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Distribution of Inorganic Constituents in Avocado Fruits

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Few data are available regarding the uniformity in composition of the various portions of the pulp and skin of avocado fruits. In 1922 Church and Chace (1) called attention to this fact when they reported an analysis showing that the outer half of the fresh pulp next to the skin contained 1.54 per cent of ash as compared with 1.36 per cent of ash in the inner half next to the seed. Differences of this kind in other fruits have since been referred to by Haas and Klotz (5) and others.

TABLE 1
Inorganic Composition of the Pulp (Without Skin) of Fuerte Avocado Fruits

Date	Fruit, half	Portion	Dry matter in fresh wt.	Ash in dry matter	Calcium in dry matter
1930	Stem	All	**Per cent**	**Per cent**	**Per cent**
Aug. 28	Tip	All	13.82	4.60	0.147
			14.37	5.08	.121
Sept. 23	Stem	All	14.58	4.97	.124
	Tip	All	15.23	5.87	.090
Nov. 26	Stem	All	24.13	4.66	.042
	Tip	All	26.35	5.32	.038
Dec. 29	Stem	All	25.32	4.95	.050
	Stem	Inner	26.11	4.18	.054
	Stem	Outer	24.24	6.26	.079
	Tip	All	24.08	6.58	.041
	Tip	Inner	27.36	4.74	.032
	Tip	Outer	22.26	7.75	.046
1931	Stem	All	29.64	3.69	.043
	Stem	Inner	30.87	3.17	.041
	Stem	Outer	28.01	4.71	.051
Feb. 10	Tip	All	29.35	4.63	.027
	Tip	Inner	32.79	3.71	.034
	Tip	Outer	24.90	6.62	.039
Apr. 13	Stem	All	36.16	3.45	.034
	Stem	Inner	37.39	3.10	.046
	Stem	Outer	34.73	4.19	.037
	Tip	All	36.65	4.27	.020
	Tip	Inner	40.48	3.13	.019
	Tip	Outer	33.33	5.85	.026
Apr. 30	Stem	All	31.45	3.95	.031
	Stem	Inner	31.98	3.57	.035
	Stem	Outer	30.03	4.76	.036
	Tip	All	29.05	5.61	.026
	Tip	Inner	30.89	4.29	.020
	Tip	Outer	27.14	6.43	.021

In table 1 will be noted the variations in the percentages of dry matter in the fresh weight of samples of fruits of the Fuerte variety collected at the Citrus Experiment Station at various times during 1930 and 1931. The fruit samples consisted of 6 to 10 fruits. The percentages of dry matter in the fresh weight of the tip halves exceeded those for the

stem halves only during the months of August to November inclusive. The inner portions of the halves contained more dry matter in their fresh weight than the outer portions of the corresponding fruit halves. The inner portion of the tip halves had greater percentages of dry matter in the fresh weight than the inner portion of the stem halves; conversely, the outer portion of the stem halves had greater percentages of dry matter in the fresh weight than the outer portion of the tip halves. As the fruits approached maturity the percentages of the dry matter decreased.

TABLE 2
Inorganic Composition of the Pulp (Without Skin) of Benik Avocado Fruits*

Date	Fruit, half	Portion	Dry matter in fresh wt.	Ash in dry matter	Calcium in dry matter
1930			**Per cent**	**Per cent**	**Per cent**
Aug. 28	Stem	All	11.73	4.86	0.216
	Tip	All	12.37	4.66	.146
Sept. 23	Tip	All	11.80	5.35	.137
Oct. 24	Stem	All	12.85	5.22	.134
	Tip	All	13.91	5.57	.080
Nov. 26	Stem	All	18.82	4.56	.103
	Tip	All	19.35	5.32	.057
1931					
Jan. 6	Stem	All	20.05	4.39	.079
	Stem	Inner	21.06	3.52	.072
	Stem	Outer	21.24	4.65	.089
	Tip	All	22.94	4.52	.040
	Tip	Inner	23.76	3.63	.041
	Tip	Outer	21.82	6.85	.067
Feb. 16	Stem	All	22.20	4.53	.083
	Stem	All	21.91	5.00	.080
	Stem	Inner	22.41	4.03	.074
	Stem	Outer	22.17	5.65	.094
	Tip	All	23.77	5.07	.047
	Tip	All	24.02	5.58	.049
	Tip	Inner	25.47	3.69	.061
	Tip	Outer	22.21	7.81	.056
Apr. 14	Stem	All	29.41	4.26	.068
	Stem	Inner	28.32	4.06	.055
	Stem	Outer	28.90	5.07	.072
	Tip	All	31.02	5.04	.040
	Tip	Inner	32.73	3.77	.027
	Tip	Outer	29.36	5.87	.032
May 29	Stem	All	31.35	4 06	.060
	Stem	Inner	32.32	3.65	.050
	Stem	Outer	30.64	4.77	.064
	Tip	All	32.70	4.52	.025
	Tip	Inner	33.92	3.90	.032
	Tip	Outer	28.37	6.77	.032

*Samples consisted of 4 to 9 fruits.

Table 2 shows the variations in the percentages of dry matter in the fresh weight of samples of fruits of the Benik variety collected at the Citrus Experiment Station during 1930 and 1931. The fruit samples consisted of 4 to 9 fruits. At all times the tip halves showed greater percentages of dry matter than the stem halves. In the tip halves the inner portion had higher percentages of dry matter than the outer portion.

In tables 1 and 2 it is seen that the ash as a percentage of the dry matter of the tip halves of the pulp (without skin) of fruits of the Fuerte and Benik varieties is greater than that of the stem halves. With but one exception the percentages of ash in both the inner and outer portions of the tip halves exceed those in the corresponding portions of the

stem halves (compare with citrus (5)). The percentages of ash in the outer portion of the stem and tip halves exceed those in the inner portion of the corresponding halves. The data for the pulp (without skin) of fruits of these and of other varieties not here presented, confirm and greatly extend the results of Church and Chace (1).

The actual acidity of the various portions of the pulp (without skin) vary according to the location of the tissue in the pulp, as shown in table 3. The pulp is more acid near the skin. This indicates that the outer tissues are better aerated and that the carbon dioxide which tends to make the tissue more alkaline (6) is more quickly removed.

TABLE 3
pH Values in Various Portions of Mature Avocado Pulp (Without Skin)

Fruit, half	Portion	Pulp, soft and edible	Pulp, hard
Stem	Inner	6.86	6.56
Stem	Outer	6.72	6.46
Tip	Inner	6.64	6.52
Tip	Outer	6.44	6.34

Church and Chace (1) showed that while the total sugar content of the pulp decreased, the fat increased. These results are confirmed, and in addition it was found that the pulp (without skin) of the stem halves usually contains more reducing and total (as reducing) sugars than that of the tip halves. In many cases the nonreducing sugar was higher in the tip than in the stem halves. The differences in sugar content of the halves decreased as the fruits reached maturity.

It was just referred to, that the percentages of ash in the dry matter of the tip halves of the pulp of Fuerte and Benik avocado fruits were found to be greater than in that of the stem halves.

Potassium is the most abundant ash constituent of avocado pulp (without skin). Potassium occurs in greater concentration in the dry matter of the tip than in that of the stem halves of the pulp (without skin) throughout the various stages of development of the fruit.

In both halves of the pulp (without skin) the percentages of potassium are greater in the outer than in the inner portion (Fig. 1). The inner and outer portions of the tip halves contain greater percentages of potassium than the corresponding portions of the stem halves.

The outer portions of the stem and tip halves of nearly mature fruits of the Fuerte and Benik varieties contain greater percentages of magnesium than the inner portions of the corresponding halves (Fig. 1).

Although the percentages of calcium are small (tables 1 and 2) they are consistently greater in the inner and outer portions of the stem halves of the pulp than in the corresponding portions of the tip halves.

The inorganic phosphate as a percentage of the dry matter of the pulp (without skin) was found to decrease with increasing maturity of the fruits.

Determinations of the copper content of the pulp and skin of mature fruits of the Anaheim variety collected at Fallbrook are reported in table 4. The greatest copper content in the pulp was found in the outer portion of the tip half.

Tables 4 and 5 indicate that avocado fruits contain considerable iron. The concentration present is quite variable and, as shown in table 6, neither of the pulp halves contains consistently the greater content of iron.

TABLE 4
Copper, Iron and Inorganic Phospate Content of the Pulp and Skin of Anaheim Avocado Fruits*

Date, 1933	Fruit, half	Portion	In dry matter		
			Copper	Iron	Inorganic phosphate
			Parts per million		Per cent
Pulp					
June 14	Stem	Inner	30.3	27	0.894
	Stem	Outer	22.0	52	.780
	Tip	Inner	26.6	43	.760
	Tip	Outer	34.1	64	.885
June 23	Stem	Inner	28.3	28	.398
	Stem	Outer	23.4	38	.336
	Tip	Inner	23.6	22	.328
	Tip	Outer	36.6	35	.378
Skin					
June 14	Stem	.....	32.1	.....	.396
	Tip	.....	44.2	.....	.638
June 23	Stem	.....	26.7	.....	.659
	Tip	.....	19.4	28	.556

*The fruit samples consisted of 1 and 2 fruits, respectively.

Data have been reported by Haas (4) which show a decreasing manganese content in the dry matter of the pulp with increasing maturity of the fruits. The manganese concentration in the tip half of the pulp (without skin) usually exceeds that in the stem half (tables 5 and 6).

The numerous fruit samples (Fuerte, Blake, Puebla, and Benik varieties) were found by Haas (4) to contain greater percentages of total nitrogen (including nitrates) in the dry matter in the tip than in the stem halves. The dry matter, therefore, contains higher percentages of both total nitrogen and potassium in the tip than in the stem halves.

In order to determine the effect of high sulfate concentrations in the irrigation water on the total sulfur accumulation in avocado fruits, mature fruits of the Challenge, Queen, Spinks, and Taft varieties were obtained from the vicinity of Oxnard on September 23, 1933 through the kindness of Mr. L. T. Sharp, of Santa Paula. The trees were growing in soil irrigated with water containing 350 to 450 parts per million of sulfate. The leaves of the trees from which these fruits were picked were affected with tipburn (2). Although fruits of other varieties (Fuerte and Anaheim) grown at the Citrus Experiment Station, where the sulfate content of the irrigation water is low, were used as controls and were collected on June 15, table 7 shows that the percentages of total sulfur and phosphorus in the dry matter of the pulp of the control fruits (Fuerte and Anaheim varieties) are less

than those for the fruits obtained from areas high in sulfate. Considerable variation occurred in the percentages of sulfur and phosphorus in the various portions of the pulp and no consistent relation was found for all of the varieties. No consistent relation of total phosphorus to the fruit halves was found in the skin of the fruits of the several varieties used. However, the percentages for total sulfur in the skin (table 7) are uniformly greater in the stem than in the tip halves. Haas (3) has reported data which indicate that avocado fruits may absorb considerable chlorine and especially in the skin. Factors that in any manner affect the fruit skin deserve study. The results of the present studies indicate the non-uniformity of the composition in various portions of avocado fruits.

TABLE 5

Iron and Manganese in the Pulp of Avocado Fruits (Without Skin)

Variety	Date	Part of fruit tested		Parts per million in dry matter	
		Half	Portion	Iron	Manganese
	1930				
Fuerte*	Dec. 29	Stem	Inner	48	3.6
		Stem	Outer	49	4.0
		Tip	Inner	49	9.2
		Tip	Outer	71	11.7
Fuerte	Dec. 29	Stem	All	45	3 9
		Tip	All	48	3.9
Fuerte	Dec. 30	Stem	All	41	3.5
		Tip	All	72	7.4
	1931				
Puebla*	Jan. 6	Stem	Inner	25	6.0
		Stem	Outer	48	5.7
		Tip	Inner	66	12.9
		Tip	Outer	59	13.4
Benik*	Jan. 6	Stem	Inner	52	5.1
		Stem	Outer	49	4.4
		Tip	Inner	50	7.7
		Tip	Outer	51	8.2

*Fruits freshly picked; remainder obtained from packing-house. The fruit samples contained 10, 2, 3, 12, and 9 fruits, respectively.

TABLE 6

Parts Per Million of Iron and Manganese in the Dry Matter of the Stem and Tip Halves of the Pulp (Without Skin)*

Variety	Date	Iron		Manganese	
		Stem halves	Tip halves	Stem halves	Tip halves
Fuerte	**1930**				
	Aug. 28	67	26	8.3	8.9
	Sept. 23	41	10	9.4	10.7
	Nov. 26	41	50	4.6	8.8
	Dec. 29	32	28	3.7	9.8
Puebla	Aug. 28	23	119	11.4	19.1
	Sept. 23	15	28	10.7	17.5
	Oct. 23	65	27	8.5	18.5
	Nov. 21	19	79	8.8	15.8
	1931				
	Jan. 6	20	51	6.0	15.0
Puebla seedling	**1930**				
	Nov. 21	19	51	4.1	5.5
	Oct. 10	16	18	4.2	6.1
	Sept. 3	32	69	5.8	7.8
Benik	Aug. 28	30	54	8.0	17.0
	Sept. 23	.....	34	.....	16.1
	Oct. 24	16	22	7.3	12.5
	Nov. 26	55	.....	8.1	.....
	1931				
	Jan. 6	36	48	4.9	7.9
Blake	**1930**				
	Aug. 28	64	40	10.8	10.2
	Sept. 15	73	23	10.0	9.6
	Oct. 10	59	54	8.5	8.8

*Samples consisted of 4 to 16 fruits.

TABLE 7
Total Sulfur and Phosphorus in the Pulp and Skin of Avocado Fruits from Trees Grown in soil Containing Considerable Sulfate

Variety	Fruit half		Portion	Parts per million in dry matter	
	Pulp	Skin		Total sulphur	Total phosphorus
1933					
Fuerte	Stem	.....	Inner	0.080	0.141
	Stem	.....	Outer	.072	.104
	Tip	.....	Inner	.073	.111
	Tip	.....	Outer	.096	.120
	.....	Stem	All	.139	.243
	.....	Tip	All	.077	.120
Anaheim	Stem	.....	Inner	.094	.149
	Stem	.....	Outer	.137	.129
	Tip	.....	Inner	.090	.143
	Tip	.....	Outer	.162	.132
	.....	Stem	All	.058	.208
	.....	Tip	All	.049	.206
Challenge	Stem	.....	Inner	.188	.280
	Stem	.....	Outer	.199	.203
	Tip	.....	Inner	.175	.230
	Tip	.....	Outer	.197	.263
	.....	Stem	All	.078	.204
	.....	Tip	All	.052	.157
Queen	Stem	.....	Inner	.196	.302
	Stem	.....	Outer	.186	.209
	Tip	.....	Inner	.219	.246
	Tip	.....	Outer	.218	.266
	.....	Stem	All	.050	.156
	.....	Tip	All	.042	.160
Spinks	Stem	.....	Inner	.190	.189
	Stem	.....	Outer	.200	.266
	Tip	.....	Inner	.230	.193
	Tip	.....	Outer	.216	.310
	.....	Stem	All	.054	.165
	.....	Tip	All	.048	.191
Taft	Stem	.....	Inner	.147	.220
	Stem	.....	Outer	.150	.192
	Tip	.....	Inner	.144	.180
	Tip	.....	Outer	.139	.191
	.....	Stem	All	.067	.163
	.....	Tip	All	.057	.166

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