Evaluation of Fatty Acid and Sterol Profiles California Olive Oil 2017/18 Season

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Evaluation of Fatty Acid and Sterol Profiles, California Olive Oil, 2017/18 Season

SUMMARY

At the request of the Olive Oil Commission of California (OOCC), the UC Davis Olive Center collected California olive oil samples produced in the 2017/18 Season and analyzed fatty acid and sterol profiles.

The study team collected 70 single-variety samples (26 varieties from 15 counties) of olive oil from California commercial producers. Samples that were found to be outside one or more parameters at the UC Davis laboratory were sent to Modern Olives Laboratory (Woodland, CA) for retesting.

The results found that 91 percent (64 of 70 samples) were within the fatty acid and sterol parameters required in California while nine percent (six samples) were outside at least one sterol parameter. This result is consistent with data from the past four seasons, which overall have had 11 percent of samples outside at least one sterol or fatty acid parameter.

All of the samples that were outside fatty acid and sterol parameters in the 2017/18 season were from varieties used in the super-high-density (SHD) system. Seventy-five percent of the 28 samples (21 samples) that have been outside fatty acid and sterol parameters over the past four seasons are from the most commonly planted SHD varieties of Arbequina, Arbosana and Koroneiki and 41 percent of the samples were from the Desert region.

The OOCC may want to consider recommending modifications to California olive oil standards so that fatty acid and sterol profile standards accommodate all olive oil produced in California.

BACKGROUND

The OOCC requested the UC Davis Olive Center to collect data on the fatty acid and sterol profile of California olive oils from commercial samples. The Commission requested that the Olive Center collect 70 samples from a wide range of varieties and counties.

California olive oil must meet standards for fatty acid and sterol profiles set by the California Department of Food and Agriculture (CDFA), California law, and the United States Department of Agriculture (USDA). Two of the key authenticity tests referenced in these standards are fatty acid profile and sterol profile[1]. Every type of cooking oil, whether corn, canola, soy, or olive, has a distinctive fatty acid and sterol profile, which is why these tests can be useful for determining whether an olive oil has been adulterated[2]. Table 1 lists indicative fatty acid/sterol parameters of common adulterants (seed or vegetable oils) detected in olive oil[3]. However, fatty acids and sterols also can be affected by factors unrelated to the authenticity of

[1] Oils mainly consist of triacylglycerols comprised of various fatty acids, including oleic, palmitic, and linolenic acids, which together make up the fatty acid profile of the oil. Each plant species also contains a unique combination of organic molecules known as sterols, including campesterol, brassicasterol, and cholesterol, which make up the sterol profile of the oil.

[2] (a) Jabeur, H., Zribi, A., Makni, J., Rebai, A., Abdelhedi, R., & Bouaziz, M. (2014). Detection of Chemlali extra-virgin olive oil adulteration mixed with soybean oil, corn oil, and sunflower oil by using GC and HPLC. Journal of agricultural and food chemistry, 62(21), 4893-4904. (b) Zhang, L., Li, P., Sun, X., Wang, X., Xu, B., Wang, X. & Ding, X. (2014). Classification and adulteration detection of vegetable oils based on fatty acid profiles. Journal of agricultural and food chemistry, 62(34), 8745-8751.

[3] (a) Al-Ismail, K. M., Alsaed, A. K., Ahmad, R., & Al-Dabbas, M. (2010). Detection of olive oil adulteration with some plant oils by GLC analysis of sterols using polar column. Food Chemistry, 121(4), 1255-1259. (b) Dubois, V., Breton,

an oil, including geographical origin[4], climate and altitude[5], cultivar and harvest period[6], irrigation strategies[7], and processing techniques[8]. These factors can lead to an authentic olive oil failing to meet one of the parameters of standards for fatty acid and sterol profiles.

Table 1. Indicative fatty acid/sterol parameters of common adulterants detected in olive oil

		USDA Standard (%)	Change of Concentration	Potential Adulterant (oil)
Key fatty acid	Palmitic acid	7.5-20.0	Increase	Palm, cottonseed
	Oleic acid	55.0-83.0	Decrease	Corn, cotton, safflower, soybean, sunflower
	Linoleic acid	3.5-21.0	Increase	Canola, corn, cotton, safflower, soybean
	Linolenic acid	≤1.5	Increase	Canola, soybean
Key sterol	Brassicasterol	≤0.1	Increase	Canola
	Campesterol	≤4.5	Increase	Canola, corn, cotton, grapeseed, palm, safflower, soybean, sunflower
	Stigmasterol	≤Campesterol	Increase	Corn, cotton, palm, safflower, soybean, sunflower
	Delta-7-stigmastenol	≤0.5	Increase	Corn, cotton, palm, safflower, soybean, sunflower
	Apparent B-Sitosterol	≥93.0	Decrease	Canola, corn, safflower, soybean, sunflower

In this report, we summarized the results of 70 single-variety California olive oil from the 2017/18 Season and compared findings with the Center's research from previous years[9], as well as research from the other olive-growing regions around the world.

S., Linder, M., Fanni, J., & Parmentier, M. (2007). Fatty acid profiles of 80 vegetable oils with regard to their nutritional potential. European Journal of Lipid Science and Technology, 109(7), 710-732. (c) Aparicio, R., & Aparicio-Ruíz, R. (2000). Authentication of vegetable oils by chromatographic techniques. Journal of Chromatography A, 881(1-2), 93-104.

[4] (a) Giacalone, R., Giuliano, S., Gulotta, E., Monfreda, M., & Presti, G. (2015). Origin assessment of EV olive oils by esterified sterols analysis. Food chemistry, 188, 279-285. (b) Borges, T. H., Pereira, J. A., Cabrera-Vique, C., Lara, L., Oliveira, A. F., & Seiquer, I. (2017). Characterization of Arbequina virgin olive oils produced in different regions of Brazil and Spain: Physicochemical properties, oxidative stability and fatty acid profile. Food chemistry, 215, 454-462.

[5] (a) Uncu, O., & Ozen, B. (2016). Geographical differentiation of a monovarietal olive oil using various chemical parameters and mid-infrared spectroscopy. Analytical Methods, 8(24), 4872-4880. (b) Rouas, S., Rahmani, M., El Antari, A., Idrissi, D. J., Souizi, A., & Maata, N. (2016). Effect of geographical conditions (altitude and pedology) and age of olive plantations on the typicality of olive oil in Moulay Driss Zarhoun. Mediterranean Journal of Biosciences, 1(3), 128-137.

[6] (a) Alowaiesh, B., Singh, Z., Fang, Z., & Kailis, S. G. (2018). Harvest time impacts the fatty acid compositions, phenolic compounds and sensory attributes of Frantoio and Manzanilla olive oil. Scientia Horticulturae, 234, 74-80. (b) Bilušić, T., Žanetić, M., Ljubenkov, I., Mekinić, I. G., Štambuk, S., Bojović, V. & Magiatis, P. (2018). Molecular characterization of Dalmatian cultivars and the influence of the olive fruit harvest period on chemical profile, sensory characteristics and oil oxidative stability. European food research and technology, 244(2), 281-289.

[7] (a) Bedbabis, S., Rouina, B. B., Mazzeo, A., & Ferrara, G. (2017). Irrigation with treated wastewater affected the minor components of virgin olive oil from cv. Chemlali in Tunisia. European Food Research and Technology, 243(11), 1887-1894. (b) Ben Brahim, S., Gargouri, B., Marrakchi, F., & Bouaziz, M. (2016). The effects of different irrigation treatments on olive oil quality and composition: a comparative study between treated and olive mill wastewater. Journal of agricultural and food chemistry, 64(6), 1223-1230.

[8] (a) López-López, A., Cortés-Delgado, A., & Garrido-Fernández, A. (2015). Effect of green Spanish-style processing (Manzanilla and Hojiblanca) on the quality parameters and fatty acid and triacylglycerol compositions of olive fat. Food chemistry, 188, 37-45. (b) Piscopo, A., De Bruno, A., Zappia, A., Ventre, C., & Poiana, M. (2016). Characterization of monovarietal olive oils obtained from mills of Calabria region (Southern Italy). Food chemistry, 213, 313-318.

[9] (a) Flynn, D., Li, X., Wang, S. (2014). Fatty acid and sterol profiles of olive oil produced in the United States. *UC Davis Olive Center publication.* http://olivecenter.ucdavis.edu/research/files/fatty-acid-and-sterol-profiles-of-olive-

SAMPLE INFORMATION

In soliciting olive oil samples produced in the 2017/18 Season, the study team sought to maximize the number of varieties and growing areas of California. The study team collected 70 samples between November 2017 and February 2018. Ninety percent of the samples (63 samples) were processed within 24 hours of harvest based on harvest dates and processing dates supplied by the producer. The other 10 percent (seven samples) did not specify the specific day of harvest and processing. The UC Davis Olive Center stored samples in a dark room at 22°C (71°F) prior to the sample being analyzed in April. Samples that did not meet one or more fatty acid or sterol parameters at the UC Davis laboratory were sent to Modern Olives laboratory (Woodland, CA) for retesting. Both laboratories used the same analytical methods specified by the International Olive Council[10]. This report considers a sample to not be within a fatty acid or sterol parameter only when the data from both laboratories agreed.

Figure 1 illustrates the location of harvest, by county, for the samples. Samples were received from 15 counties (one sample was labeled as "Yuba-Sutter" and counted as one county) and three regions: Central Valley, Wine Country and Desert. The Central Valley represents 80 percent of the samples, which is appropriate given that this region is the source of a very high proportion of California olive oil. The number of samples from each county is shown in red.

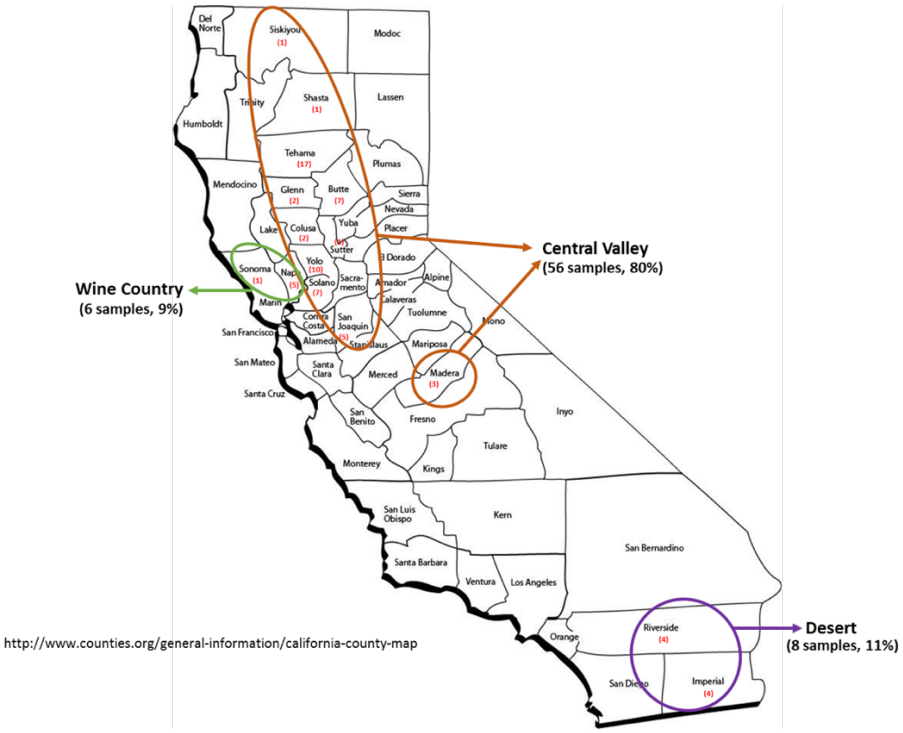

Figure 1. Sample distribution by California counties and regions

oilproduced-in-the-united-states. (b) UC Davis Olive Center. (2016). Evaluation of Fatty Acid and Sterol Profiles California Olive Oil 2014/15 Season. *UC Davis Olive Center*. (c) UC Davis Olive Center. (2016). Evaluation of Fatty Acid and Sterol Profiles California Olive Oil 2015/16 Season, *UC Davis Olive Center*. (d) UC Davis Olive Center. (2017). Evaluation of Fatty Acid and Sterol Profiles California Olive Oil 2016/17 Season. *UC Davis Olive Center.*

[10] (a) Determination of fatty acid methyl esters by gas chromatography, COI/T.20/Doc. No 33, February 2015. (b) Determination of the composition and content of sterols and triterpene dialcohols by capillary column gas chromatography, COI/ T.20/ Doc. No 30/Rev. 1, November 2013.

The study team collected 26 varieties in all, with 46 percent (34 of 70 samples) of the varieties typically planted in the super-high-density system and 54 percent (36 of 70 samples) typically grown in lower-density planting configurations (Table 2). The super-high-density varieties included multiple samples of the dominant California oil varieties of Arbequina, Arbosana and Koroneiki, as well as newer varieties: Chiquitita (Arbequina and Picual cross), 9803-20 (Arbequina and Arbosana cross), 9805-01 (Koroneiki and Arbosana cross), Oliana (Arbosana and Arbequina cross), Don Carlo and Favolosa (both derived from Frantoio), and Lecciana (Leccino and Arbosana cross).

Table 2. Samples by variety, county and region

CODE	VARIETY	COUNTY (# SAMPLES)
CENTRAL VALLEY REGION - 56 SAMPLES (80%)		
27	Mission	Butte (7)
29	Chiquitita	
32	Oliana	
33	9805-01	
34	Lecciana	
35	9803-20	
37	Arbequina	
19	Arbequina	Colusa (2)
20	Arbequina	
24	Ascolano	Glenn (2)
28	Koroneiki	
3	Arbequina	Madera (3)
4	Arbosana	
5	Koroneiki	
16	Koroneiki	San Joaquin (5)
17	Koroneiki	
18	Arbosana	
31	Arbosana	
42	Arbequina	
76	Ascolano	Shasta (1)
10	Mission	Siskiyou (1)
8	Taggiasca	Solano (7)
9	Frantoio	
11	Pendolino	
12	Moraiolo	
13	Leccino	
14	Mission	
26	Arbequina	
25	Manzanillo	Tehama (17)
30	Arbequina	
43	Arbequina	
55	Arbequina	

59	Arbosana	
60	Ascolano	
61	Barnea	
62	Coratina	
63	Don Carlo	
64	Favolosa	
65	Frantoio	
66	Hojiblanca	
67	Leccino	
69	Sevillano	
70	Taggiasca	
71	Arbequina	
72	Picual	
21	Picual	Yolo (10)
22	Arbosana	
23	Coratina	
36	Arbequina	
40	Koroneiki	
44	Arbequina	
45	Taggiasca	
46	Frantoio	
47	Picual	
58	Ascolano	
38	Arbequina	Yuba-Sutter (1)
WINE COUNTRY REGION - 6 SAMPLES (9%)		
15	Sevillano	Napa (5)
74	Taggiasca	
75	Sevillano	
77	Mission	
78	Koroneiki	
48	Moraiolo	Sonoma (1)
DESERT REGION - 8 SAMPLES (11%)		
1	Arbosana	Imperial (4)
2	Koroneiki	
49	Arbosana	
50	Mission	
51	Mission	Riverside (4)
52	Grignon	
53	Dolce	
54	Chemlali	

RESULTS AND DISCUSSION

Test results indicate that 64 of 70 samples (91 percent) were within the parameters for fatty acid and sterol profiles required of California olive oil, slightly higher than the 87 percent passage rate from the previous season.

Average values and standard deviations (when available) of key fatty acids are shown in Table 3. The 13 Arbequina samples from the Central Valley had a similar fatty acid profile as Arbequina samples from the same region in the previous season[9b]. Arbosana and Koroneiki from the Desert had higher levels of palmitic acid (C16:0), palmitoleic acid (C16:1), linolenic acid (C18:2) and linolenic acid (C18:3); and a lower level of oleic acid (C18:1) than the same varieties from the Central Valley. Overall, regardless of the difference in varieties and regions, oleic acid levels tended to correlate negatively with palmitic acid and linoleic acid levels.

Table 3. Fatty acid profile by variety

Variety	**Region**	**Palmitic Acid (C16:0)**	**Palmitoleic Acid (C16:1)**	**Stearic Acid (C18:0)**	**Oleic Acid (C18:1)**	**Linoleic Acid (C18:2)**	**Linolenic Acid (C18:3)**
USDA Standard		***7.5-20.0***	***0.3-3.5***	***0.5-5.0***	***55.0-83.0***	***3.5-21.0***	***≤1.5***
9803-20	Central Valley	15.5	1.3	2.4	74.0	5.1	0.6
9805-01	Central Valley	14.9	1.2	2.1	74.4	5.8	0.7
Arbequina	Central Valley	15.6±1.0	1.3±0.2	1.9±0.2	70.7±1.8	8.8±1.0	0.5±0.1.0
Arbosana	Central Valley	15.1±1.2	1.4±0.3	1.9±0.3	73.7±2.3	6.1±1.2	0.6±0.1
	Desert	18.9±1.4	2.6±0.3	2.2±0.1	58.6±3.9	15.2±1.8	1.1±0.3
Ascolano	Central Valley	13.9±0.1	1±0.1	1.7±0.3	73.6±1.7	8.0±1.5	0.7±0.0
Barnea	Central Valley	12.7	0.7	1.8	73.0	10.6	0.7
Chemlali	Desert	18.0	1.9	1.8	62.6	14.5	0.7
Chiquitita	Central Valley	16.3	1.4	1.9	70.4	8.5	0.7
Coratina	Central Valley	14.1±2.3	0.5±0.1	1.7±0.2	74.6±4.5	7.5±1.5	0.9±0.2
Dolce	Desert	12.8	0.8	1.8	72.2	11.2	0.8
Don Carlo	Central Valley	11.5	0.5	1.5	80.8	4.5	0.5
Favolosa	Central Valley	14.0	0.9	1.3	74.7	7.8	0.8
Frantoio	Central Valley	14.4±0.4	1.2±0.1	2.0±0.2	71±1.9	9.9±2.1	0.7±0.2
Grignon	Desert	13.8	0.9	1.8	73.4	8.9	0.7
Hojiblanca	Central Valley	12.3	1.0	2.8	78.8	3.6	0.8
Koroneiki	Central Valley	12.7±1.0	0.8±0.2	2.2±0.1	77.4±1.4	5.3±0.4	0.6±0.0
	Wine Country	13.4	0.9	1.9	71.5	10.3	0.9
	Desert	17.1	1.3	2.6	69.1	8.2	0.7

Lecciana	Central Valley	15.9	1.1	0.1	73.2	5.9	0.6
Leccino	Central Valley	13.9±0.3	1.1±0.1	2.0±0.1	73.8±0.5	7.8±0.2	0.6±0.1
Manzanillo	Central Valley	15.8	1.3	2.9	73.8	3.8	0.9
Mission	Central Valley	13.2±0.4	0.9±0.1	2.5±0.6	75.2±1.0	6.5±1.4	0.7±0.1
	Wine Country	11.9	0.6	2.3	74.1	9.2	0.8
	Desert	11.8±0.2	0.7±0.1	2.3±1.0	69.2±6.2	14.4±4.1	1.0±0.3
Moraiolo	Central Valley	15.3	1.1	1.9	71.4	9.0	0.6
	Wine Country	12.4	0.5	1.9	76.0	7.6	0.7
Oliana	Central Valley	16.3	1.7	1.7	68.8	9.9	0.6
Pendolino	Central Valley	13.1	0.9	2.2	74.6	7.8	0.6
Picual	Central Valley	13.7±1.3	1.2±0.2	2.2±0.7	77.2±1.0	3.8±0.2	0.9±0.3
Sevillano	Central Valley	12.6	0.8	2.5	72.6	9.1	1.1
	Wine Country	12.9±0.3	0.6±0.1	2.2±0.1	73.0±0.8	9.1±0.9	0.9±0.0
Taggiasca	Central Valley	14.1±0.4	1.1±0.1	1.9±0.1	71.8±1.7	9.5±1.9	0.7±0.2
	Wine Country	13.4	1.0	2.4	73.4	8.5	0.6

Average values and standard deviations (when available) of key sterols are shown in Table 4. Koroneiki from the Desert had higher levels of campesterol, stigmasterol, delta-7-stigmastenol and total sterols as well as a lower level of apparent β-sitosterol than the same variety from the other regions. In general, campesterol levels tended to correlate negatively with apparent β-sitosterol levels but positively with stigmasterol levels; and apparent β-sitosterol levels tended to correlate positively with the levels of total sterols.

Table 4. Sterol profile by variety

Variety	**Region**	**Cholesterol**	**Brassicasterol**	**Campesterol**	**Stigmasterol**	**Delta-7-stigmastenol**	**Apparent *B*-sitosterol**	**Total Sterols**
USDA Standard		***≤0.5***	***≤0.1***	***≤4.5***	***≤Campesterol***	***≤0.5***	***≥93.0***	***≥1000***
9803-20	Central Valley	0.1	0.0	4.1	0.9	0.1	93.9	1334
9805-01	Central Valley	0.1	0.0	5.1	1.4	0.2	92.4	1226
Arbequina	Central Valley	0.1±0.0	0.0±0.0	4.0±0.2	1.0±0.1	0.2±0.1	93.9±0.3	1350±130
Arbosana	Central Valley	0.1±0.0	0.0±0.1	3.8±0.3	0.9±0.1	0.1±0.1	94.3±0.2	1721±227
	Desert	0.2±0.1	0.1±0.1	3.6±0.9	0.9±0.6	0.2±0.1	94.4±1.1	1723±579
Ascolano	Central Valley	0.1±0.0	0.0±0.1	3±0.1	1.1±0.1	0.1±0.0	95.2±0.1	1611±186
Barnea	Central Valley	0.1	0.1	4.5	0.7	0.2	93.6	1508
Chemlali	Desert	0.1	0.0	3.3	0.6	0.2	94.8	2145

Chiquitita	Central Valley	0.1	0.0	4.5	1.1	0.2	93.5	1153
Coratina	Central Valley	0.1±0.0	0.1±0.1	3.4±0.2	0.7±0.1	0.2±0.1	95.1±0.7	1397±210
Dolce	Desert	0.1	0.1	3.1	0.7	0.2	95.1	1662
Don Carlo	Central Valley	0.1	0.1	5.5	0.9	0.3	92.5	1092
Favolosa	Central Valley	0.1	0.1	2.7	1.5	0.1	94.9	1477
Frantoio	Central Valley	0.1±0.0	0.1±0.1	3.5±0.3	0.7±0.1	0.2±0.2	94.6±0.3	1349±249
Grignon	Desert	0.1	0.1	3.0	1.3	0.2	94.5	1273
Hojiblanca	Central Valley	0.1	0.1	3.4	0.7	0.1	95.0	1553
Koroneiki	Central Valley	0.1±0.0	0.1±0.1	4.5±0.4	0.8±0.2	0.2±0.1	93.4±0.3	1131±123
	Wine Country	0.1	0.1	3.1	0.6	0.1	95.2	1495
	Desert	0.1	0.1	4.9	1.7	0.3	92.5	1610
Lecciana	Central Valley	0.1	0.0	4.5	1.2	0.2	93.1	1333
Leccino	Central Valley	0.1±0.0	0.1±0.1	3.2±0.1	0.8±0.1	0.2±0.1	94.7±0.0	1250±105
Manzanillo	Central Valley	0.1	0.0	2.7	1.4	0.2	95.2	1576
Mission	Central Valley	0.1±0.1	0.1±0.1	2.8±0.7	0.7±0.2	0.2±0.1	95.3±0.9	1530±283
	Wine Country	0.1	0.1	3.1	0.6	0.1	95.2	1640
	Desert	0.1±0.0	0.0±0.0	3.2±0.0	0.9±0.1	0.1±0.0	95.1±0.2	2059±360
Moraiolo	Central Valley	0.1	0.1	2.9	0.7	0.1	95.2	1307
	Wine Country	0.1	0.0	3.4	0.6	0.1	94.9	1072
Oliana	Central Valley	0.1	0.0	4.1	1.3	0.2	93.6	1853
Pendolino	Central Valley	0.1	0.0	3.2	0.9	0.1	95.2	1897
Picual	Central Valley	0.1±0.0	0.1±0.1	3.0±0.3	0.9±0.1	0.1±0.1	94.9±0.7	1484±361
Sevillano	Central Valley	0.1	0.1	3.2	1.1	0.1	94.7	1353
	Wine Country	0.1±0.0	0.1±0.0	2.8±0.1	0.8±0.1	0.2±0.1	95.5±0.4	1409±177
Taggiasca	Central Valley	0.1±0.1	0.1±0.1	3.3±0.5	0.7±0.1	0.2±0.1	94.8±0.3	1418±156
	Wine Country	0.1	0.1	3.1	0.6	0.3	94.5	1304

Table 5 shows that six of the 70 samples (nine percent) were found by both the UC Davis (UCD) and Modern Olives (MO) laboratories to be outside at least one USDA sterol parameter: one sample came

from the Desert region, and five came from the Central Valley. Four of the six samples were of the Koroneiki variety.

All of the Koroneiki samples, as well as a new variety (9805-01) that is a cross of Koroneiki and Arbosana, were above the limit for campesterol and three of these samples were also outside the range for apparent β-sitosterol. These results are consistent with the results in the Center's previous studies[9] as well as research in Australia[11 d]. Another new variety, Don Carlo, also was outside the range for these two parameters.

Table 5. Samples that were outside sterol standards

Code	County	Variety	Lab	Campesterol	Apparent B-sitosterol	Total Sterols
USDA Standard				≤4.5	≥93.0	≥1000
2	Imperial	Koroneiki	UCD	4.7 (0.01)[1]	91.8 (0.20)[1]	
			MO	4.9 (0.20)[2]	92.5 (0.20)[2]	
5	Madera	Koroneiki	UCD	4.6 (0.00)	92.9 (0.08)	972 (30)[1]
			MO	4.8 (0.20)	92.9 (0.20)	1018 (146)[2]
16	San Joaquin	Koroneiki	UCD	4.7 (0.01)		
			MO	4.7 (0.20)		
17	San Joaquin	Koroneiki	UCD	4.8 (0.04)		
			MO	4.8 (0.20)		
33	Butte	9805-01	UCD	4.8 (0.03)	92.9 (0.08)	
			MO	5.1 (0.20)	92.4 (0.20)	
63	Tehama	Don Carlo	UCD	5.3 (0.02)	92.6 (0.05)	
			MO	5.5 (0.20)	92.5 (0.20)	

[1] UC Davis (UCD) lab provides standard deviation (SD) to quantify the amount of variation or dispersion of replicates.
[2] Modern Olives (MO) lab provides uncertainty (U) to characterize the dispersion of the values attributed to a measured quantity.

An Arbosana sample from Imperial County was not included in the above table because the two laboratories that analyzed the sample did not have agreement on whether the sample was within the limit of apparent β-sitosterol. This sample also was on the borderline of the palmitic acid upper limit and oleic acid lower limit.

[11] (a) Ceci, L. N., Carelli, A. A. (2007) Characterization of monovarietial Argentinian olive oils from new productive zones, J. Am. Oil Chem. Soc., 84, 1125–1136. (b) Mailer, R. J., Ayton, J. (2008) A survey of Australian olive cultivars to determine compliance with international standards, RIRDC Pub No 08/167. (c) Lombardo, N., Marone, E., Alessandrino, M., Godino, G., Madeo, A., & Fiorino, P. (2008). Influence of growing season temperatures in the fatty acids (FAs) of triacilglycerols (TAGs) composition in Italian cultivars of Olea europaea. Advances in Horticultural Science, 49-53. (d) Mailer, R. J., Ayton, J., & Graham, K. (2010). The influence of growing region, cultivar and harvest Timing on the diversity of Australian olive oil. Journal of the American Oil Chemists' Society, 87(8), 877-884. (e) Rondanini, D. P., Castro, D. N., Searles, P. S., Rousseaux, M. C. (2011) Fatty acid profiles of varietal virgin olive oils (Olea europaea L.) from mature orchards in warm arid valleys of Northwestern Argentina (La Rioja). Grasas Aceites, 62, 399–409.

SUMMARY OF PAST FOUR SEASONS

The research team combined the data for 261 olive oil samples analyzed over the past four seasons. In total, 11 percent (28 samples) were outside the standard for fatty acid and/or sterol parameters.

As shown in Figure 2, the super-high-density varieties comprised the largest proportion of the four-year sample set, with Arbequina at 19 percent, Koroneiki at 12 percent and Arbosana at 11 percent for a total of 42 percent; followed by Mission at 7 percent, Picual at 6 percent, Frantoio at 5 percent and Leccino at 4 percent. The other 96 samples comprised an additional 26 varieties.

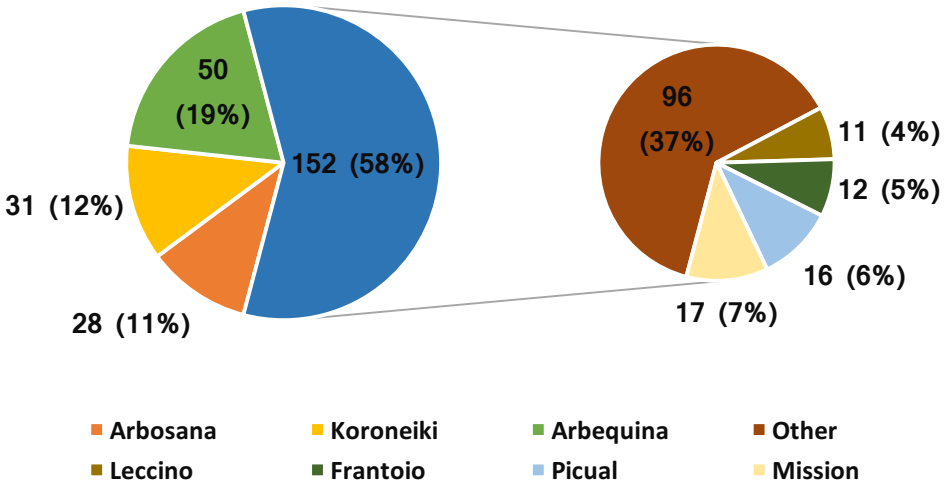

Figure 2. Distribution of samples with different varieties over four harvest seasons

Most of the samples analyzed over the past four years were sourced from the Central Valley. As shown in Figure 3, 71 percent of samples came from Central Valley, 12 percent from the Desert, 11 percent from Wine Country and 5 percent from the South Coast.

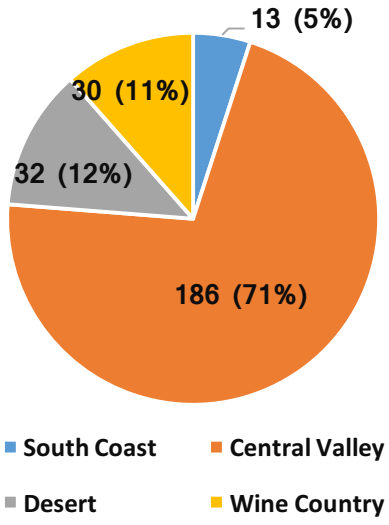

Figure 3. Distribution of samples from four regions over four harvest seasons

Table 6 summarizes the samples that were outside fatty acid and sterol parameters over the past four harvest seasons (2014/15 to 2017/18). All oil samples were sourced from California producers except in 2014/15 when 20 of the 50 samples analyzed that season were produced on Abencor bench-scale equipment from fresh olives that were shipped to UC Davis laboratory.

As shown in Table 6, half of the 28 samples that were outside the limits were of the Koroneiki variety. Forty-five percent (14 of 28) Koroneiki samples were outside the standards for one or more sterol standards. The Koroneiki samples failed in three regions with diverse climates: Central Valley, Desert and Wine Country, and was the only variety that was outside standards in each of the four past seasons. Elevated campesterol and low apparent β-sitosterol found in the Desert Koroneiki samples are consistent with previous research in Argentina[11a] and Australia[11b]. In addition, high campesterol and low total sterols in Central Valley Koroneiki samples, a region characterized by hot and dry summers and cold winters, is consistent with Australian research[11d].

The variety that failed most often after Koroneiki was Arbequina, which comprised four of the 28 samples outside the limit and eight percent (four of 50) Arbequina samples. Arbequina samples were outside the limits in three of the past four seasons, solely in the Desert region. These results are consistent with studies in Australia[11b] and Italy[11c], which indicated that hot climates tend to correlate with lower levels of oleic acid and elevated palmitic acid and polyunsaturated linoleic acid.

After Arbequina the variety that was most often outside standards was Arbosana, which comprised three of the 28 samples outside the limit and 11 percent (three of 28) of Arbosana samples. All of the Arbosana samples failed in the 2014/15 season. Two of the three Arbosana samples were from the Desert region, and had elevated campesterol and low apparent β-sitosterol, consistent with research in Argentina[11a] and Australia[11b]. One Arbosana sample from the Central Valley had a high value of 0.4% for heptadecenoic acid (California standard ≤ 0.3%), and similar results were reported in the Center's recent study where 24 of 27 Arbosana samples were found to have consistently high values of 0.3% for heptadecenoic acid[12].

Thus, 75 percent of the 28 samples that were outside fatty acid or sterol parameters were from the commonly planted SHD varieties, which is almost double the 42 percent incidence of these samples among the entire four-year sample set as shown in Figure 2. The other seven samples that were outside fatty acid or sterol parameters are from relatively minor varieties in California, although some have the potential to become more widely planted.

As shown in Table 6, of the 28 samples that were outside standards, 50 percent (14 samples) were from the Central Valley, 46 percent (13 samples) were from the Desert, and 4 percent (one sample) was from the Wine Country region. The region where the samples failed most often was the Desert, with 41 percent (13 of 32 samples) outside at least one fatty acid or sterol parameter. Eight percent of Central Valley samples (14 of 186 samples) and three percent of Wine Country samples (one of 30 samples) were outside the parameters.

[12] UC Davis Olive Center. (2018). Heptadecenoic Acid (C17:1) in California Olive Oil: A Review. UC Davis Olive Center.

Table 6. Samples outside the USDA Standard of fatty acid and/or sterol profile from 2014/15 to 2017/18 harvest seasons

Harvest Season	Failure Rate	Variety	Harvest County	Palmitic Acid (C16:0)	Palmitoleic Acid (C16:1)	Heptadecenoic Acid (C17:1)	Oleic Acid (C18:1)	Linoleic Acid (C18:2)	Linolenic Acid (C18:3)	Campe-sterol	Apparent B-sitosterol	Total Sterols
USDA Standard				**7.5-20.0%**	**0.3-3.5%**	**≤0.3%**	**55.0-83.0%**	**3.5-21.0%**	**≤1.5%**	**≤4.5**	**≥93.0**	**≥1000**
2014/15 Harvest Season *50 samples 14 varieties 12 counties*	10/50 (20%)	Arbequina (A)	Imperial	22.7	4.0		44.0			5.6	91.9	
		Arbosana (A)	Imperial				53.3			4.8	92.2	
		Picual (A)	Imperial		3.8							
		Leccino (A)	Imperial				46.6	27.6	2.3			
		Picual (A)	Yolo					3.4				
		Arbosana (A)	Riverside	22.0	4.0		44.3	24.8				
		Arbequina (A)	Riverside	23.4	4.6		37.7	30.3		5.0	92.8	
		Koroneiki (A)	Tehama									791
		Koroneiki	Madera								92.7	
		Arbosana	San Joaquin			0.4						
2015/16 Harvest Season *71 samples 23 varieties 20 counties*	3/71 (4%)	Arbequina	Imperial	21.3 (0.1)			47.4 (0.1)	23.8 (0.0)		5.5 (0.1)		
		Koroneiki	Imperial							5.1 (0.1)		
		Koroneiki	Glenn									892 (105)
2016/17 Harvest Season *70 samples 22 varieties 20 counties*	9/70 (13%)	Arbequina	Imperial	21.2 (0.01)			49.3 (0.02)	23 (0.03)		5.0 (0.20)	92.7 (0.26)	
		Koroneiki	Imperial							5.0 (0.20)	92.3 (0.26)	
		Koroneiki	Imperial							5.0 (0.20)	92.2 (0.26)	
		Koroneiki	Imperial							5.1 (0.20)	91.9 (0.26)	
		Koroneiki	Tehama									980 (146.09
		Koroneiki	Yolo									846 (146.09
		Koroneiki	Napa									918 (146.09
		Nocellara del Belice	Kern							4.7 (0.20)	91.9 (0.26)	
		Pendolino	Kern	20.0 (0.01)					2.0 (0.003)			
	6/70 (9%)	Koroneiki	Imperial							4.9 (0.20)	92.5 (0.20)	

'017/18 Harvest Season 70 amples 26 arieties 15 ounties		Koroneiki	Madera							4.8 (0.20)	92.9 (0.20)	1018 (146)
		Koroneiki	San Joaquin							4.7 (0.20)		
		Koroneiki	San Joaquin							4.8 (0.20)		
		9805-01	Butte							5.1 (0.20)	92.4 (0.20)	
		Don Carlo	Tehama							5.5 (0.20)	92.5 (0.20)	

CONCLUSIONS AND RECOMMENDATIONS

- Of 70 samples collected and analyzed in the 2017/18 harvest season, nine percent (six samples) were outside at least one sterol parameter. Samples outside at least one fatty acid or sterol parameter averages 11 percent (28 out of 261 samples) over the past four seasons.

- All of the samples that were outside fatty acid and sterol parameters in the 2017/18 season were from varieties in the SHD system. Of 28 samples that have been outside fatty acid and sterol parameters over the past four seasons, 75 percent (21 samples) were from the most commonly planted SHD varieties of Arbequina, Arbosana and Koroneiki.

- Our finding that some legitimate olive oil is outside fatty acid or sterol profile standards is consistent with California data from previous seasons[9, 12], as well as similar research in Australia, Chile, Argentina, New Zealand, Italy, Spain and Tunisia[11, 13]. The commission may want to recommend modifications to California olive oil standards so that fatty acid and sterol profile standards accommodate all olive oil produced in California.

[13] (a) Rivera del Alamo, R.M., Fregapane, G., Aranda, F., Gómez-Alonsa, S., Salvador, M.D. (2004) Sterol and alcohol composition of Cornicabra virgin olive oil: the campesterol content exceeds the upper limit of 4% established by EU regulations. Food Chem., 84, 533–537. (b) Zarrouk, W., Baccouri, B., Taamalli, W., Trigui, A., et al. (2009), Oil fatty acid composition of eighteen Mediterranean olive varieties cultivated under the arid conditions of Boughrara (southern Tunisia). Grasas Aceites, 60, 498–506.

APPENDIX

Table 1A. Summary of samples collected from 2014/15 to 2017/18 harvest seasons. (A) denotes samples extracted on the Abencor equipment at the Olive Center

2014-2015 Harvest Season (50 samples, 14 varieties, 12 counties)			2015-2016 Harvest Season (71 samples, 23 varieties, 20 counties)			2016-2017 Harvest Season (70 samples)			2017-2018 Harvest Season (70 Commercial)		
Variety	**Harvest County**	**Region**	**Variety**	**Harvest County**	**Region**	**Variety**	**Harvest County**	**Region**	**Variety**	**Harvest County**	**Region**
Arbequina (9)	Glenn	Central Valley	**Allegra (1)**	Lake	Wine Country	**Aglandau (1)**	Solano	Central Valley	**9803-20 (1)**	Butte	Central Valley
	Glenn	Central Valley	**Arbequina (12)**	Butte	Central Valley	**Arbequina (12)**	Glenn	Central Valley	**9805-01 (1)**	Butte	Central Valley
	Glenn	Central Valley		Colusa	Central Valley		Glenn	Central Valley	**Arbequina (13)**	Butte	Central Valley
	San Joaquin	Central Valley		Fresno	Central Valley		Imperial	Desert		Colusa	Central Valley
	San Joaquin	Central Valley		Glenn	Central Valley		Napa	Wine Country		Colusa	Central Valley
	Solano	Central Valley		Imperial	Desert		Sacramento	Central Valley		Madera	Central Valley
	Sonoma	Wine Country		Madera	Central Valley		San Joaquin	Central Valley		San Joaquin	Central Valley
	Tehama	Central Valley		San Joaquin	Central Valley		San Joaquin	Central Valley		Solano	Central Valley
	Yolo	Central Valley		San Luis Obispo	South Coast		Solano	Central Valley		Tehama	Central Valley
Arbequina (A) (4)	Imperial	Desert		Sutter	Central Valley		Solano	Central Valley		Tehama	Central Valley
	Riverside	Desert		Tehama	Central Valley		Stanislaus	Central Valley		Tehama	Central Valley
	Tehama	Central Valley		Ventura	South Coast		Tehama	Central Valley		Tehama	Central Valley
	Yolo	Central Valley		Yolo	Central Valley		Yolo	Central Valley		Yolo	Central Valley
Arbosana (3)	San Joaquin	Central Valley	**Arbosana (9)**	Butte	Central Valley	**Arbosana (6)**	Colusa	Central Valley		Yolo	Central Valley
	Tehama	Central Valley		Fresno	Central Valley		San Joaquin	Central Valley		Yuba-Sutter	Central Valley
	Yolo	Central Valley		Imperial	Desert		San Joaquin	Central Valley	**Arbosana (7)**	Imperial	Desert
Arbosana (A) (3)	Imperial	Desert		Madera	Central Valley		San Joaquin	Central Valley		Imperial	Desert
	Riverside	Desert		San Joaquin	Central Valley		San Joaquin	Central Valley		Madera	Central Valley
	Yolo	Central Valley		Santa Barbara	South Coast		Yolo	Central Valley		San Joaquin	Central Valley
	Tahama	Central Valley		Tehama	Central Valley		Glenn	Central Valley		San Joaquin	Central Valley

Ascolano (2)	Tehama	Central Valley		Tulare	Central Valley	**Ascolano (2)**	Kern	Central Valley		Tehama	Central Valley
Barnea (A) (1)	Yolo	Central Valley		Yolo	Central Valley	**Chemlali (1)**	Riverside	Desert		Yolo	Central Valley
Chiquitita (1)	Sutter	Central Valley	**Ascolano (2)**	Kern	Central Valley	**Coratina (2)**	Kern	Central Valley	**Ascolano (4)**	Glenn	Central Valley
Frantoio (1)	Sacramento	Central Valley		Tehama	Central Valley		Sonoma	Wine Country		Shasta	Central Valley
Koroneiki (5)	Madera	Central Valley	**Barnea (1)**	Tehama	Central Valley	**Dolce di Morocco (1)**	Riverside	Desert		Tehama	Central Valley
	San Joaquin	Central Valley	**Chemlali (1)**	Riverside	Desert	**Frantoio (4)**	Alameda	Wine Country		Yolo	Central Valley
	San Joaquin and Yolo	Central Valley	**Coratina (3)**	Kern	Central Valley		Kern	Central Valley	**Barnea (1)**	Tehama	Central Valley
	Sonoma	Wine Country		Sonoma	Wine Country		Solano	Central Valley	**Chemlali (1)**	Riverside	Desert
	Yolo	Central Valley		Tehama	Central Valley		Sonoma	Wine Country	**Chiquitita (1)**	Butte	Central Valley
Koroneiki (A) (4)	Imperial	Desert	**Dolce di Morocco (1)**	Riverside	Desert	**Grapolo (1)**	Santa Barbara	South Coast	**Coratina (2)**	Tehama	Central Valley
	Riverside	Desert	**Favolosa (1)**	Tehama	Central Valley	**Grignon (1)**	Riverside	Desert		Yolo	Central Valley
	Tahama	Central Valley	**Frantoio (4)**	Kern	Central Valley	**Koroneiki (9)**	Colusa	Central Valley	**Dolce di Morocco (1)**	Riverside	Desert
	Yolo	Central Valley		Mendocino	Wine Country		Imperial	Desert	**Don Carlo (1)**	Tehama	Central Valley
Leccino (1)	Sacramento	Central Valley		Solano	Central Valley		Imperial	Desert	**Favolosa (1)**	Tehama	Central Valley
Leccino (A) (3)	Imperial	Desert		Sonoma	Wine Country		Imperial	Desert	**Frantoio (3)**	Solano	Central Valley
	Sonoma	Wine Country	**Grignon (1)**	Riverside	Desert		Napa	Wine Country		Tehama	Central Valley
	Yolo	Central Valley	**Hojiblanca (1)**	Tehama	Central Valley		Riverside	Desert		Yolo	Central Valley
Manzanillo (1)	Butte	Central Valley	**Koroneiki (6)**	Glenn	Central Valley		San Joaquin	Central Valley	**Grignon (1)**	Riverside	Desert
Mission (2)	Butte	Central Valley		Imperial	Desert		Tehama	Central Valley	**Hojiblanca (1)**	Tehama	Central Valley
	Tehama	Central Valley		Madera	Central Valley		Yolo	Central Valley	**Koroneiki (7)**	Glenn	Central Valley
Pendolino (1)	Sacramento	Central Valley		Tehama	Central Valley	**Leccino (2)**	Solano	Central Valley		Imperial	Desert

Pendolino (A) (2)	Sonoma	Wine Country		Tulare	Central Valley		Solano	Central Valley		Madera	Central Valley
	Yolo	Central Valley		Yolo	Central Valley	**Manzanillo (4)**	Butte	Central Valley		Napa	Wine Country
Picholine (1)	Sonoma	Wine Country	**Leccino (3)**	Mendocino	Wine Country		Napa	Wine Country		San Joaquin	Central Valley
Picual (2)	Sonoma	Wine Country		Tehama	Central Valley		Santa Barbara	South Coast		San Joaquin	Central Valley
	Yolo	Central Valley		Yolo	Central Valley		Tehama	Central Valley		Yolo	Central Valley
Picual (A) (3)	Imperial	Desert	**Lucca (1)**	Santa Barbara	South Coast	**Maurino (3)**	Kern	Central Valley	**Lecciana (1)**	Butte	Central Valley
	Tahama	Central Valley	**Manzanillo (3)**	Butte	Central Valley		Riverside	Desert	**Leccino (2)**	Solano	Central Valley
	Yolo	Central Valley		Santa Barbara	South Coast		Santa Barbara	South Coast		Tehama	Central Valley
Sevillano (1)	Sonoma	Wine Country		Tehama	Central Valley	**Mission (4)**	Butte	Central Valley	**Manzanillo (1)**	Tehama	Central Valley
			Maurino (1)	Kern	Central Valley		Solano	Central Valley	**Mission (6)**	Butte	Central Valley
			Mission (5)	Butte	Central Valley		Tehama	Central Valley		Imperial	Desert
				Lake	Wine Country		Tehama	Central Valley		Napa	Wine Country
				Riverside	Desert	**Moraiolo (2)**	Solano	Central Valley		Riverside	Desert
				Ventura	South Coast		Sonoma	Wine Country		Siskiyou	Central Valley
				Yolo	Central Valley	**Nocellara del Belice (2)**	Kern	Central Valley		Solano	Central Valley
			Moraiolo (3)	Mendocino	Wine Country		San Diego	South Coast	**Moraiolo (2)**	Solano	Central Valley
				Sonoma	Wine Country	**Pendolino (3)**	Kern	Central Valley		Sonoma	Wine Country
				Tehama	Central Valley		Solano	Central Valley	**Oliana (1)**	Butte	Central Valley
			Nocellara Belice (1)	Kern	Central Valley		Solano	Central Valley	**Pendolino (1)**	Solano	Central Valley
			Pendolino (3)	Solano	Central Valley	**Picholine (1)**	Los Angeles	South Coast	**Picual (3)**	Tehama	Central Valley
				Tehama	Central Valley	**Picual (5)**	Kern	Central Valley		Yolo	Central Valley
				Yolo	Central Valley		San Diego	South Coast		Yolo	Central Valley
			Picual (3)	Kern	Central Valley		Tehama	Central Valley	**Sevillano (3)**	Napa	Wine Country
				Tehama	Central Valley		Tehama	Central Valley		Napa	Wine Country
				Yolo	Central Valley		Yolo	Central Valley		Tehama	Central Valley
			Sevillano (1)	Tehama	Central Valley	**Sevillano (2)**	Napa	Wine Country	**Taggiasca (4)**	Napa	Wine Country
			Taggiasca (4)	Santa Barbara	South Coast		Tehama	Central Valley		Solano	Central Valley
				Solano	Central Valley		Napa	Wine Country		Tehama	Central Valley

	Tehama	Central Valley	**Taggiasca (2)**	Solano	Central Valley		Yolo	Central Valley
	Yolo	Central Valley						