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THE COMPOSITION OF CALIFORNIA LEMONS.

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CONTENTS.

THE CALIFORNIA LEMON INDUSTRY.

Beginning in 1887 with the shipment of 12 cars of fruit, the California lemon industry has increased a thousandfold, the 1919–20 shipment being approximately 12,000 cars. The California growers have generally settled upon the Eureka and Lisbon varieties as the most satisfactory in that State, and, although there are scattered orchards of other varieties, the new plantings are confined to these two.

According to A. D. Shamel (1),[2] the Eureka variety originated in 1858 in Los Angeles, through the planting of seeds obtained from Sicilian lemons. These seedlings bore about 12 years later, at which time several were selected as worthy of propagation. Buds from these trees are responsible for the present Eureka variety of lemon. The Lisbon variety was imported directly from Australia in 1874 (2). While some plantings now in existence can be traced to the original shipment, later importations are also responsible for the Lisbon, the most widely planted variety in California to-day. The Villa Franca lemon has been planted to some extent, but has generally been abandoned in favor of the Eureka and Lisbon varieties.

[1] The writers are greatly indebted to F. E. Denny for help with the calculations and for criticism of the manuscript, as well as to C. O. Young and R. H. Kellner for collaboration in the analytical work.

[2] Figures in parenthesis refer to Bibliography at end of bulletin.

At various times attempts have been made to utilize the culls from the lemon industry. The first effort which was ultimately successful was that of a company, organized in 1898, now manufacturing essential oils and citrate of lime. Another company, established early in 1914, at present produces citric acid and essential oil. Several smaller firms are making citric acid, citrate of lime, and bottled lemon juice. As the history of the undertaking has been treated by others (3) (4), it need not be considered further here.

PURPOSE OF INVESTIGATION.

So far as known, there has been no systematic attempt to study the composition of the California lemon. Analyses of scattered samples have been published, but no series of results from carefully selected trees, where sampling was continued throughout the season, has been reported. It is highly desirable that this information be made accessible to the lemon grower, as well as to the lemon by-product manufacturer, who is especially interested in the oil and acid content of the fruit which he purchases.

INVESTIGATIONAL WORK.

METHOD OF SAMPLING.

In a territory as extensive as the lemon-growing section of California, adequate sampling presents many difficulties. Since the number of samples which can be examined is necessarily limited by the size of the laboratory force and its facilities, care was taken to select typical locations in each well-recognized growing district. In some instances, circumstances prevented sampling, so that a small number of centers are not adequately represented, and in a few cases certain districts are more fully represented than was at first planned. In all, satisfactory samples were taken in about 20 locations in the following centers: Bonita, Chula Vista, Escondido, Whittier, Santa Paula, Carpenteria, San Fernando, Glendora, San Dimas, and Claremont. From other work conducted at the same time it was possible to obtain data on fruit grown at Corona.

The trees selected originally were such as to give an equal number of locations of the Eureka and Lisbon varieties. Because of irregular sampling, the final selections consist of 10 Eureka and 6 Lisbon trees. The judgment of experienced growers was the deciding factor in selecting typical trees. It is possible that some of the trees included in the final results are not of the best strains, but, as many groves of such trees exist in the State, the effectiveness of the data is not materially impaired.

Again, the number of fruits to each sample was a matter of concern. Manifestly, the larger the number the better the chance of satisfactorily representing the composition of the grove or district

from which the sample came. After removing the sample for the experimental work, the trees from which they were taken were picked in the usual commercial way. In a few cases an insufficient number of fruits had reached the proper size when time for the next sampling arrived.

Both the Eureka and Lisbon varieties of lemons in California blossom throughout the year, and pickings of fruit are made monthly, except in September or October, when they are usually omitted. Whenever possible samples were taken at monthly intervals in the course of the investigation here reported.

As a rule, from 18 to 24 fruits were forwarded to the laboratory in cardboard cartons furnished for the purpose. Seldom were they more than 24 hours en route. At the laboratory they were kept in the cartons in cool storage (40° to 50° F.) until analysis was begun. Usually not more than three days elapsed between the time of picking and analysis.

METHODS OF ANALYSIS.

Unfortunately, in order to make a satisfactory determination of the essential oil of the fruit, it was necessary to divide the sample. After the specific gravity of the fruit had been determined by weighing in the air and under water, this division was made as evenly as possible, both as to size and color. Half the sample was ground by being passed through a food grinder three times, and the oil was determined in a portion of it by steam distillation, according to the method of Wilson and Young (5). The acidity of the whole fruit was determined on another portion of this sample by titration with alkali solution, using phenolphthalein as indicator.

The remaining lemons were quartered, the thickness of the skin estimated, and the juice expressed by a small hand press.

In estimating the thickness of the peel, the following arbitrary method was used: The cross section of the peel was measured in several places by calipers, and the average taken. When this was found to be less than 3 mm., the peel was designated as thin; 3 to 5 mm., medium; and above 5 mm., thick (fig. 1). Rarely did peel exceed 7 mm. in thickness.

The acidity of the juice was determined by titration against alkali. All acid is calculated as citric with the water of crystallization included.

RESULTS OF INVESTIGATION.

The data derived from the analyses of Eureka and Lisbon lemons grown in California are shown in Tables 1 and 2. Table 3 gives the results on samples of the Villa Franca variety; Table 4, those on samples of fruit from a Eureka location in central California; and Table 5, those on samples of lemons of an unknown variety from Arizona. It is not thought advisable to attempt to compare the results in Tables 3, 4, and 5 with those in Tables 1 and 2, for the reason that the number of Villa Franca locations was small, al-

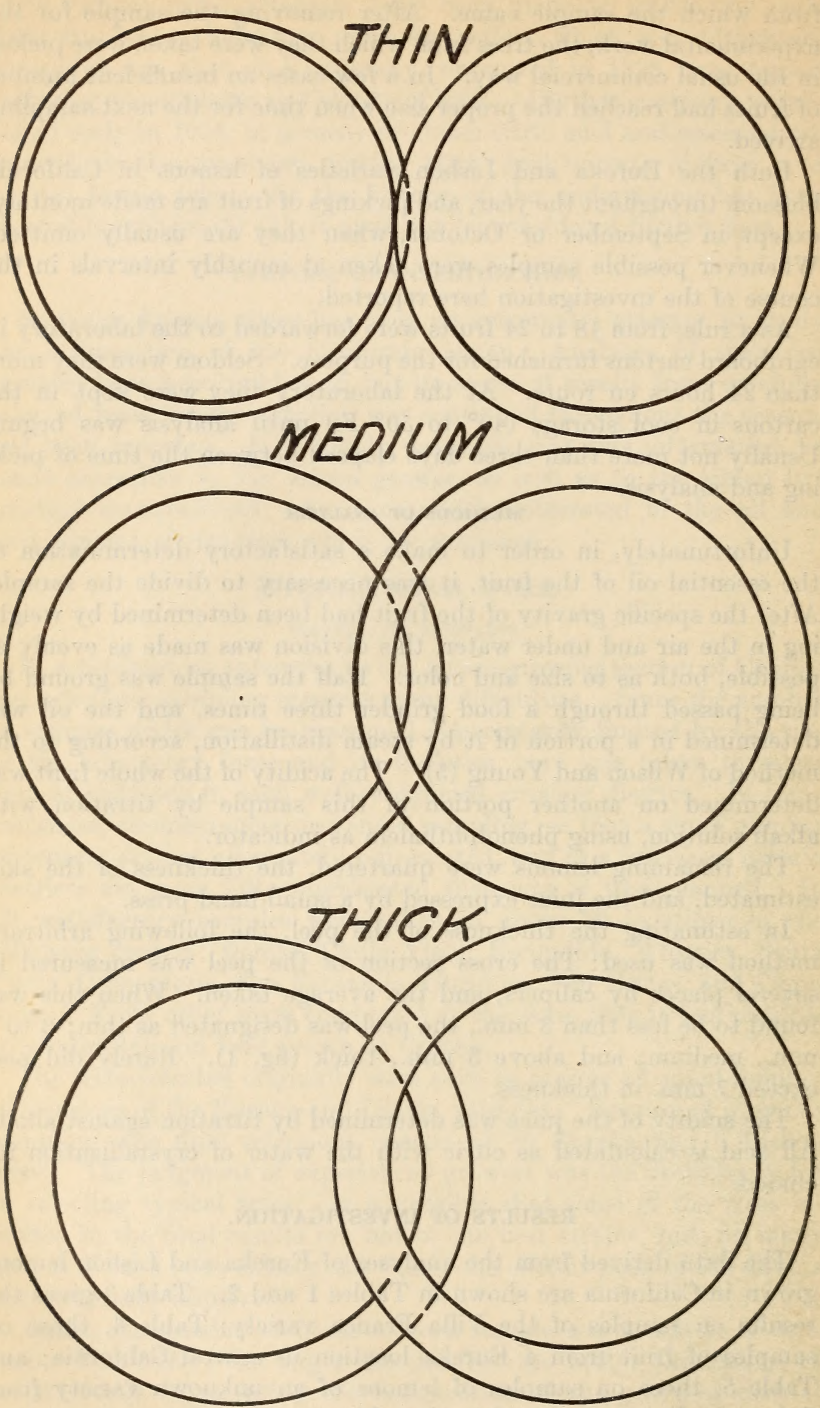

FIG. 1.—Standards used to determine the thickness of the peel.

though not too small to preclude satisfactory results had the variability encountered been less. While the averages of the three sets are taken from a sufficient number of samples to make them worthy of consideration, the monthly averages depend on but three samples, too small a number from which to draw conclusions. Moreover, neither Tulare County nor Arizona is a large lemon-shipping center, and the number of samples analyzed from each of these districts was small. In Tulare County the lemon season begins in September and lasts but a few months, so that comparison with lemons grown in other districts throughout the season is impossible. The data contained in Tables 3, 4, and 5, however, are of no little interest to lemon growers, and it is felt that they should be published here.

TABLE 1.—*Composition of Eureka lemons grown in various sections of California.*

BONITA (TREE 1).

Sample No.	Month picked.	Color.[1]	Thickness of peel.	Specific gravity of fruit.	Oil in fruit, by weight.	Oil per ton of fruit.	Acid in fruit.[2]	Acid per ton of fruit.	Acid in juice.[2]
					Per cent.	*Pounds.*	*Per cent.*	*Pounds.*	*Per cent.*
489	July	DG–Y	Thin	.....	0.52	10.4	3.86	77.2	7.23
564	Sept.	DG	Very thin	0.9791	.41	8.2	4.27	85.4	6.82
594	Oct.	LG	Thin	.9822	.34	6.8	4.41	88.2	6.57
628	Nov.	LY	do	.9853	.42	8.4	4.16	83.2	6.63
673	Dec.	FY	Medium	.9214	.66	13.2	3.73	74.6	7.25
778	Feb.	LY	do	.9215	.45	9.0	3.10	62.0	6.91
821	Mar.	LY	Thick	.9274	.44	8.8	3.24	64.8	6.55
881	Apr.	FY	Medium	.9287	.45	9.0	3.62	72.4	6.72
919	May	FY	Thick	.9368	.52	10.4	3.48	69.6	6.88
974	June	FY[3]	Medium	.9537	.67	13.4	3.71	74.2	7.55
1026	July	LY	Thin	.9618	.56	11.2	3.34	66.8	.....
1056	Aug.	LY	do	.9769	.51	10.2	3.66	73.2	.....
	Average			**.9522**	**.50**	**9.9**	**3.71**	**74.3**	**6.91**

SANTA PAULA (TREE 10).

641	Dec.	LG	Medium	0.9432	0.53	10.6	3.72	74.4	7.73
679	Jan.	LG	Thick	.9220	.44	8.8	3.50	70.0	7.30
723	Feb.	LY	Medium	.9238	.42	8.4	3.36	67.2	7.09
788	Mar.	LY	do	.9162	.43	8.6	3.22	64.4	6.91
846	Apr.	DG–LY	do	.9190	.40	8.0	3.27	65.4	6.37
891	May	LG	do	.9394	.39	7.8	3.41	68.2	6.71
940	June	DG	.....	.9520	.44	8.8	3.83	76.6	7.00
984	July	LG–DG	Medium-thin	.9517	.50	10.0	3.87	77.4	7.21
1039	Aug.	LG	Thin	.9524	.43	8.6	4.10	82.0	7.25
1073	Sept.	LY	Medium	.9419	.57	11.4	4.06	81.2	7.74
1084	Nov.	Y	Thin	.9627	.51	10.2	4.00	80.0	6.69
	Average			**.9386**	**.46**	**9.2**	**3.67**	**73.3**	**7.09**

SANTA PAULA (TREE 11).

639	Dec.	LG	Medium	0.9347	0.43	8.6	3.43	68.6	7.18
680	Jan.	LG	Thick	.9238	.30	6.0	3.37	67.4	6.84
724	Feb.	LY	Medium	.9357	.45	9.0	3.49	69.8	7.00
789	Mar.	LG	do	.9241	.42	8.4	3.53	70.6	7.04
847	Apr.	LG	Thick	.9201	.39	7.8	3.23	64.6	6.53
892	May	LG	Medium	.9347	.41	8.2	3.50	70.0	6.65
941	June	DG	do	.9478	.48	9.6	3.45	69.0	6.97
985	July	LG–DG	do	.9498	.46	9.2	3.43	68.6	6.76
1040	Aug.	LG	do	.9568	.45	9.0	3.57	71.4	7.27
1074	Sept.	LG–LY	do	.9393	.46	9.2	3.99	79.8	7.30
1086	Oct.	LG–Y	do	.9447	.58	11.5	3.43	68.6	6.38
1113	Nov.	LY–Y	do	.9773	.51	10.1	3.06	61.2	6.83
	Average			**.9407**	**.44**	**8.9**	**3.46**	**69.1**	**6.90**

[1] DG, dark green; LG, light green; LY, light yellow; FY, full yellow.
[2] All acid is calculated as citric with water of crystallization.
[3] Much sunburn.

TABLE 1.—*Composition of Eureka lemons grown in various sections of California*—Continued.

SAN FERNANDO (TREE 13).

Sample No.	Month picked.	Color.	Thickness of peel.	Specific gravity of fruit.	Oil in fruit, by weight.	Oil per ton of fruit.	Acid in fruit.	Acid per ton of fruit.	Acid in juice.
					Per cent.	*Pounds.*	*Per cent.*	*Pounds.*	*Per cent.*
631	Nov	LG	Medium	0.9332	0.57	11.4	3.61	72.2	6.62
678	Dec	LG	Thin	.9279	.60	12.0	3.64	72.8	6.79
717	Jan	LG	Medium	.9124	.57	11.4	3.47	69.4	6.30
769	Feb	LG	Thin	.9262	.55	11.0	3.50	70.0	6.53
842	Mar	LY	Medium	.9234	.54	10.8	3.51	70.2	6.39
897	Apr	LY	do	.9312	.58	11.6	3.50	70.0	6.41
927	May	LG	Thin	.9617	.61	12.2	3.95	79.0	6.60
973	June	DG	Medium	.9530	.53	10.6	2.84	56.8	6.39
1031	July	DG	do	.9513	.50	10.0	3.16	63.2	6.65
1055	Aug	DG	do	.9508	.47	9.4	3.41	68.2	6.90
1090	Oct	DG–LY	do	.9470	.62	12.3	2.31	46.2	6.48
1108	Nov	LG–Y	do	.9730	.64	12.8	3.06	61.2	6.90
Average				**.9408**	**.56**	**11.3**	**3.33**	**66.6**	**6.58**

WHITTIER (TREE 14).

624	Nov	LG	Medium	0.9392	0.60	12.1	3.30	66.0	6.31
666	Dec	LY	do	.9488	.65	13.0	3.41	68.2	6.35
705	Jan	LY	do	.9321	.50	10.0	3.13	62.6	6.55
770	Feb	LY	do	.9227	.43	8.6	2.93	58.6	6.67
832	Mar	LY	do	.9115	.39	7.8	3.01	60.2	5.95
879	Apr	LY–DG	do	.9352	.38	7.6	2.99	59.8	6.21
928	May	LG	do	.9593	.48	9.6	3.01	60.2	6.51
968	June	DG	do	.9624	.55	11.0	3.10	62.0	6.33
1054	Aug	LG	Thin	.9653	.43	8.6	3.30	66.0	6.29
1076	Sept	DG–LY	Medium	.9538	.55	11.0	2.87	57.4	6.62
1088	Oct	LG	do	.9398	.52	10.3	2.75	55.0	6.58
Average				**.9427**	**.50**	**10.0**	**3.07**	**61.4**	**6.40**

WHITTIER (TREE 16).

646	Dec	DG	Thick	0.9408	0.48	9.6	3.33	66.6	6.76
693	Jan	LG	do	.9164	.42	8.4	3.08	61.6	6.83
751	Feb	LG	do	.9 75	.38	7.6	2.92	58.4	6.91
808	Mar	LG	do	.9270	.31	6.2	2.94	58.8	6.65
863	Apr	LG	do	.9365	.....	.....	3.35	67.0	6.48
909	May	LG	Medium	.9453	.41	8.2	3.36	67.2	6.72
955	June	LY	do	.9554	.47	9.4	3.56	71.2	7.35
1013	July	LG	do	.9576	.46	9.2	3.34	66.8	7.04
1044	Aug	LG	do	.9528	.50	10.0	3.74	74.8	7.16
1070	Sept	DG–LY	Thick	.9350	.43	8.6	3.13	62.6	7.10
1082	Oct	DG	do	.9315	.42	8.4	3.22	64.4	7.00
1098	Nov	G–Y	do	.9247	.44	8.7	2.91	58.2	7.11
1117	Dec	LG–FY	do	.9729	.47	9.5	2.64	52.8	7.21
Average				**.9403**	**.43**	**8.6**	**3.19**	**63.9**	**6.95**

WHITTIER (TREE 18).

664	Dec	LY	Thick	0.9206	0.62	12.4	3.41	68.2	7.21
713	Jan	LG	do	.8912	.42	8.4	2.98	59.6	6.41
791	Feb	LY	Medium	.8986	.....	.....	3.06	61.2	6.39
849	Apr	LY	Thick	.9000	.39	7.8	3.14	62.8	6.23
889	May	LG	Medium	.9359	.42	8.4	3.04	60.8	6.23
924	June	LY	Thick	.9199	.44	8.8	3.18	63.6	5.99
983	July	LY–DG	Medium	.9415	.45	9.0	2.87	57.4	6.06
1059	Aug	DG	Thin	.9500	.50	10.0	3.26	65.2	7.00
1078	Sept	DG–LY	Thick	.9359	.55	11.0	3.12	62.3	7.00
1091	Oct	LG	do	.9389	.52	10.3	3.02	60.4	6.58
Average				**.9232**	**.48**	**9.6**	**3.11**	**62.1**	**6.51**

TABLE 1.—*Comparison of Eureka lemons grown in various sections of California*—Continued.

SAN DIMAS (TREE 21).

Sample No.	Month picked.	Color.	Thickness of peel.	Specific gravity of fruit.	Oil in fruit, by weight.	Oil per ton of fruit.	Acid in fruit.	Acid per ton of fruit.	Acid in juice.
					Per cent.	*Pounds.*	*Per cent.*	*Pounds.*	*Per cent.*
656	Dec.	LG	Medium	0.9313	0.66	13.2	3.47	69.4	6.67
704	Jan.	LY	do	.9187	.41	8.2	3.44	68.8	6.31
761	Feb.	LY	Thick	.9186	.57	11.4	3.38	67.6	6.46
815	Mar.	LY	Medium	.9176	.53	10.6	3.40	68.0	6.55
876	Apr.	LY	do	.9260	.52	10.4	3.47	69.4	6.25
923	May	LY	do	.9346	.58	11.6	3.32	66.4	6.25
960	June	DG–FY	do	.9404	.46	9.2	3.00	60.0	6.16
1029	July	DG	do	.9498	.41	8.2	2.84	56.8	6.23
1051	Aug.	DG	Thin	.9407	.35	7.0	2.99	59.8	6.36
1079	Sept.	LG	Medium	.9611	.46	9.2	3.86	77.2	6.53
1087	Oct.	DG–LY	Thick	.9370	.49	9.7	2.68	53.6	6.44
1102	Nov.	LG–Y	Medium	.9780	.67	13.4	Lost.	Lost.	7.14
Average				**.9378**	**.51**	**10.2**	**3.26**	**65.2**	**6.45**

CLAREMONT (TREE 22).

699	Jan.	LY	Medium	0.9242	0.47	9.4	3.52	70.4	6.16
763	Feb.	LY	do	.9141	.50	10.0	3.01	60.2	6.62
824	Mar.	LY	do	.9187	.44	8.8	2.89	57.8	6.27
872	Apr.	LG–FY		.9130	.46	9.2	2.88	57.6	5.95
908	May	LY	Medium	.9278	.47	9.4	3.64	72.8	5.88
957	June	LY–DG	Thick	.9329	.45	9.0	2.87	57.4	5.92
1019	July	DG	Medium	.9420	.39	7.8	2.59	51.8	6.42
1047	Aug.	DG	do	.9507	.50	10.0	2.85	57.0	6.53
1068	Sept.	DG–LG	do	.9560	.53	10.6	3.44	68.8	6.79
1083	Oct.	DG	Thin	.9464	.52	10.4	2.57	51.5	6.11
1099	Nov.	Y	Medium	.9735	.63	12.5	3.43	68.6	6.79
1119	Dec.	LG–Y	do	.9775	.53	10.7	3.13	62.6	6.55
Average				**.9397**	**.49**	**9.8**	**3.07**	**61.4**	**6.33**

CARPENTERIA (TREE 24).

682	Jan.	LY	Thick	0.8991	0.49	9.8	2.64	52.8	6.58
726	Feb.	FY	do	.9089	.45	9.0	2.66	53.2	6.63
792	Mar.	LY	do	.8966	.32	6.4	2.66	53.2	5.90
850	Apr.	LY	do	.9068	.32	6.4	2.28	45.6	5.39
902	May	LG	do	.9215			2.54	50.8	5.74
939	June	DG	do	.9504	.34	6.8	2.28	45.6	6.20
998	July	LG	Very thick	.9823	.40	8.0	2.21	44.2	5.74
1036	Aug.	LG	Thick	.9421	.35	7.0	2.13	42.6	5.90
1067	Sept.	LG	do	.9377	.39	7.8	2.56	51.2	6.27
1080	Oct.	DG–Y	do	.9256	.41	8.2	2.07	41.3	5.95
1096	Nov.	DG–Y	do	.9306	.44	8.8	1.91	38.2	5.75
Average				**.9274**	**.39**	**7.8**	**2.36**	**47.2**	**6.00**

TABLE 2.—*Composition of Lisbon lemons grown in various sections of California.*

BONITA (TREE 2).

Sample No.	Month picked.	Color.[1]	Thickness of peel.	Specific gravity of fruit.	Oil in fruit, by weight.	Oil per ton of fruit.	Acid in fruit.[2]	Acid per ton of fruit.	Acid in juice.[2]
					Per cent.	*Pounds.*	*Per cent.*	*Pounds.*	*Per cent.*
490	July	LG–FY	Medium	0.8375	0.58	11.6	3.50	70.0	6.93
570	Sept.	LY	Thin	.9252	.59	11.8	3.96	79.1	7.42
595	Oct.	FY	Thick	.9186	.57	11.4	4.05	81.0	6.55
629	Nov.	LG–LY	Medium	.9012	.57	11.4	3.52	70.4	7.35
674	Dec.	LY	Thin		.52	10.4	3.94	78.8	6.97
779	Feb.	LY	Medium	.8511	.44	8.8	3.17	63.4	6.79
822	Mar.	LY	do	.9159	.41	8.2	2.92	58.4	6.23
882	Apr.	LY	do	.9118	.44	8.8	3.24	64.8	6.21
920	May	LY	Thick	.9074	.49	9.8	2.94	58.8	6.49
975	June	FY	Medium-thin	.9148	.53	10.6	3.50	70.0	7.07
1027	July	FY	Medium	.9215	.48	9.6	3.43	68.6	6.83
1057	Aug.	LY	do	.9455	.67	13.4	3.62	72.4	6.97
	Average			**.9046**	**.52**	**10.5**	**3.48**	**69.6**	**6.82**

CHULA VISTA (TREE 4).

492	July	LG–LY	Medium-thick	0.8485	0.62	12.3	3.68	73.5	7.24
543	Aug.	DG–FY	do	.9044	.50	10.0	3.57	71.4	6.90
573	Sept.	LY	Medium	.9318	.52	10.3	3.59	71.8	6.93
597	Oct.	DG–LG	do	.9173	.50	10.0	3.77	75.4	7.14
636	Nov.	LG–LY	do	.9306	.61	12.2	3.60	72.0	7.54
662	Dec.	LY	do	.9269	.66	13.2	3.87	77.4	8.05
764	Feb.	LY	Thick	.8931	.53	10.6	3.08	61.6	6.83
851	Mar.	LG	Very thick	.8990	.43	8.6	2.82	56.4	6.32
877	Apr.	LG	Thick	.9101	.57	11.4	3.27	65.4	6.34
937	June	LY	do	.9081	.55	11.0	3.00	60.0	6.58
1025	July	LY	Medium	.9207	.54	10.8	3.47	69.4	7.42
1049	Aug.	LG	do	.9405	.48	9.6	3.65	73.0	7.51
1072	Sept.	DG–Y	do	.9263	.49	9.8	3.50	71.1	7.49
	Average			**.9121**	**.54**	**10.8**	**3.45**	**69.1**	**7.10**

CHULA VISTA (TREE 5).

493	July	LG–LY	Thick	0.9423	0.56	11.2	3.41	68.2	6.79
544	Aug.	DG	Medium	.9396	.50	10.1	3.43	68.6	6.82
574	Sept.	LG	do	.9487	.59	11.8	3.94	78.8	7.32
598	Oct.	LG–LY	do	.9368	.50	9.9	3.88	77.6	6.81
637	Nov.	LG	do	.9307	.69	13.8	3.50	70.0	7.74
663	Dec.	LG	do	.9421	.84	16.8	3.47	69.4	7.81
765	Feb.	LY	do	.9084	.54	10.8	3.78	75.6	6.83
852	Mar.	LG	Thick	.9152	.49	9.8			6.27
878	Apr.	LG	Medium	.9268	.53	10.6	3.22	64.4	5.81
936	June	DG–LG	Very thick	.9314	.49	9.8	2.69	53.8	6.55
1023	July	LY	do	.9351	.49	9.8	2.99	59.8	7.44
1048	Aug.	LG	Thick	.9363	.54	10.8	2.95	59.0	7.32
1071	Sept.	DG–Y	Medium	.9280	.43	8.6	3.31	66.2	7.14
	Average			**.9324**	**.55**	**11.1**	**3.38**	**67.6**	**6.97**

ESCONDIDO (TREE 6).

505	July	DG–FY	Medium-thick	0.9437	0.48	9.6	3.22	64.4	6.02
534	Aug.	LG–FY	do	.9369	.50	10.0	3.22	64.4	6.23
568	Sept.	DG	Thick	.9205	.60	12.0	2.87	57.4	6.12
599	Oct.	DG	do	.9074	.58	11.6	2.82	56.4	6.42
626	Nov.	DG	Medium	.9186	.63	12.6	2.99	59.8	6.37
671	Dec.	LG	do	.9240	.59	11.8	3.03	60.6	6.51
766	Feb.	LY	Thick	.8991	.42	8.4	2.62	52.4	6.20
826	Mar.	LG	do	.9231	.49	9.8	2.76	55.2	6.28
885	Apr.	LG	Medium	.9210			2.80	56.0	6.27
925	May	LG	do	.9247	.50	10.0	2.95	59.0	6.04
971	June	DG–LY	do	.9410	.50	10.0	2.97	59.4	6.27
1021	July	DG	Thick	.9313	.37	7.4	2.58	51.6	6.30
1062	Aug.	LG	do	.9341	.39	7.8	3.03	60.6	6.97
	Average			**.9250**	**.50**	**10.1**	**2.91**	**58.2**	**6.31**

[1] DG, dark green; LG, light green; LY, light yellow; FY, full yellow.
[2] All acid is calculated as citric with water of crystallization.

TABLE 2.—*Composition of Lisbon lemons grown in various sections of California*—Continued.

SANTA PAULA (TREE 12).

Sample No.	Month picked.	Color.	Thickness of peel.	Specific gravity of fruit.	Oil in fruit, by weight.	Oil per ton of fruit.	Acid in fruit.	Acid per ton of fruit.	Acid in juice.
					Per cent.	*Pounds.*	*Per cent.*	*Pounds.*	*Per cent.*
640	Dec.	LG–LY	Medium	0.9182	0.50	10.0	3.34	66.8	7.28
681	Jan.	LY	Thick	.8955	.40	8.0	2.99	59.8	6.97
725	Feb.	LG	Medium	.9140	.42	8.4	2.95	59 0	6.86
790	Mar.	LG	do	.8973	.30	6.0	2.80	56.0	6.76
848	Apr.	LG	do	.8908	.30	6.0	3.10	62.0	6.44
893	May	LG	do	.9099	.41	8.2	3.21	64.2	6.74
942	June	LG	do	.9205	.41	8.2	3.39	67.8	6.77
986	July	LG–DG	do	.9239	.49	9.8	3.47	69.4	6.88
1042	Aug.	LY	do	.9204	.40	8.0	3.69	73.8	7.22
1075	Sept.	LY	do	.8952	.40	8.0	3.83	76.7	7.25
1085	Nov.	LG–Y	do	.9168	.42	8.4	2.95	59.0	7.28
1114	Dec.	LG–Y	do	.9666	.47	9.5	2.98	59.6	7.18
Average				.9141	.41	8.1	3.22	64.5	6.97

WHITTIER (TREE 15).

625	Nov.	DG	Thick	0.9073	0.70	14.0	3.02	60.4	6.37
667	Dec.	LY	do	.9049	.70	14.0	3.06	61.2	6.88
706	Jan.	LY	do	.8867	.55	11.0	2.93	58.6	6.51
771	Feb.	LY	Medium	.9053	.47	9.4	2.80	56.0	6.37
833	Mar.	LG	do	.9056	.37	7.4	2 64	52.8	6.31
880	Apr.	LY	do	.8884	.38	7.6	2.82	56.4	5.90
929	May	LY	Thick	.9067	.45	9.0	2.96	59.2	6.34
969	June	LY–FY	do	.8945	.46	9.2	2.92	59.4	6.37
1032	July	LG	do	.9445	.48	9.6	2.85	57.0	7.11
1053	Aug.	DG–FY	do	.9297	.42	8.4	3.12	62.4	6.65
1077	Sept.	LY	Medium	.9390	.49	9.8	3.32	66.4	6.79
1089	Oct.	DG–Y	Thick	.9382	.54	10.7	2.57	51.4	6.48
Average				.9126	.50	10.0	2.92	58.4	6.51

TABLE 3.—*Composition of Villa Franca lemons grown in various sections of California.*

BONITA (TREE 3).

Sample No.	Month picked.	Color.[1]	Thickness of peel.	Specific gravity of fruit.	Oil in fruit, by weight.	Oil per ton of fruit.	Acid in fruit.[2]	Acid per ton of fruit.	Acid in juice.[2]
					Per cent.	*Pounds.*	*Per cent.*	*Pounds.*	*Per cent.*
491	July	DG–LG	Medium-thick	0.9455	0.62	12.3	3.40	68.0	7.07
565	Sept.	DG	Thin	.9628	.47	9.4	4.16	83.2	7.28
596	Oct.	LG	Medium	.9557	.50	10.0	4.00	80.0	6.97
630	Nov.	DG	Thick	.9319	.59	11.8	3.73	74.6	7.58
675	Dec.	LY	Medium	.9304	.70	14.0	3.85	77.0	7.63
780	Feb.	LY	Thick	.8957	.54	10.8	3.20	64.0	7.07
823	Mar.	LY	do	.8753	.54	10.8	3.16	63.2	6.90
883	Apr.	LG	Medium-thick	.8965	.58	11.6	3.35	67.0	6.65
921	May	LG	Thick	.9079	.62	12.4	3.70	74.0	7.11
976	June	LY–FY	do	.9095	.57	11.4	3.63	72.6	7.28
1028	July	FY	Medium	.9222	.55	11.0	3.41	68.2	7.14
1058	Aug.	LY	do	.9631	.74	14.8	4.01	80.2	7.56
Average				.9247	.58	11.7	3.63	72.7	7.19

[1] DG, dark green; LG, light green; LY, light yellow; FY, full yellow.
[2] All acid is calculated as citric with water of crystallization.

TABLE 3.—*Composition of Villa Franca lemons grown in various sections of California*—Continued.

ESCONDIDO (TREE 7).

Sample No.	Month picked.	Color.	Thickness of peel.	Specific gravity of fruit.	Oil in fruit, by weight.	Oil per ton of fruit.	Acid in fruit.	Acid per ton of fruit.	Acid in juice.
					Per cent.	*Pounds.*	*Per cent.*	*Pounds.*	*Per cent.*
504	July	LG–LY	Thin–thick	0.9388	0.48	9.6	2.87	57.4	5.46
535	Aug	DG–LG	Medium–thick	.9427	.58	11.6	3.10	62.0	5.42
569	Sept	DG	Thick	.9198	.60	12.0	2.20	44.0	5.74
600	Oct	DG	do	.9268	.58	11.6	2.61	52.2	5.92
627	Nov	LG	do	.9410	.50	10.0	2.58	51.6	6.27
672	Dec	LG	do	.9115	.65	13.0	2.19	43.8	5.99
767	Feb	LY	Medium	.9210	.38	7.6	2.56	51.2	6.16
827	Mar	LY	Thick	.9221	.42	8.4	2.54	50.8	5.81
886	Apr	LG	Medium	.9330	.38	7.6	2.65	53.0	5.67
926	May	LY	do	.9185	.50	10.0	3.06	61.2	6.13
972	June	LG–LY	Thick	.9395	.54	10.8	2.54	50.8	5.64
1022	July	LG	do	.9332	.42	8.4	2.63	52.6	5.99
1063	Aug	LG	Medium	.9598	.51	10.2	2.84	56.8	5.64
	Average			.9314	.50	10.1	2.64	52.9	5.83

WHITTIER (TREE 17).

647	Dec	LG	Thick	0.9077	0.62	12.4	3.30	66.0	7.11
694	Jan	LY	Medium	.9025	.50	10.0	3.24	64.8	6.79
752	Feb	FY	Thick	.8917	.52	10.4	3.17	63.4	6.46
809	Mar	LY	do	.8903	.44	8.8	3.00	60.0	6.70
864	Apr	LY	do	.9093	.44	8.8	3.31	66.2	6.67
910	May	LY	Medium	.9233	.51	10.2	3.45	69.0	7.11
956	June	LY	Thick	.9309	.45	9.2	3.37	67.4	7.23
1011	July	LG	do	.9311	.56	11.2	3.22	64.4	6.91
1045	Aug	DG	Medium	.9499	.58	11.6	3.12	62.4	6.69
1069	Sept	DG–LY	do	.9447	.59	11.8	3.40	68.0	6.44
1081	Oct	DG	do	.9167	.51	10.2	2.71	54.3	6.55
1097	Nov	LG–Y	do	.9515	.49	9.8	2.66	53.2	6.51
1118	Dec	LG–Y	Thick	.9435	.56	11.3	2.47	49.4	7.28
	Average			.9225	.52	10.4	3.11	62.2	6.80

TABLE 4.—*Composition of Eureka lemons (Tree 9) grown in Lemon Cove, Calif.*

Sample No.	Month picked.	Color.[1]	Thickness of peel.	Specific gravity of fruit.	Oil in fruit, by weight.	Oil per ton of fruit.	Acid in fruit.[2]	Acid per ton of fruit.	Acid in juice.[2]
					Per cent.	*Pounds.*	*Per cent.*	*Pounds.*	*Per cent.*
602	Oct	LG	Medium	0.9481	0.62	12.4	3.75	75.0	7.00
623	Nov	LY	do	.9406	.62	12.3	3.50	70.0	6.06
665	Dec	FY	do	.9368	.54	10.8	3.42	68.4	6.20
703	Jan	FY	do	.9166	.56	11.2	3.08	61.6	6.13
766	Feb	FY	Thick	.8752	.41	8.2	2.98	59.6	5.83
819	Mar	FY	Medium	.8485	.38	7.6	2.32	46.4	4.59
	Average			.9110	.52	10.4	3.18	63.5	5.97

[1] DG, dark green; LG, light green; LY, light yellow; FY, full yellow.
[2] All acid is calculated as citric with water of crystallization.

TABLE 5.—*Composition of lemons (Tree 19), variety unknown, grown at Yuma, Ariz.*

Sample No.	Month picked.	Color.[1]	Thickness of peel.	Specific gravity of fruit.	Oil in fruit, by weight.	Oil per ton of fruit.	Acid in fruit.[2]	Acid per ton of fruit.	Acid in juice.[2]
					Per cent.	*Pounds.*	*Per cent.*	*Pounds.*	*Per cent.*
620	Nov	LY	Medium	0.9636	0.65	13.0	3.99	79.8	6.93
643	Dec	FY	Thin	.9818	.68	13.6	3.95	79.0	6.81
657	Dec	LY		.9527	.57	11.4	3.72	74.4	6.77
762	Feb	FY	Very thin	.9325	.40	8.0	3.88	77.6	6.31
	Average			.9576	.57	11.5	3.88	77.7	6.70

[1] DG, dark green; LG, light green; LY, light yellow; FY, full yellow.
[2] All acid is calculated as citric with water of crystallization.

TABLE 6.—*Summary of composition of Eureka, Lisbon, and Villa Franca lemons (Tables 1 to 3).*

Tree No.	Specific gravity of fruit.	Oil per ton of fruit.	Acid per ton of fruit.
		Pounds.	*Pounds.*
Eureka:			
1	0.9522	9.9	74.3
10	.9386	9.2	73.3
11	.9407	8.9	69.1
13	.9408	11.3	66.6
14	.9427	10.0	61.4
16	.9403	8.6	63.9
18	.9232	9.6	62.1
21	.9378	10.2	65.2
22	.9397	9.8	61.4
24	.9274	7.8	47.2
Average	**.938 ± .004**	**9.5 ± .3**	**64.5 ± 1.3**
Lisbon:			
2	.9046	10.5	69.6
4	.9121	10.8	69.1
5	.9324	11.1	67.6
6	.9250	10.1	58.2
12	.9141	8.1	64.5
15	.9126	10.0	58.4
Average	**.917 ± .004**	**10.1 ± .3**	**64.7 ± 1.2**
Villa Franca:			
3	.9247	11.7	72.7
7	.9314	10.1	52.9
17	.9225	10.4	62.2
Average	**.926 ± .004**	**10.7 ± .3**	**62.6 ± 1.2**

TABLE 7.—*Summary of analyses of different strains of Eureka and Lisbon lemons grown at Corona, Calif.*

Variety.	Number trees.	Specific gravity of fruit.	Oil per ton of fruit.	Rind.	Insoluble solids in pulp.	Sugars in juice.	Acidity of juice.
			Pounds.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Eureka	10	0.939 (±0.005)	9.5 (±0.4)	36.2(±0.9)	1.9 (±0.1)	2.5 (±0.1)	5.3
Lisbon	5	.905 (±0.004)	10.8(±0.4)	38.8(±0.5)	1.7(±0.07)	1.9 (±0.1)	5.7

TABLE 8.—*Relation between color and thickness of peel.*

Color.	Number samples examined.	Number samples found to be—		
		Thin skinned.	Medium skinned.	Thick skinned.
Eureka:				
Dark green	15	4	8	3
Light green	36	6	17	13
Light yellow	32	3	21	8
Full yellow	5	0	3	2
Lisbon:				
Dark green	6	0	2	4
Light green	21	0	14	7
Light yellow	24	2	13	9
Full yellow	3	1	1	1

TABLE 9.—*Relation of color to composition of fruit.*

Determination.	Dark green.	Light green.	Light yellow.	Full yellow.
Eureka:				
Specific gravity	0.950	0.939	0.926	0.929
Oil per ton of fruit (pounds)	9.1	9.2	9.6	11.0
Acid per ton of fruit (pounds)	62.0	66.0	66.0	69.0
Lisbon:				
Specific gravity	.921	.922	.912	.918
Oil per ton of fruit (pounds)	11.3	9.8	10.0	10.5
Acid per ton of fruit (pounds)	59.0	62.0	66.0	73.0

TABLE 10.—*Correlation between thickness of peel and composition of fruit.*

Determination.	Composition.		
	Thick skin.	Medium skin.	Thin skin.
Eureka:			
Specific gravity	0.924	0.936	0.958
Oil per ton of fruit (pounds)	8.4	9.9	9.6
Acid per ton of fruit (pounds)	59.0	67.0	72.0
Lisbon:			
Specific gravity	.913	.920	.920
Oil per ton of fruit (pounds)	10.3	10.0	11.2
Acid per ton of fruit (pounds)	60.0	65.0	75.0

TABLE 11.—*Comparison of composition of coastal with that of inland Eureka lemons.*

Location.	Specific gravity of fruit.	Oil per ton of fruit.	Acid per ton of fruit.
Coastal:		*Pounds.*	*Pounds.*
Bonita	0.962	9.9	74.3
Whittier	.943	10.0	61.4
Do	.940	8.6	63.9
Do	.923	9.6	62.1
Carpenteria	.927	7.8	47.2
Average	**.939**	**9.2**	**61.8**
Average (excluding Carpenteria data)	**.942**	**9.5**	**65.3**
Inland:			
Santa Paula	.939	9.2	73.3
Do	.941	8.9	69.1
San Fernando	.941	11.3	66.6
San Dimas	.938	10.2	65.2
Claremont	.940	9.8	61.4
Average	**.940**	**9.7**	**67.1**

DISCUSSION OF RESULTS.

DIFFERENCES IN VARIETIES.

The average composition of the Eureka, Lisbon, and Villa Franca varieties is shown in Table 6. The figures below the averages are the probable errors of the mean. For instance, under specific gravity the figure 0.938 is the average obtained from more than 100 samples. Had the specific gravity of each sample been 0.938, there would be no doubt that that figure represented the true average of the lot. This was not the case, however, and never is, where

natural products are under consideration. The samples varied decidedly from this average, some having a higher and some a lower specific gravity. It is necessary, therefore, to use mathematical formulas applicable to such cases, with the result that the chances are even that the true mean is not greater than 0.942 or less than 0.934, or, as it is expressed, 0.938 ± 0.004. The same explanation applies to the other figures. The results reveal little difference in the composition of these varieties of lemons.

By applying other formulas it is possible to ascertain whether the differences shown are really significant, and, if so, to what extent. For instance, the odds are 78 to 1 that the difference between the specific gravity of Eureka and that of Lisbon lemons shown is significant. On the other hand, the odds are only even (1 to 1) that there is a significant difference between the specific gravity of Villa Francas and that of the Lisbons, and about 5 to 1 that the difference of 0.012 between the Eureka and the Villa Franca specific gravities is significant. It is probable also that no significant difference exists between the oil content of the Eureka and Lisbon varieties, nor between that of the Lisbon and Villa Franca lemons. The odds, however, are 18 to 1 that the difference between the oil content of the Eureka and that of Villa Franca lemons is significant. No significant difference is shown in the citric acid content of the varieties.

As these averages are obtained from trees located in all parts of the lemon-growing area of California and from samples taken consistently throughout the year, there is little doubt that the data are representative of the actual composition of these varieties as grown in California.

In this connection, it is interesting to consider some data obtained from analyzing 18 sets of samples of the Eureka and Lisbon varieties of different strains grown in two groves at Corona. These sets are derived from monthly samples taken over a period of two years. In considering them, the fact that all the Eureka trees were in one grove and all the Lisbons in another should be kept in mind, as this makes the data less desirable for comparative purposes than those from the field samples. The fact that these trees were chosen to illustrate differences between strains within their respective varieties rather than those between the two varieties also lessens their value for comparison. Interesting studies of the strains of these varieties have been reported by Shamel and his coworkers (1) (2).

There are certain marked differences, however, that are not apparent between strains within the variety, but become apparent when the varieties are compared. To illustrate, the fruit of 10 Eureka trees under observation had an average specific gravity varying from 0.925 to 0.989, the average being that shown in Table 7. The fruit of the three Lisbon trees had specific gravities ranging

from 0.898 to 0.915, with the average shown in Table 7. Here it is perfectly apparent that the difference is one between the varieties, for the maximum specific gravity of Lisbon strains is lower than the minimum specific gravity of the Eureka strains. This difference corroborates that already found between the regular samples of each variety.

When the averages for oil are considered, the results are less satisfactory. The averages for all the Eureka strains vary between 7.6 and 11.2 pounds per ton; on the other hand, the Lisbon averages vary from 8.6 to 12.9 pounds per ton. The averages in Table 7, with the probable error of the means, show that the odds are 7 to 1 that the difference is significant in the case of these samples. Whether or not this significance would be maintained throughout the entire plantings of the State would depend largely upon the preponderance of the strains having high oil content. At present no data establishing such a preponderance are available.

Likewise, the acidity of the juice of the Corona samples shows some difference between the varieties, but there is a similar difference between the strains within the varieties, so that this is not significant when the varieties are considered as a whole.

The same conditions apply to the averages on percentage of rind shown in Table 7. Apparently nothing significant in the averages of the insoluble solids is shown, although a significant difference is apparent in some of the strains within the variety.[3]

The averages for sugar show a rather marked difference, which is more significant between the varieties than between the strains within the variety. Only a single Lisbon strain has an average sugar content greater than 2 per cent, while not one Eureka strain has an average below that figure. Therefore, the odds of over 200 to 1 that the difference is significant probably apply to the varieties as a whole.

SEASONAL DIFFERENCES.

The marked differences found in the samples of lemons harvested at different times of the year are interesting. As previously stated, lemons may be harvested during every month of the year, the selection being made according to size and not according to color. As the samples were harvested in the same manner as the commercial fruit, the changes which are discussed in the following pages are due not to the different stages of maturity but to the composition of fruit maturing at different times of the year. All of the samples analyzed were commercially mature.

[3] This difference will be discussed in a forthcoming publication.

Figure 2 [4] shows the specific gravity of the fruit in both varieties as harvested monthly. The monthly average shown here must not be interpreted too literally, for usually the differences from month to month are small. A general trend is shown, however, and there is little doubt that the changes from season to season are really significant. For the first four months of the year, the Eurekas change but little, while there is a gradual increase in the specific gravity of the Lisbons. With the advent of spring, the Eurekas begin to increase rapidly, and this increase continues without interruption until midsummer. During the corresponding period, the Lisbons also increase rapidly, reaching the maximum in August. From midsummer to January there is a marked decline in the specific gravity of both

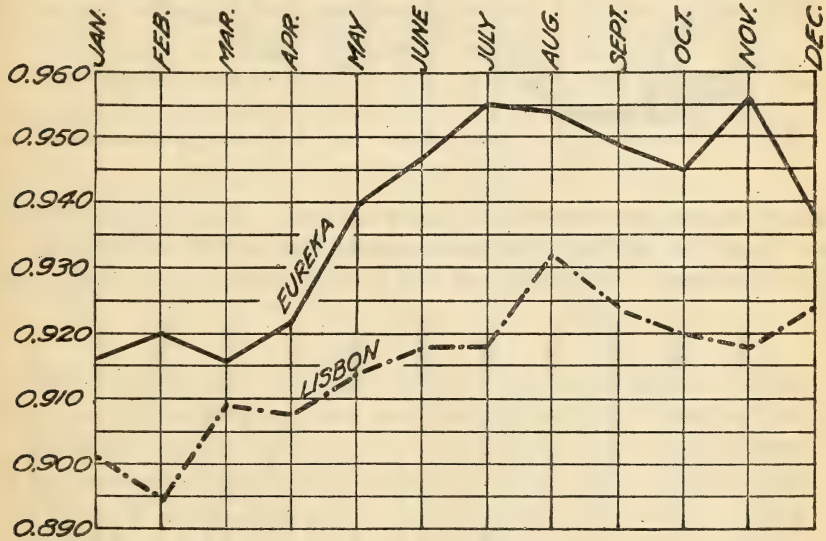

FIG. 2.—Monthly averages of specific gravity.

varieties. The data leave no doubt that both varieties have the lowest specific gravity during the winter months and the highest in midsummer.

Figure 3 shows the variation in the oil content of the fruit harvested each month of the year. Here again indisputable differences occur in both varieties, and the general trend of both is very much the same. The late winter and spring fruit contains a minimum amount of oil. The oil content is only slightly increased in the summer fruit, but with the advent of fall it rises rapidly, until December finds the oil content at a maximum in both varieties.

[4] In determining the monthly averages, where there are several monthly samples from one tree, the average is taken. Where monthly samples are missing, the results are interpolated, the average of the preceding and succeeding months being used.

Figure 4 shows the periodical differences in acid content. Apparently the acid content of lemons varies more from month to month than any other constituent, the graphs being very irregular. It would seem that the Eureka variety has a rather well-defined period of low

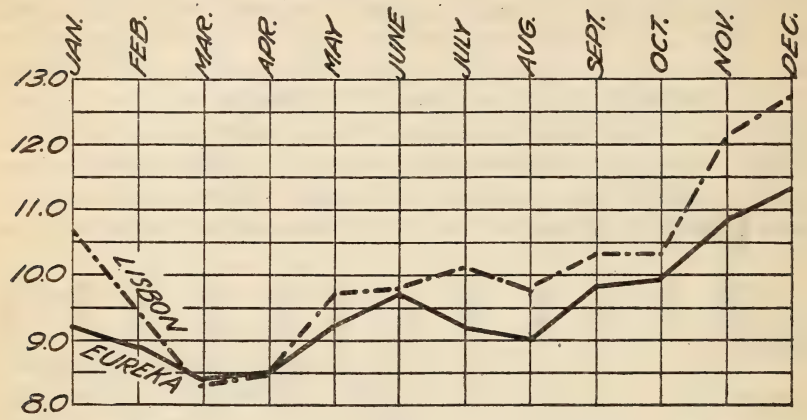

FIG. 3.—Monthly averages of pounds of oil per ton of fruit.

acidity in the late winter and spring months. Rising rapidly from that time, the acid is at its maximum in September, after which it again declines. The acidity of the Lisbon samples was much less

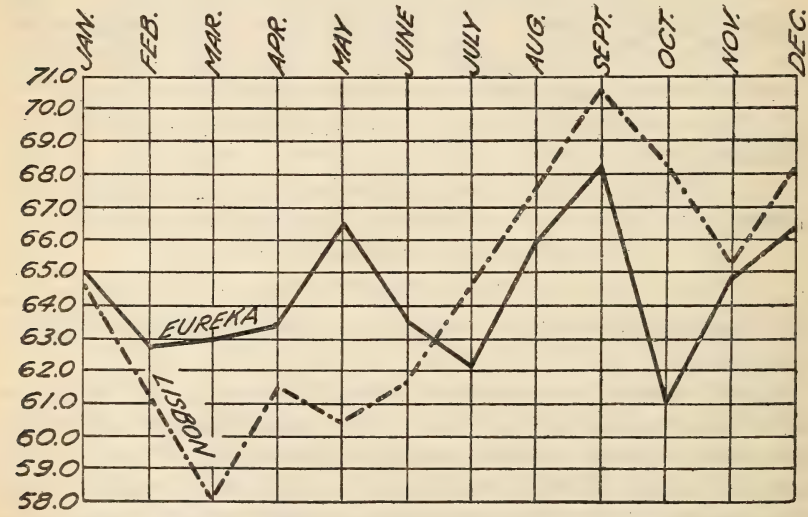

FIG. 4.—Monthly averages of pounds of acid per ton of fruit.

uniform, the general trend of the curve being broken by several inexplicable irregularities. While the maximum occurs in September, as with the Eurekas, there is no well-defined minimum, low averages being shown in both July and October. During the first six months

of the year, the Eureka variety contains the greater amount of acid; during the last six months, the reverse holds true.

COLOR AND THICKNESS OF PEEL.

Apparently little correlation exists between the color and composition of the fruit. The data were carefully selected so as to omit those from samples containing too great a mixture of colors to be accurately estimated.

The better part of both varieties had peel of medium thickness, but the Eurekas had a larger percentage of thin-skinned fruit and a smaller one of thick-skinned than the Lisbons (Table 8).

Few conclusions can be drawn from these data. Where some correlation may exist in one of the varieties, it fails to show with the other. For instance, the Eureka seems to decline in specific gravity as the color lightens, but the Lisbons show no such tendency. Likewise, the acid seems to increase with the Lisbons as the color decreases, but this is not apparent in the case of the Eurekas, although the dark green and full yellow correlate.

Classifying the samples according to thickness of skin, 26 thick-skinned, 49 medium-skinned, and 13 thin-skinned Eurekas were found, and 21 thick-, 30 medium-, and 3 thin-skinned Lisbons (Table 8). Unfortunately there are too few thin-skinned Lisbon samples to render the results under this particular head of value, and no account is taken of them in discussing the data.

Two correlations seem apparent from these data: (1) The specific gravity increases as the thickness of the peel decreases; and (2) the acidity of the fruit increases as the peel decreases. Both seem in line with what might be supposed would take place. Thick-skinned fruit often has a hollow center and is generally coarser than that with thinner peel. Inasmuch as the peel contains no acid, naturally the fruit having the greatest amount of peel is likely to contain the least amount of acid. As the oil-bearing part of the peel is near its surface and does not correspond in any way with the thickness, it would hardly be expected to change.

EFFECT OF LOCATION.

It was thought at first that the data obtained in this investigation might throw some light upon the effect of environment on the composition of the fruit. Locations near the coast as well as in the inland valleys were selected, and if any marked difference in composition between lemons from the two sections existed it should have been revealed. The 10 Eureka locations were equally divided as to situation, 5 being on or near the coast and 5 inland or separated from the coast by ranges of hills. What at first appears to be a slight difference in the results (Table 11) is found in the oil content of fruit from the

two sets of locations, and a more pronounced difference in the acid content. If, however, the location at Carpenteria, which is apparently abnormal as to the oil and acid content of the fruit, is discarded, the averages are too nearly the same to render any conclusion possible.

These data are offered not as a final statement upon the subject of the difference in composition between coastal and inland lemons, but merely to show that so far no difference has been found.

CONCLUSIONS.

A few well-defined differences between the varieties of lemons examined exist, the most striking of which is in the specific gravity of the fruit. The specific gravity of the Eureka variety is greater than that of the other varieties, and that of the Villa Franca appears to be practically the same as that of the Lisbon variety.

The Villa Francas have more oil than the Eurekas. Otherwise no absolute difference in the oil content is shown, although there is some indication that the Eureka has the lowest oil content.

There is no difference in the acid content of the three varieties.

A marked difference in sugar content between Eureka and Lisbon lemons exists.

The acidity of lemons is highest in the early fall. Lemons have the lowest specific gravity during the winter months and the highest in midsummer. Their oil content is lowest in late winter and spring and highest in the fall.

No absolute correlation between the color of the peel and the composition of the fruit was found. As the thickness of the peel increases, the specific gravity of the fruit decreases, as does the acid content.

No correlation is shown between color and thickness of the peel.

No difference in composition between lemons grown on the coast and those grown inland is shown.

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