite sample of 15 avocados. [b] Date fruit arrived at Shankman Laboratories. [c] The range of error estimated by Dr. Shankman as ±0.7%. [d] Plus related acids. [e] Unsaturated fatty acids/saturated fatty acids. [f] Polyunsaturated fatty acids/saturated fatty acids. [g] The unsaponifiable fraction was not determined so 2% of the total fat has been assumed to be due to non-fatty acid content.

method (1957) was done on avocado oil which was kept frozen at −20° until assayed. The color reagent $FeCl_3$–dipyridyl used in this analysis was made using glacial acetic acid instead of the usual ethanol. This reagent is preferred since it is light insensitive compared to the ethanol reagent.

RESULTS

The percentage compositions of the major nutrients of the edible pulp of the Fuerte and Hass avocados at various levels of lipid content are shown in Table I. The caloric content is also listed as calculated using the values of 9 kcal/g of fat and 4 kcal/g for protein and carbohydrate. Average values for each variety are shown per 100 g of pulp and for 80.8 g which has been estimated to be an average serving of avocado.

In Table II are shown the fatty acids as percent of the total fatty acids and as percent of the edible pulp; furthermore, the table contains the ratio of unsaturated to saturated fatty acids for each variety and for each time period tested. From these same samples the content of vi-

Table III. Vitamins of California Avocados[a] (per 100 g)

Component, unit	Fuerte					Hass			Reported for avocados[c]
	10/22/68[b]	2/13/69	12/17/68	4/5/68	Av	4/5/68	6/4/68	Av	
Fat soluble									
β-Carotene (vit. A), IU	410	370	545	610	484 ± 50[d]	610	870	740 ± 50[d]	630[e]
α-Tocopherol (vit. E), IU	2.5	4.2	2.0	0.8	2.4 ± 0.5	1.4	1.7	1.6 ± 0.5	1.7[f]
Water soluble									
Ascorbic acid (vit. C), mg	4.0	7.2	4.8	7.0	5.8 ± 1.0	13.0	7.1	10.1 ± 1.0	1.6,[g] 30[e]
Biotin, μg	2.5	2.3	3.7	4.2	3.2 ± 1.0	2.9	3.5	3.2 ± 1.0	10,[h] 5.5F, 5.6H[i]
Choline, mg	21.0	15.0	12.0	22.2	17.6 ± 3.0	19.3	19.6	19.5 ± 3.0	
Folacin, μg	105	42	22	73	61 ± 10	62	61	62 ± 10	30F, 40H[i]
Niacin, mg	1.05	1.74	1.60	1.54	1.48 ± 0.20	2.30	2.42	2.36 ± 0.20	1.1,[g] 3.5[e] 1.45F, 2.16H[i]
Pantothenic acid, mg	0.78	0.95	0.96	0.82	0.87 ± 0.20	0.93	1.20	1.07 ± 0.20	0.25,[h] 0.9F, 1.14H[i]
Pyridoxine (vit. B_6), mg	0.26	0.20	0.19	0.22	0.22 ± 0.03	0.22	0.21	0.22 ± 0.03	0.61F, 0.62H,[i] 0.45[j]
Riboflavine (vit. B_2), μg	94	100	77	110	95 ± 15	160	140	150 ± 15	140–430[e,g,h,k] 220F, 230H[i]
Thiamine–HCl (vit. B_1), μg	100	78	125	110	103 ± 10	110	119	115 ± 10	60–240[k–m] 140H, 90H[i]

[a] Average of two determinations on the ripe edible pulp from a composite sample of 15 avocados, except folacin and riboflavine where five levels were determined from a single weighing. [b] Date fruit arrived in Shankman Labs. [c] F, Fuerte; H, Hass. [d] Range of similar measurements made in Shankman Labs. [e] USDA Bulletin No. 72, 1971. [f] Dicks, 1965. [g] Wooster, 1958. [h] Lassen et al., 1944a. [i] Hall, et al., 1955. [j] Polansky and Murphy, 1966. [k] Church and Church, 1970. [l] Lassen et al., 1944b. [m] Yearbook of the California Avocado Society, 1943.

tamins is shown in Table III and the minerals content of the ash in Table IV.

DISCUSSION

It is known that the water content of the avocado pulp decreases as the fat content increases (Appleman and Noda, 1941; Hall et al., 1955). In the data reported here the sum of percent water and fat is constant at 89.5% with a range of 88.1–91.3%. When the percent of water is plotted against the percent of the total lipid as shown in Figure 1, it is evident that they are inversely proportional to each other; thus, % water = 89.49 − % fat. While the line was drawn for the Fuerte, it appears that over the range measured it holds equally as well for the Hass. This relationship reveals that for a fat content from 8 to 22%, each gram of water lost from the pulp is replaced by a gram of fat.

The data of Polansky and Murphy (1966) show total solids as 30.5% at 20% fat; if one assumes that everything except total solids is water, 69.5%, then the relationship is substantiated. Likewise, in the study by Hall et al. (1955), where data on Hass for 1 year and 4 crop years of Fuerte were reported, of the 32 averages given, only one group of 7 Fuerte avocados was more than 2 times the standard error of the estimate from our curve. Also, the values for avocados in Wooster (1958) and USDA Bulletin No. 72 (1971) confirm this relationship.

The value of this relationship lies in the ability to analyze data where conditions of storage or treatment of the avocado are to be examined; thus, in the 61-day refrigeration test in the data of Hall et al. (1955), Table III, one can observe that only small changes have occurred to the avocados since the data points all fall within 2 times the standard error of the estimate of the regression line. It should also be possible to assume from their data that no serious dehydration has occurred in the study since the fat–water relationship remains intact.

The fiber content appears to decrease in the Fuerte and increase in the Hass with an increase in the fat content. This relationship is shown in Figure 2. The Fuerte line shows that % fiber = 3.45 − 0.0735 (% fat). The correlation of these two components is not as good as with water and fat; however, the correlation coefficient squared, r^2 = 0.82, indicates that much of the variation in fiber content can be related to the fat content. Thus, within the range of 8–22% fat content, the fiber in pulp is 0.07 g less for each gram increase in fat content of the Fuerte avocado. Qualitatively, the Hass shows an opposite effect in that it shows a small increase in fiber content with an increase in fat content.

The protein content of the Fuerte increases as the fat content increases (see Figure 3) with a high degree of correlation, r^2 = 0.98. The correlation is % protein = 1.483 + 0.052 (% fat). Thus, we see that for each gram increase in fat there is an increase in protein content of 0.052 g. As with the fiber, the protein relationship to fat in the Hass avocado appears to bear a different relationship than is seen for the Fuerte. However, it should be pointed out that from the 1953 crop Hall et al. (1955) found the Hass avocado to have 2.6% protein in fruit with 20% fat, while the Fuerte has 2.5% protein with 17% fat. The older literature (Jaffa and Goss, 1923) shows the protein content to be much less, i.e. 1.39% with a fat content of 24.77% and water content of 67.31%. While the source is not given, USDA Bulletin No. 72 (1971) lists California avocado protein as 2.32% for a fat content of 17.1% which value falls within the standard error of the estimate of the line for Figure 3.

Since the protein and fat content shows such good correlation in the Fuerte avocado, as does the fat and water

Table IV. Minerals in California Avocados[a] (mg per 100 g of Edible Pulp)

Mineral	Fuerte 10/22/68[b]	Fuerte 2/13/69	Fuerte 12/17/68	Fuerte 4/5/68	Fuerte Av	Hass 4/5/68	Hass 6/4/68	Hass Average	Ratio av H/F[c]	Reported for avocados
Potassium	640	410	670	500	555	436	1010	723	1.3	340,[d] 640[e]
Magnesium	18	30	27	87	41	64	63	64	1.6	41[f]
Phosphorus	25	32	28	34	30	28	55	42	1.4	38,[g] 42,[e] 80,[f] 21–64[h]
Silicon	4	2	9	70	21	51	10	31	1.5	
Calcium	7.0	11.0	7.0	13.0	9.5	9.3	15.0	12.0	1.3	10,[d,e,i] 13[f]
Sodium	6.0	12.0	7.0	11.0	9.0	11.0	18.0	15.0	1.7	3,[d] 4[e]
Iron	1.80	0.45	0.63	2.70	1.40	1.60	2.30	1.95	1.4	0.5–1.28[h] 0.6[d–f,i,j]
Boron	0.50	2.80	0.30	1.20	1.20	2.60	4.80	3.70	3.1	
Strontium	0.37	0.50	0.33	0.58	0.45	0.45	0.97	0.71	1.6	
Manganese	0.19	0.17	0.08	0.90	0.34	0.40	0.31	0.36	1.1	
Aluminum	0.40	0.08	0.60	0.19	0.32	0.32	0.23	0.28	0.9	
Copper	0.20	0.40	0.16	0.16	0.23	0.18	0.34	0.26	1.1	0.18[k]
Chromium	0.060	0.160	0.012	0.016	0.062	0.013	0.018	0.016	0.3	
Titanium	0.050	0.000	0.050	0.084	0.046	0.028	0.000	0.014	0.3	
Lithium	0.001	0.020	0.023	0.070	0.029	0.080	0.070	0.075	2.6	
Nickel	0.400	0.030	0.000	0.000	0.020	0.000	0.210	0.110	5.5	
Silver	0.003	0.008	0.000	0.000	0.003	0.000	0.000	0.000		
Min. total					670			894	1.3	
Av ash					1220			1640	1.3	
% min. in ash					55			55		

[a] The spectrographic analyses were done at the Pacific Spectrochemical Labs using a single composite ash sample from Shankman Labs made from 15 avocados. Dr. Shankman estimates the error of any determination to be as high as ±50%. [b] Date avocados arrived at Shankman Labs. [c] Hass/Fuerte. [d] Wooster, 1958. [e] Church and Church, 1970. [f] Yearbook of the California Avocado Society, 1943. [g] Lassen et al., 1945. [h] Munsell et al., 1950. [i] USDA Bulletin No. 72, 1971. [j] Stiebeling, 1958. [k] Giral and Castillo, 1953.

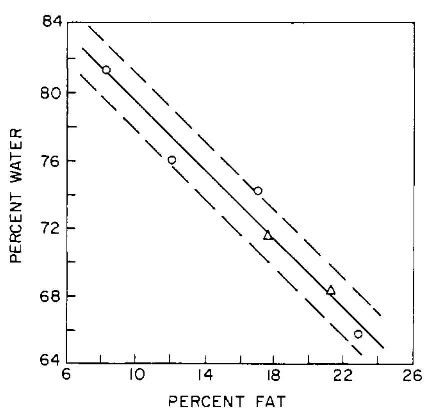

Figure 1. Correlation of fat and water content of the Fuerte and Hass avocados: dashed line is the standard error of the estimate; (O) Fuerte; (Δ) Hass.

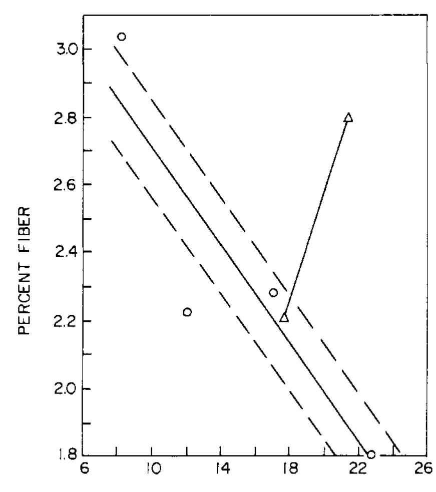

Figure 2. Correlation of fat and fiber content of Fuerte avocados: dashed line is the standard error of the estimate; (O) Fuerte; (Δ) Hass.

content, one would expect the water and protein to show good correlation as seen in Figure 4. The coefficient of determination, r^2, is 0.89 and the line is % protein = 5.807 − 0.048 (% water). Thus, we find the avocado must decrease its water content by about 20% to increase the protein content 1%. The Hass avocado values fall within 2 times the standard error of the estimate of the line.

The ash, Table I, is quite variable, although its concentration per 100 g of pulp appears to increase with increased fat content in both the Fuerte and the Hass, but the average value for the Hass is higher than the Fuerte, 1.64 vs. 1.22. The carbohydrate content shows no constant change with any other parameter, perhaps due to the fact that the amount of carbohydrate contained in the fruit is obtained by difference, and, therefore, subject to rather large variation.

The average fat content of 15.1% for Fuerte (composing about 75% of the crop) and 19.5% for Hass (composing about 25% of the crop) to give a rough average for the whole crop of 16.2% (Table I) compares well with a previous study of all California avocados by the Giannini Foundation (1968), in which a weighted average showed that 95% of the time the oil content, in harvested fruit, was 16% or below. Most studies have used single trees or a few trees from a single district. It should be noted that about 65–70% of California's avocados come from San Diego county where the lowest oil content usually occurs.

The calorie value of the avocado is almost entirely accounted for by its fat content so the causes of variation in fat are the causes of variation in caloric content. Thus, the caloric content increases with the age of the fruit reaching about the same amount in both the Fuerte and

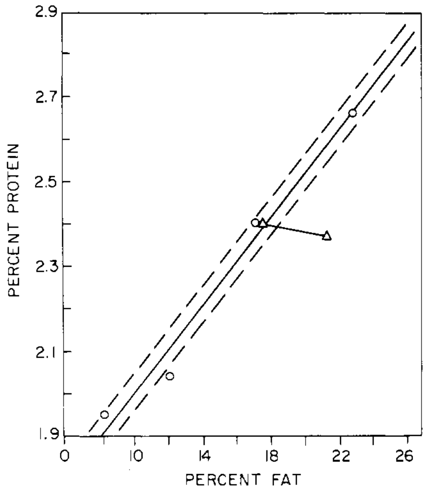

Figure 3. Correlation of fat and protein content of the Fuerte avocado: dashed line is the standard error of the estimate; (O) Fuerte; (Δ) Hass.

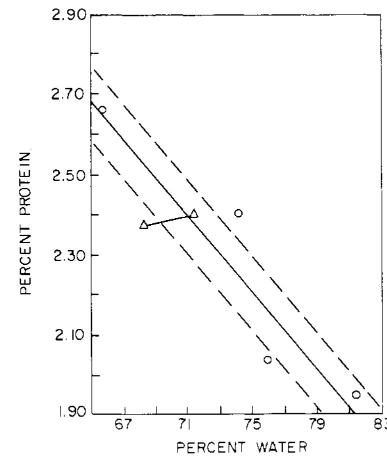

Figure 4. Correlation of protein and water content of the Fuerte and Hass avocados: dashed line is the standard error of the estimate; (O) Fuerte, (Δ) Hass.

Hass at maturity. Since there has been a determined effort by the avocado industry to reduce the size of commercial fruit, the caloric values reported in the older literature are in most cases higher than those reported in Table I; for example, USDA Bulletin No. 72 (1971) reports 284 g for the average avocado weight against the 213 g measured as the average avocado weight in a study of the whole California crop by Calavo.

An examination of the avocado fatty acids shown in Table II indicates that the major saturated fatty acid is palmitic and the main unsaturated fatty acid is oleic; furthermore, it can be seen that as a percentage of the total fatty acids the palmitic acid decreases and the oleic acid increases in concentration as the fruits become more mature. The average content of palmitoleic acid is about 4% but is quite variable; linoleic and other polyunsaturated fatty acids comprise 2 to 12% of the total fatty acids with an average value around 8%. At maturity the Fuerte and Hass appear to be distinctly different in polyunsaturated fatty acid content, 11 vs. 2%, respectively. It is interesting to note that avocados have a high content of unsaturated fatty acids, which are at all times at least 5 times higher than the concentration of saturated fatty acids; the average ratio of unsaturated/saturated fatty acids in the Fuerte is 7.4 while in the Hass it is 14.3.

Since nutritionists find the ratio of polyunsaturated fatty acids to saturated fatty acids to be an indicator of nutritional value, the P/S ratio has been calculated and is shown in Table II. It can be seen that the ratio increases with maturity in the Fuerte and decreases in the Hass. However, the averages for both avocados are about the same, 0.73 and 0.75.

In order to estimate the percentage of fatty acids in the edible pulp, Table II, the unsaponifiable fraction of total fat was assumed to be 2% of the total fat content, since when the unsaponifiable fraction has been measured, the value has been reported to be from 1 to 4% in various avocado varieties. No cholesterol is found in the unsaponifiable fraction contrary to nonscientific popular belief. Palmitic acid, in the Fuerte avocado, is seen to increase with age as a percent of the pulp while its percent of the fatty acids is decreasing; however, the Hass shows in its content of palmitic acid such a sharp decrease as it matures that at 21.3% fat its pulp content is only 0.85%. This lowered palmitic acid concentration is reflected in the high content of oleic acid (19.4) found in the Hass at 21.3% fat; the Fuerte, in contrast, at its maximum total fat content, still contains only 16% oleic acid. It is interesting, however, that the total unsaturated fatty acids at the highest total fat content are the same for the Fuerte, 19.91%, and the Hass, 19.97%.

Apparently most previous analyses for fatty acids of California avocados have been done on a small sample, from selected growing areas, and at different times of the year, since they show such a wide range of values; thus, oleic acid has been reported to be from 59 to 81%, palmitic from 7 to 22%, linoleic from 7 to 14%, and palmitoleic from 3 to 11% (Eckey, 1954; Grant, 1960; Kikuta, 1968; Schlierf et al., 1969; Gunning et al., 1964).

The fat-soluble vitamin contents of the two species of avocados are reported in Table III. The USDA Home and Garden Bulletin No. 72 (1971) shows the vitamin A content of California avocados to be 630 IU per 100 g, which is higher than the average of 484 for the Fuerte, but less than the average of 740 for the Hass. Both the Fuerte and Hass tend to have an increased concentration with age, but the Hass would appear to have a higher β-carotene level than the Fuerte at a corresponding age of development. USDA Bulletin No. 72 (1971) does not report on vitamin E; however, Dicks (1965) gives a value of 1.7 IU if the conversion factor of 1.49 IU/mg is used. While the average values for Fuerte and Hass are probably not significantly different in vitamin E, it is evident that in the Fuerte the more mature fruit has a lower concentration than at earlier times, 0.8 vs. 2.5 IU. Vitamins D and K were not measured since previous reported levels are extremely low, vitamin D was not detected by Lassen et al. (1945), and vitamin K measured in California Fuerte avocados was only 8 μg/100 g (Lassen et al., 1944b).

The avocado also contains significant quantities of most of the water-soluble vitamins (Table III). Ascorbic acid appears to be lower than that reported previously, 16 mg (Hall et al., 1955) and 30 mg (USDA Bulletin No. 72, 1971). No consistent change occurs in vitamin C with age in Fuerte avocados; the Hass, however, shows a decrease in vitamin C concentration when the fat content increases from 17.6 to 21.3%. Furthermore, the Hass has a higher average vitamin C content than does the Fuerte.

In 1944, the California avocado was reported to contain 10 μg % of biotin (Lassen et al., 1944a); later, in 1955, Hall et al. showed that the Fuerte had 5.5 and the Hass 5.6 μg %; Table III shows an average of 3.2 μg % for both varieties. However, the range of biotin of 4 to 7 in the older data (Hall et al., 1955) and 1.3 to 5.2 in the data reported here shows reasonable agreement. The choline concentration, as with biotin, appears to be the same in both the Fuerte and the Hass avocados.

Folic acid (folacin) was found by Hall et al. (1955) to be 30 μg % for the Fuerte and 30 μg % for the Hass with a range of ±20 μg; Table III shows general agreement with these data in that the Fuerte and Hass avocados are about the same, but the range of values for the Fuerte would appear to be greater than previously reported.

Niacin is reported in the Nutritional Data by Wooster (1958) as 1.1 mg % and as 3.5 mg % in USDA Bulletin No. 72 (1971); however, the data in Table III seem to be in agreement with the values reported by Hall et al. (1955) who found 1.45 mg % for the Fuerte and 2.16 mg·% for the Hass. Thus, as with ascorbic acid there appears to be a varietal difference in the content of niacin.

Pantothenic acid was reported in the older literature (Lassen et al., 1944a) as 0.25 mg %; however, our data are in good agreement with those of Hall et al. (1955) in that they reported the Fuerte as having 0.90 mg % and the Hass as having 1.14 mg %. The data are so variable that it cannot be concluded that the Fuerte and Hass are different in this respect.

Pyridoxine was measured by Hall et al. (1955) by both a microbiological and a bioassay method. While the microbiological data were about 50% higher than the bioassay data they chose to use the microbiological data. Our values are even lower than their bioassay data, but we are in agreement with the value reported by Polansky and Murphy (1966). Furthermore, since we see no difference in the Fuerte and Hass and neither did Hall et al. (1955) it is probably unimportant that Polansky and Murphy (1966) did not specify which California avocados were used. Their note of "Spring" would indicate most likely that they used Fuerte avocados.

The amount of riboflavine in avocados reported in the literature ranges from 0.14 to 0.43% (Wooster, 1958; USDA Bulletin No. 72, 1971; Lassen et al., 1944a,b; Church and Church, 1970) with Hall et al. (1955) reporting 0.22 for Fuerte and 0.23 for Hass avocados. In Table III the average Fuerte value is 0.095 while the Hass is 0.150 mg %; thus, our data, in contrast to that of Hall et al. (1955), would indicate a difference in the concentration of riboflavine to be found in Fuerte and Hass avocados. It should be remembered that the values reported in Table III are from samples of all California avocados, while the data of Hall et al. (1955) were from selected areas where all avocados came from the same groups of trees, even though sampled through four crop years. It may be that other changes such as irrigation, fertilization, insecticide treatment, and climatic effects have occurred in the span of years between 1955 and 1968–1969 that could affect the concentration of riboflavine.

We are in agreement with Church and Church (1970) and Hall et al. (1955) on the content of thiamine in avocados. The actual averages differ slightly, but in view of the technical differences and fruit variability the values Hall et al. (1955) report for the Fuerte of 0.14 mg and 0.09 mg for the Hass would be similar to our 0.10 and 0.12 mg, respectively. Furthermore, there seems little change in thiamine over the years, since a value of 0.10 was used in the 1943 Yearbook of the California Avocado Society.

The total mineral contents of ashed pulp in both the Fuerte and the Hass avocados are the same, 55%, as is seen in Table IV; thus, the ratio of Hass to Fuerte in ash and total minerals is 1.3. It is apparent that this 1.3 ratio is a reflection of the potassium content of the ash, because it is 83% in the case of the Fuerte and 81% in the Hass. The potassium, magnesium, phosphorus, silicon, calcium, sodium, iron, and strontium all have ratios of Hass to Fuerte of 1.3 to 1.7 and probably indicate that in the Hass the functional or structural units involving these minerals are more numerous. These are the minerals which occur at concentrations higher than 0.001% of the pulp except for strontium. Boron, conversely, on the average is more concentrated than 0.001% of the pulp, has a H/F ratio of 3.1, and, therefore, would appear to be distinctly different in the Hass and the Fuerte. The other minerals at levels less than 0.001% of the pulp show wide variance in the H/F ratio, from 0.3 to 5.5, probably showing the combination of a large relative variation in their determination combined with the accumulation of minerals that is variable due to soils, fertilizers, and environmental factors.

Avocados have been known for many years to have a high level of potassium. In fact, bananas and avocados have the highest levels found in fresh fruit. It would appear from Table IV that the Fuerte avocado has a lower concentration of potassium, 555 vs. 723 for the Hass. Wooster (1958) reports that the avocado contains 340 mg %; however, Church and Church (1970) show the avocado as having 604 mg %.

Since magnesium is found so universally in foods, few analyses for the avocado are found in the literature, but the Yearbook of the California Avocado Society of 1943 reported a level of 41 mg %, the same as our average value for the Fuerte. The same report gives the concentration of phosphorus as 80 mg %, about twice that shown in Table IV; other tabulations are shown in Table IV.

The data on silicon show great variability; however, no reports are known on the concentration in avocados, although its presence has been noted by the Calavo Growers in 1958.

Calcium was given as 13 mg % in the Yearbook of the California Avocado Society in 1943, and a value of 10 mg % was tabulated by Wooster in 1958 and by Church and Church in 1970. In USDA Bulletin No. 72 (1971) California avocados, mid- and late-winter, are listed as having 22 mg of calcium per avocado which, using their data, yields 10 mg %. Thus, it appears that calcium has been found rather consistently in all avocados in the 7–15 mg % range. Our data would indicate, perhaps, a slight increase in calcium concentration with development to maturity in both the Fuerte and the Hass avocados.

The amount of sodium found in avocados was reported to be at least 10 times too high in the older literature (Jaffa and Goss, 1923; Yearbook of the California Avocado Society, 1943). More recent tabulations give values of 3 and 4 mg % (Wooster, 1958; Church and Church, 1970). Our data would indicate that the sodium concentration of California avocados should be significantly higher than 3–4, and more in the range of 9 to 15 mg %. The high potassium and low sodium content of avocados, 62 times higher K/Na in Fuerte and 48 times higher for Hass, presents a fruit of particular value to those requiring a high potassium diet.

Iron in avocados, like sodium, appears to have been reported at much too high a level in the older literature (Jaffa and Goss, 1923). Avocados from Guatemala were found to have from 0.5 to 1.28 mg % of iron (Munsell et al., 1950), while the tabulated data for other avocados from 1932 through 1971 (Wooster, 1958; USDA Bulletin No. 72, 1971; Church and Church, 1970; Yearbook of the California Avocado Society, 1943; Stiebeling, 1932) show 0.6 mg %. Thus, it appears likely that they are all using the same source of information, and few determinations of iron were made during this period. Although individual Fuerte avocados can obviously be lower than 0.45 mg %, our data would indicate that 0.6 mg % is too low for California avocados, and on the average the Fuerte has 1.40 mg % while the Hass has 1.95 mg %.

While traces of the other minerals found in Table IV have been reported, actual numbers have not usually been used. Of these minerals, all of which are found in human tissue, only copper and manganese are now considered essential in human nutrition. Copper has been reported by Ciral and Castillo (1953) at 0.18 mg % and its requirement is low, estimated at 2 mg per day.

In Table V are shown the percent of the Recommended Daily Dietary Allowances (RDA) (National Academy of Sciences, 1974) supplied by the nutrients in an average portion of Fuerte avocado. An average portion is one-half of an average Fuerte avocado, calculated to be 80.8 g. The

Table V. Percent of the RDA[a] Provided by an Average Portion[b] of Fuerte[c] Avocado

Nutrient	% RDA		
	Children 7–10 yr	Males 23–50 yr	Females 23–50 yr
Protein, g	5	3	4
Calories, kcal	6	5	7
Fat-soluble vitamins, IU			
Vitamin A (carotene)	12	8	10
Vitamin E	19	13	16
Water-soluble vitamins, mg			
Ascorbic acid	12	10	10
Folacin	16	12	12
Niacin	8	7	9
Pyridoxine	15	9	9
Thiamine	7	7	8
Riboflavine	6	5	6
Minerals, mg			
Calcium	1	1	1
Iron	11	11	6
Magnesium	13	9	11
Phosphorus	3	3	3

[a] Recommended dietary allowance (1974). [b] One-half average avocado = 3.75 oz × 76% edible = 2.85 oz or 80.8 g. [c] Approximately 75% of the California avocado crop.

Fuerte avocado was used since it comprises 70–80% of the total California avocado crop. One-half a Fuerte avocado supplies an appreciable percentage of a day's requirements for all the nutrients listed in the RDA except vitamin B_{12}, iodine, and zinc. The avocado may contain iodine, but as far as known it has not been measured. The avocado supplies 19% of the vitamin E required by children; on the other hand, avocados supply only 1% of the daily requirement of calcium. Since iron is difficult to obtain, the 6–11% of the nutritional requirement supplied by one-half an avocado could be a nutritionally important contribution to the diet.

ACKNOWLEDGMENT

The authors wish to acknowledge their appreciation for the many suggestions made in the preparation of this manuscript by the Nutritional Research Committee of the California Avocado Advisory Board.

LITERATURE CITED

Appleman, D., Noda, L., "California Avocado Society Yearbook", Los Angeles, Calif., 1941, p 60.
Association of Official Agricultural Chemists, "Official Methods of Analysis", 10th ed, 1965, 2.044, p 16; 22.033, p 352; 22.038, p 352; 23.003, p 346; 26.056, modified, p 430; 39.015b, 39.016, 39.017, 39.018, p 758; 39.042, 39.085, 39.088, p 765.
Association of Vitamin Chemists, "Methods of Analysis", 2nd ed, 1951, p 87.
Association of Vitamin Chemists, "Methods of Analysis", 3rd ed, 1966, pp 172, 201, 212, 227, 247, and 415, Lim and Schall method.
Calavo Growers of California, "Analysis of Calavo Avocados", 1958, Report No. 171.
Church, C. F., Church, H. N., "Food Values of Portions Commonly Used", 11th ed, J. P. Lippincott Co., Philadelphia, Pa., 1970, p 39.
Dicks, M. W., Bulletin No. 435, Agricultural Experiment Station, University of Wyoming, Laramie, Wyo., 1965, p 76.
Eckey, E. W., Reinhold, New York, N.Y., 1954, p 417.
Giannini Foundation, University of California, Berkeley, Calif., 1968.
Giral, J., Castillo, M. T., *Men. Congr. Cient. Mex. IV Canterario, Univ. Mex.* **2**, 232 (1953); *Chem. Abstr.*, 1981c (1955).
Grant, W. C., *Proc. Soc. Exp. Biol. Med.* **104**, 45 (1960).
Gunning, B. E., Imaichi, K., Splitter, S. D., Kinsell, L. W., *Lancet*, 336 (Aug 15, 1964).
Hall, A. P., Moore, J. G., Morgan, A. F., *J. Agric. Food Chem.* **3**, 250 (1955).
Jaffa, E. E., Goss, H., Bulletin No. 365, Part II, University of California Agricultural Experiment Station, Berkeley, University of California Printing Office, Berkeley, Calif., 1923, p 64.
Kikuta, Y., *J. Fac. Agric., Hokkaido Univ.* **55**, 469 (1968).
Lassen, S., Bacon, K., Hinderer, E., *J. Am. Diet. Assoc.* **20**, 688 (1944a).
Lassen, S., Bacon, K., Sutherland, J., *Food Res.* **10**, 1 (1945).
Lassen, S., Bacon, K., Sutherland, J., *J. Am. Diet. Assoc.* **20**, 761 (1944b).
Munsell, H. E., Williams, L. O., Guild, L. P., Troescher, C. B., Nightingale, G., Harris, R. S., *Food Res.* **15**, 16 (1950).
National Academy of Sciences, Washington, D.C., "Recommended Dietary Allowances", 8th ed, 1974, p 129.
Polansky, M. M., Murphy, E. W., *J. Am. Diet. Assoc.* **48**, 109 (1966).
Rasmussen, F. B., Hjarde, W., *Acta Chim. Scand.* **11**, 34 (1957).
Schlierf, C., Falor, W. H., Wood, P. D., Lee, Y. L., Kinsell, L. W., *Am. J. Clin. Nutr.* **22**, 79 (1969).
Sebrell, W. H., Jr., Haggerty, J. J., and the Editors of Life, "Food and Nutrition", Time Inc., New York, N.Y., 1967, p 194.
Stiebeling, H. K., *U.S. Dep. Agric. Circ.* **205**, 1 (1932).
U.S. Department of Agriculture, Home and Garden Bulletin No. 72, Washington, D.C., 1971, p 19.
U.S. Department of Agriculture, Circular No. 549, 1940, p 1.
Wooster, H. A., "Nutritional Data", 2nd ed, H. J. Heinz Co., Pittsburgh, Pa., 1958, p 108.
Yearbook of the California Avocado Society, 1943, p 24.

Received for review September 26, 1974. Accepted January 20, 1975.