Evaluation of Fatty Acid and Sterol Profiles California Olive Oil 2016/17 Season

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Olive Oil Commission of California

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UCDAVIS OLIVE CENTER
at the Robert Mondavi Institute

Evaluation of Fatty Acid and Sterol Profiles, California Olive Oil, 2016/17 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 2016/17 Season and analyzed fatty acid and sterol profiles.

The study team collected 70 single-variety samples 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. Both laboratories agreed that 61 of 70 samples (87 percent) were within the fatty acid and sterol parameters required in California. Nine samples (13 percent) were outside at least one fatty acid or sterol parameter.

The Commission may wish to recommend modifications to California olive oil standards so that fatty acid and sterol profile standards accommodate all olive oil produced in California and assess new and advanced methods to analyze olive oil purity with the potential to cost less, be more accurate, and minimize laboratory variability.

BACKGROUND

The Olive Oil Commission of California 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 at least 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).[1] Two of the key authenticity tests referenced in these standards are fatty acid profile and sterol profile.[2]

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. However, fatty acids and sterols also can be affected by factors unrelated to the authenticity of an oil, including geographical origin,[3] climate and altitude,[4] cultivar and harvest timing,[5,6] irrigation strategies[7], and processing techniques[8]. These factors can lead to an authentic olive oil failing to meet all of the parameters of standards for fatty acid and sterol profiles.

In this report, we summarized the results of 70 single-variety California olive oil from the 2016/17 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.

SAMPLE INFORMATION

In soliciting olive oil samples produced in the 2016/17 Season, the study team sought to maximize diversity in varieties and California counties. The study team collected 70 samples between October 2016 and January 2017. Samples were stored in a dark room at 22°C (71°F) prior to the sample being analyzed in February and March 2017.

Figure 1 and Table 1 summarize the samples by harvest location, which totaled 18 counties and four regions. Figure 1 shows the number of samples from each county in red. Table 1 shows that 46 of the samples (66 percent) were from the Central Valley region, the area producing the largest volume of olive oil. Nine samples (13 percent) were from the Wine Country region, 6 samples (9 percent) were from the South Coast region, and 9 samples (13 percent) were from the Desert region. Table 2 shows the samples by variety. Of the 22 olive varieties collected, the most-widely planted varieties (Arbequina, Arbosana, and Koroneiki) comprised 39 percent (27 of 70 samples).

Figure 1. Sample distribution by California counties and regions

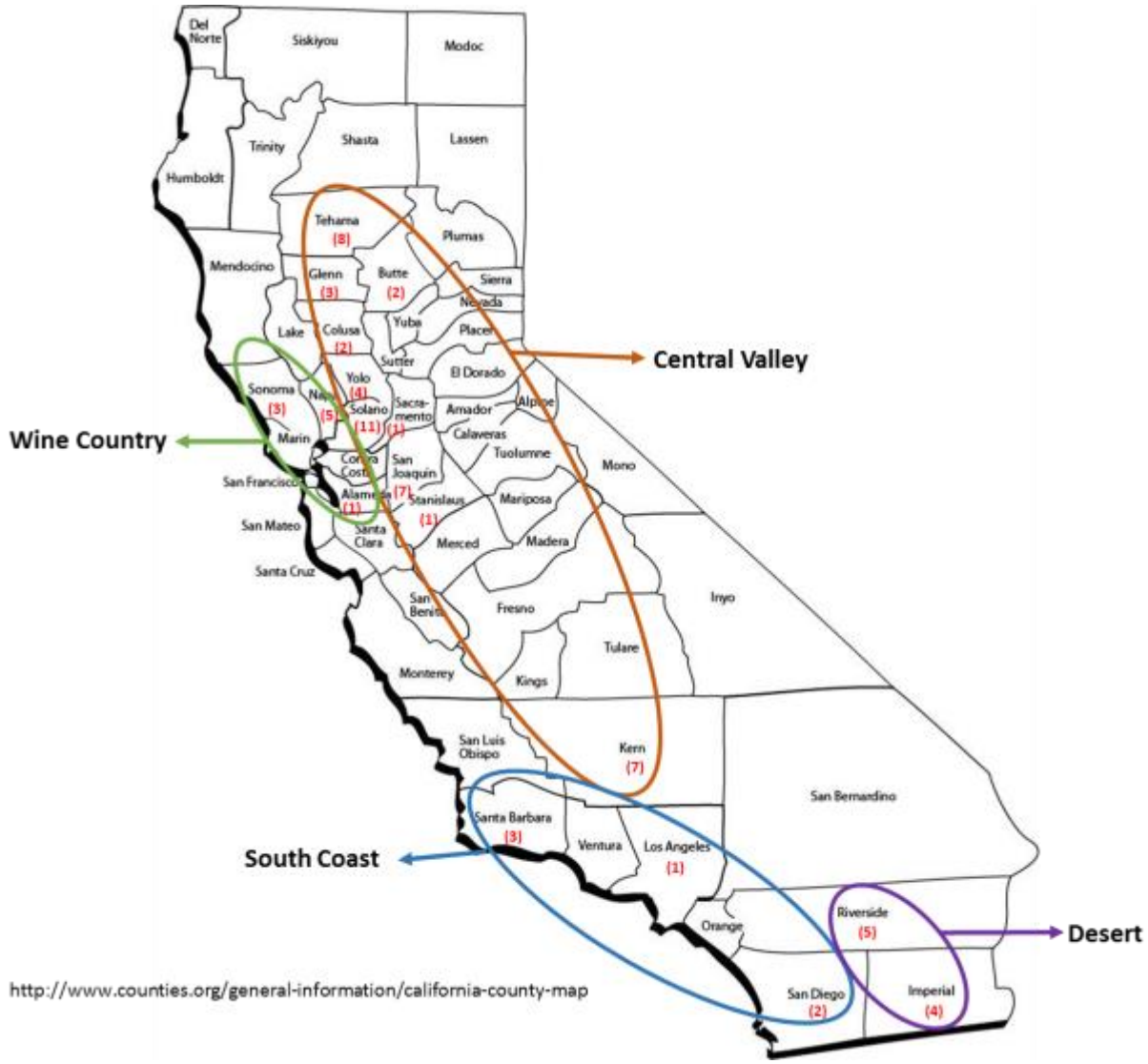

Table 1. Samples by harvest location

CODE	VARIETY	COUNTY (# SAMPLES)
CENTRAL VALLEY REGION – 46 SAMPLES (66%)		
49	Manzanillo	Butte (2)
50	Mission	
13	Arbosana	Colusa (2)
45	Koroneiki	
5	Arbequina	Glenn (3)
6	Arbequina	
48	Ascolano	
53	Ascolano	Kern (7)
54	Coratina	
55	Frantoio	
56	Maurino	
57	Nocellara del Belice	
58	Pendolino	
59	Picual	
24	Arbequina	Sacramento (1)
7	Arbequina	San Joaquin (7)
11	Arbequina	
14	Arbosana	
15	Arbosana	
16	Arbosana	
17	Arbosana	
18	Koroneiki	
30	Leccino	Solano (11)
33	Mission	
35	Pendolino	
42	Arbequina	
22	Aglandau	
25	Arbequina	
28	Frantoio	
31	Leccino	
34	Moraiolo	
36	Pendolino	
38	Taggiasca	
12	Arbequina	Stanislaus (1)
47	Sevillano	Tehama (8)
51	Mission	
52	Picual	

68	Manzanillo	
69	Mission	
70	Picual	
8	Arbequina	
9	Koroneiki	
10	Koroneiki	Yolo (4)
26	Arbequina	
43	Arbosana	
46	Picual	
WINE COUNTRY REGION – 9 SAMPLES (13%)		
44	Frantoio	Alameda (1)
23	Arbequina	Napa (5)
27	Taggiasca	
29	Koroneiki	
32	Manzanillo	
37	Sevillano	
39	Coratina	Sonoma (3)
40	Frantoio	
41	Moraiolo	
SOUTH COAST REGION – 6 SAMPLES (9%)		
66	Picholine	Los Angeles (1)
19	Grapolo	Santa Barbara (3)
20	Manzanillo	
21	Maurino	
65	Nocellara del Belice	San Diego (2)
67	Picual	
DESERT REGION – 9 SAMPLES (13%)		
1	Arbequina	Imperial (4)
2	Koroneiki	
3	Koroneiki	
4	Koroneiki	
60	Chemlali	Riverside (5)
61	Dolce di Morocco	
62	Grignon	
63	Koroneiki	
64	Maurino	

Table 2. Samples by variety

CODE	VARIETY	HARVEST COUNTY	REGION
22	Aglandau (1)	Solano	Central Valley
5	Arbequina (12)	Glenn	Central Valley
6		Glenn	
1		Sacramento	
23		San Joaquin	
24		San Joaquin	
7		Solano	
11		Solano	
42		Stanislaus	
25		Tehama	
12		Yolo	
8		Napa	Wine Country
26		Imperial	Desert
13	Arbosana (6)	Colusa	Central Valley
14		San Joaquin	
15		San Joaquin	
16		San Joaquin	
17		San Joaquin	
43		Yolo	
48	Ascolano (2)	Glenn	Central Valley
53		Kern	
60	Chemlali (1)	Riverside	Desert
54	Coratina (2)	Kern	Central Valley
39		Sonoma	Wine Country
61	Dolce di Morocco (1)	Riverside	Desert
44	Frantoio (4)	Kern	Central Valley
55		Solano	
28		Alameda	Wine Country
40		Sonoma	
19	Grapolo (1)	Santa Barbara	South Coast
62	Grignon (1)	Riverside	Desert
45	Koroneiki (9)	Colusa	Central Valley
2		San Joaquin	
3		Tehama	
4		Yolo	
29		Napa	Wine Country
63		Imperial	Desert
18		Imperial	

9		Imperial	
10		Riverside	
30	Leccino (2)	Solano	Central Valley
31		Solano	
49	Manzanillo (4)	Butte	Central Valley
32		Tehama	
20		Napa	Wine Country
68		Santa Barbara	South Coast
56	Maurino (3)	Kern	Central Valley
64		Santa Barbara	South Coast
21		Riverside	Desert
50	Mission (4)	Butte	Central Valley
33		Solano	
51		Tehama	
69		Tehama	
34	Moraiolo (2)	Solano	Central Valley
41		Sonoma	Wine Country
57	Nocellara del Belice (2)	Kern	Central Valley
65		San Diego	South Coast
58	Pendolino (3)	Kern	Central Valley
35		Solano	
36		Solano	
66	Picholine (1)	Los Angeles	South Coast
59	Picual (5)	Kern	Central Valley
67		Tehama	
52		Tehama	
70		Yolo	
46		San Diego	South Coast
37	Sevillano (2)	Tehama	Central Valley
47		Napa	Wine Country
27	Taggiasca (2)	Solano	Central Valley
38		Napa	Wine Country

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 if the data from both laboratories agreed.

RESULTS AND DISCUSSION

Test results indicate that 61 of 70 samples (87 percent) were within the parameters for fatty acid and sterol profiles required of California olive oil, lower than 96 percent rate for 71 commercial samples analyzed from the 2015/16 season.

The average value and standard deviation (when available) of key fatty acids and sterols are shown in Tables 3 and 4. Super-high-density (SHD) varieties (Arbequina, Arbosana and Koroneiki) from the Desert region had higher levels of palmitic acid, palmitoleic acid, linolenic acid and linolenic acid; and a lower level of oleic acid than the same varietals from other regions. These varieties also had higher levels of campesterol, stigmasterol, delta-7-stigmastenol and total sterols; and a lower level of apparent B-sitosterol from the Desert region than other regions. Overall, regardless of the difference in varieties and regions, oleic acid level tended to correlate negatively with palmitic acid and linoleic acid. Similarly, campesterol level tended to correlate negatively with apparent B-sitosterol but positively with stigmasterol.

As shown in Table 5, nine of the 70 samples (13 percent) were found by both the UC Davis (UCD) and Modern Olives (MO) laboratories to be outside at least one USDA fatty acid or sterol parameter. Four of the nine samples came from the emerging Desert region, four came from the Central Valley, which is most widely planted olive region in California, and one came from the wine country. Seven of the nine samples outside the parameters were of SHD varieties including six Koroneiki and one Arbequina.

- Sample #1, an Arbequina oil from Imperial County, was outside the parameters for palmitic acid, oleic acid, linoleic acid, campesterol, and apparent B-sitosterol. These results are consistent with the Olive Center's data from previous years for Arbequina from the same desert regions,[9] as well as research in Australia and Argentina.[11] Hot climates are associated with lower levels of oleic acid while cooler climates are associated with higher levels of oleic acid.[11a] Hot climates also tend to correlate with elevated palmitic acid and polyunsaturated linoleic acid.[11b, 11c]

- Three Koroneiki sample (#2, #3, and #4) from the same desert area was outside the parameters for campesterol and apparent B-sitosterol, which is consistent with desert samples in the Center's previous studies[9] as well as research in Australia and Argentina.[11]

- Two Koroneiki sample (#9 and #10) from Tehama County and Yolo County respectively in the Central Valley was outside the parameter for total sterols, which is consistent with central valley samples in the Center's previous studies[9] and with previous research in the United States and Australia.[8, 11b]

- One additional Koroneiki sample (#29) from Napa County was outside the parameter for total sterols due to the similar Mediterranean climate compared to Yolo County and Tehama County.

- Sample #57, a Nocellara del Belice oil from Kern County, was outside the parameters for campesterol and apparent B-sitosterol. However, the other Nocellara del Belice oil from San Diego County, which is in the South Coast region, did not fail any parameter. To confirm if these results are variety-dependent, it's important to continue analyzing this specific variety from coastal and inland counties.

- A Pendolino oil, sample #58, also from Kern County, was outside the parameters of palmitic acid and linolenic acid. High thermal sums during fruit growth can decrease oleic acid content which is often compensated by an increase in palmitic acid and polyunsaturated fatty acids.[11c] The high

linolenic acid value is consistent with Pendolino samples analyzed in Australian research.[11b] This could also be another result of the climate characteristics in Kern County.

Table 3. Fatty acid profile by variety

Varity	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***
Aglandau	Central Valley	16.4	1.3	2.5	69.9	8.1	0.5
Arbequina	Central Valley	16.7±1.3	1.4±0.2	2.1±0.1	68.4±3.1	9.7±1.7	0.5±0.1
	Wine Country	15.7	1.5	2.2	71.8	7.2	0.7
	Desert	21.2	2.1	2.1	49.3	23.0	0.9
Arbosana	Central Valley	15.1±1.1	1.4±0.3	2±0.1	72.7±2.7	7±1.3	0.6±0.1
Ascolano	Central Valley	17.3±3.0	1.6±0.5	1.9±0.1	67.5±4.3	9.7±0.4	0.8±0.2
Chemlali	Desert	18.3	1.8	2.5	64.0	11.8	0.7
Coratina	Central Valley	14.8	0.5	2.4	70.7	9.6	0.9
	Wine Country	10.7	0.4	2.3	79.3	5.7	0.7
Dolce di Morocco	Desert	14.8	1.3	1.9	67.5	13.0	0.7
Frantoio	Central Valley	16.2±1.9	1.3±0.1	2.1±0.1	67.1±5.6	11.7±3.4	0.7±0.3
	Wine Country	11.9±0.5	0.7±0.1	2.2±0.4	75.8±2.8	8±1.7	0.6±0.1
Grapolo	South Coast	14.6	1.1	2.8	73.7	6.1	0.6
Grignon	Desert	14.8	1.1	2.4	70.3	9.8	0.7
Koroneiki	Central Valley	14.1±0.5	1±0.1	2.5±0.3	74.4±1.7	6.4±1.2	0.5±0.1
	Wine Country	13.1	0.8	2.5	76.3	5.7	0.6
	Desert	16.1±1.3	1.1±0.2	2.6±0.0	69.1±2.8	9±1.2	0.9±0.1
Leccino	Central Valley	15.2±0.3	1.4±0.0	2.2±0.1	72±0.9	8±1.3	0.5±0.0
Manzanillo	Central Valley	14.9±0.3	1.2±0.2	3.9±0.0	71.9±1.1	6.2±0.7	0.6±0.0
	South Coast	14.8	1.2	2.9	72.2	7.4	0.5
	Wine Country	14.6	1.1	2.8	72.7	6.9	0.6
Maurino	Central Valley	18.7	1.5	1.8	60.1	16.0	1.1
	South Coast	15.7	1.2	2.1	69.1	10.4	0.7
	Desert	16.4	1.3	2.1	65.5	13.0	0.9
Mission	Central Valley	12.5±1.1	0.8±0.2	2.5±0.7	75.1±1.6	7.3±0.6	0.9±0.2
Moraiolo	Central Valley	16.5	1.0	2.1	70.5	8.4	0.6
	Wine Country	12.8	0.6	1.8	76.2	7.2	0.6
Nocellara del Belice	Central Valley	16.8	1.3	2.3	66.3	11.1	1.2
	South Coast	9.7	0.3	3.4	75.5	9.3	0.6
Pendolino	Central Valley	16.9±2.7	1.3±0.2	1.9±0.1	66.7±6.5	11.2±2.9	1.1±0.8
Picholine	South Coast	14.0	0.9	2.1	70.2	11.3	0.7
Picual	Central Valley	15±0.5	1.3±0.2	2.4±0.2	75.4±1.4	4.3±0.5	0.8±0.1
	South Coast	13.7	0.9	3.2	73.9	6.7	0.7
Sevillano	Central Valley	15.7	0.9	2.1	69.6	9.2	1.2
	Wine Country	13.0	0.7	2.7	73.7	7.7	0.8
Taggiasca	Central Valley	15.0	1.4	2.0	70.9	9.4	0.5
	Wine Country	13.2	0.8	2.8	73.1	8.6	0.6

Table 4. Sterol profile by variety

Varity	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***
Aglandau	Central Valley	0.1	0.0	2.6	0.5	0.3	95.5	1310
Arbequina	Central Valley	0.0±0.0	0.0±0.0	3.9±0.3	0.8±0.1	0.2±0.0	94.3±0.3	1440±247
	Wine Country	0.0	0.0	4.1	0.8	0.2	93.8	2329
	Desert	0.1	0.1	5.0	1.4	0.3	92.7	2130
Arbosana	Central Valley	0.0±0.0	0.0±0.0	3.9±0.2	0.8±0.1	0.1±0.0	94.6±0.2	1745±195
Ascolano	Central Valley	0.0±0.0	0.0±0.0	3.2±0.1	1.2±0	0.2±0.1	94.9±0	2101±634

Chemlali	Desert	0.0	0.0	3.5	0.6	0.3	94.9	1768
Coratina	Central Valley	0.1	0.0	3.7	0.8	0.3	94.7	1608
	Wine Country	0.0	0.0	3.7	0.5	0.1	95.1	1209
Dolce di Morocco	Desert	0.0	0.0	3.2	1.0	0.2	95.0	1609
Frantoio	Central Valley	0.1±0.0	0.1±0.1	3.4±0.6	0.6±0.1	0.4±0.1	94.7±0.5	1656±465
	Wine Country	0.0±0.0	0.0±0.0	3.2±0.3	0.5±0.1	0.2±0.0	95.4±0.1	1472±216
Grapolo	South Coast	0.0	0.0	3.0	0.7	0.2	95.2	1179
Grignon	Desert	0.0	0.0	3.4	1.3	0.3	94.3	1362
Koroneiki	Central Valley	0.1±0.1	0.1±0.0	4.2±0.2	0.7±0.1	0.3±0.1	93.6±0.7	1305±515
	Wine Country	0.1	0.1	4.0	0.7	0.2	93.6	918
	Desert	0.1±0.0	0.1±0.0	4.7±0.6	1.5±0.5	0.4±0.1	92.7±1.2	1447±140
Leccino	Central Valley	0.0±0.0	0.0±0.0	2.7±0.0	0.8±0.1	0.4±0.1	95.1±0.5	1234±74
Manzanillo	Central Valley	0.0±0.0	0.0±0.0	2.7±0.1	1.2±0.5	0.2±0.1	95.3±0.6	1124±14
	South Coast	0.1	0.0	3.1	0.9	0.5	94.6	1218
	Wine Country	0.0	0.0	3.0	0.8	0.2	95.3	1283
Maurino	Central Valley	0.0	0.0	3.2	0.4	0.4	95.1	2506
	South Coast	0.0	0.0	3.1	0.3	0.2	95.1	1467
	Desert	0.0	0.0	3.1	0.7	0.4	94.8	1897
Mission	Central Valley	0.0±0.0	0.0±0.0	2.8±0.3	0.7±0.1	0.2±0.1	95.7±0.1	1992±521
Moraiolo	Central Valley	0.1	0.0	2.8	0.4	0.3	95.3	1072
	Wine Country	0.0	0.0	3.1	0.7	0.2	95.3	1054
Nocellara del Belice	Central Valley	0.1	0.1	4.7	2.2	0.3	91.9	1142
	South Coast	0.0	0.0	3.4	0.4	0.2	95.1	1532
Pendolino	Central Valley	0.0±0.0	0.0±0.0	3.0±0.3	0.4±0.2	0.3±0.2	95.2±0.4	1735±653
Picholine	South Coast	0.0	0.0	2.9	0.5	0.2	95.7	1691
Picual	Central Valley	0.0±0.0	0.0±0.0	3.0±0.1	0.9±0.2	0.3±0.1	95.2±0.2	1395±256
	South Coast	0.1	0.0	3.2	0.7	0.3	95.1	1477
Sevillano	Central Valley	0.0	0.0	2.6	1.2	0.2	95.5	1779
	Wine Country	0.0	0.0	3.3	0.7	0.2	95.1	1605
Taggiasca	Central Valley	0.0	0.0	2.7	0.5	0.3	95.4	1306
	Wine Country	0.0	0.0	2.8	0.6	0.4	94.8	1448

Table 5. Samples that were outside fatty acid and/or sterol profile standards

Code	County	Variety	Lab	Palmitic Acid (C16:0)	Oleic Acid (C18:1)	Linoleic Acid (C18:2)	Linolenic Acid (C18:3)	Campesterol	Apparent B-sitosterol	Total Sterols
USDA Standard				***7.5 – 20.0***	***55.0 – 83.0***	***3.5 – 21.0***	***≤1.5***	***≤4.5***	***≥93.0***	***≥1000***
1	Imperial	Arbequina	UCD	23.2 (0.14)[1]	49.0 (0.51)	21.8 (0.18)		5.0 (0.03)	92.9 (0.06)	
			MO	21.2 (0.01)[2]	49.3 (0.02)	23.0 (0.03)		5.0 (0.20)	92.7 (0.26)	
2	Imperial	Koroneiki	UCD					4.9 (0.01)	92.7 (0.01)	
			MO					5.0 (0.20)	92.3 (0.26)	
3	Imperial	Koroneiki	UCD					5.1 (0.00)	92.4 (0.08)	
			MO					5.0 (0.20)	92.2 (0.26)	
4	Imperial	Koroneiki	UCD					5.0 (0.03)	92.3 (0.08)	
			MO					5.1 (0.20)	91.9 (0.26)	
9	Tehama	Koroneiki	UCD							973 (1.37)
			MO							980 (146.09)
10	Yolo	Koroneiki	UCD							892 (7.22)
			MO							846 (146.09)
29	Napa	Koroneiki	UCD							886 (29.44)
			MO							918 (146.09)
57	Kern	Nocellara del Belice	UCD					4.7 (0.03)	92.2 (0.03)	
			MO					4.7 (0.20)	91.9 (0.26)	
58	Kern	Pendolino	UCD	20.7 (0.10)			1.8 (0.04)			
			MO	20.0 (0.01)			2.0 (0.003)			

[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.

Table 6. Summary of samples collected from 2014/15 to 2016/17 harvest seasons. (A) denotes samples extracted on the Abencor equipment at the Olive Center.

2014/15 Harvest Season (20 Abencor, 30 Commercial)			2015/16 Harvest Season (71 Commercial)			2016/17 Harvest Season (70 Commercial)		
Variety	**County**	**Region**	**Variety**	**County**	**Region**	**Variety**	**County**	**Region**
Arbequina (9)	Glenn	Central Valley	Allegra (1)	Lake	Wine Country	Aglandau (1)	Solano	Central Valley
	Glenn	Central Valley	Arbequina (12)	Butte	Central Valley	Arbequina (12)	Glenn	Central Valley
	Glenn	Central Valley		Colusa	Central Valley		Glenn	Central Valley
	San Joaquin	Central Valley		Fresno	Central Valley		Imperial	Desert
	San Joaquin	Central Valley		Glenn	Central Valley		Napa	Wine Country
	Solano	Central Valley		Imperial	Desert		Sacramento	Central Valley
	Sonoma	Wine Country		Madera	Central Valley		San Joaquin	Central Valley
	Tehama	Central Valley		San Joaquin	Central Valley		San Joaquin	Central Valley
	Yolo	Central Valley		San Luis Obispo	South Coast		Solano	Central Valley
Arbequina (A) (4)	Imperial	Desert		Sutter	Central Valley		Solano	Central Valley
	Riverside	Desert		Tehama	Central Valley		Stanislaus	Central Valley
	Tehama	Central Valley		Ventura	South Coast		Tehama	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
	Tehama	Central Valley		Fresno	Central Valley		San Joaquin	Central Valley
	Yolo	Central Valley		Imperial	Desert		San Joaquin	Central Valley
Arbosana (A) (3)	Imperial	Desert		Madera	Central Valley		San Joaquin	Central Valley
	Riverside	Desert		San Joaquin	Central Valley		San Joaquin	Central Valley
	Yolo	Central Valley		Santa Barbara	South Coast		Yolo	Central Valley
Ascolano (2)	Tehama	Central Valley		Tehama	Central Valley	Ascolano (2)	Glenn	Central Valley
	Tehama	Central Valley		Tulare	Central Valley		Kern	Central Valley
Barnea (A) (1)	Yolo	Central Valley		Yolo	Central Valley	Chemlali (1)	Riverside	Desert
Chiquetita (1)	Sutter	Central Valley	Ascolano (2)	Kern	Central Valley	Coratina (2)	Kern	Central Valley
Frantoio (1)	Sacramento	Central Valley		Tehama	Central Valley		Sonoma	Wine Country
Koroneiki (5)	Madera	Central Valley	Barnea (1)	Tehama	Central Valley	Dolce di Morocco (1)	Riverside	Desert
	San Joaquin	Central Valley	Chemlali	Riverside	Desert	Frantoio	Alameda	Wine Country

			(1)			(4)		
	San Joaquin and Yolo	Central Valley	Coratina (3)	Kern	Central Valley		Kern	Central Valley
	Sonoma	Wine Country		Sonoma	Wine Country		Solano	Central Valley
	Yolo	Central Valley		Tehama	Central Valley		Sonoma	Wine Country
Koroneiki (A) (4)	Imperial	Desert	Dolce (1)	Riverside	Desert	Grapolo (1)	Santa Barbara	South Coast
	Riverside	Desert	Favolosa (1)	Tehama	Central Valley	Grignon (1)	Riverside	Desert
	Tehama	Central Valley	Frantoio (4)	Kern	Central Valley	Koroneiki (9)	Colusa	Central Valley
	Yolo	Central Valley		Mendocino	Wine Country		Imperial	Desert
Leccino (1)	Sacramento	Central Valley		Solano	Central Valley		Imperial	Desert
Leccino (A) (3)	Imperial	Desert		Sonoma	Wine Country		Imperial	Desert
	Sonoma	Wine Country	Grignon (1)	Riverside	Desert		Napa	Wine Country
	Yolo	Central Valley	Hojiblanca (1)	Tehama	Central Valley		Riverside	Desert
Manzanillo (1)	Butte	Central Valley	Koroneiki (6)	Glenn	Central Valley		San Joaquin	Central Valley
Mission (2)	Butte	Central Valley		Imperial	Desert		Tehama	Central Valley
	Tehama	Central Valley		Madera	Central Valley		Yolo	Central Valley
Pendolino (1)	Sacramento	Central Valley		Tehama	Central Valley	Leccino (2)	Solano	Central Valley
Pendolino (A) (2)	Sonoma	Wine Country		Tulare	Central Valley		Solano	Central Valley
	Yolo	Central Valley		Yolo	Central Valley	Manzanillo (4)	Butte	Central Valley
Picholine (1)	Sonoma	Wine Country	Leccino (3)	Mendocino	Wine Country		Napa	Wine Country
Picual (2)	Sonoma	Wine Country		Tehama	Central Valley		Santa Barbara	South Coast
	Yolo	Central Valley		Yolo	Central Valley		Tehama	Central Valley
Picual (A) (3)	Imperial	Desert	Lucca (1)	Santa Barbara	South Coast	Maurino (3)	Kern	Central Valley
	Tehama	Central Valley	Manzanillo (3)	Butte	Central Valley		Riverside	Desert
	Yolo	Central Valley		Santa Barbara	South Coast		Santa Barbara	South Coast

Sevillano (1)	Sonoma	Wine Country

	Tehama	Central Valley
Maurino (1)	Kern	Central Valley
Mission (5)	Butte	Central Valley
	Lake	Wine Country
	Riverside	Desert
	Ventura	South Coast
	Yolo	Central Valley
Moraiolo (3)	Mendocino	Wine Country
	Sonoma	Wine Country
	Tehama	Central Valley
Nocellara Belice (1)	Kern	Central Valley
Pendolino (3)	Solano	Central Valley
	Tehama	Central Valley
	Yolo	Central Valley
Picual (3)	Kern	Central Valley
	Tehama	Central Valley
	Yolo	Central Valley
Sevillano (1)	Tehama	Central Valley
Taggiasca (4)	Santa Barbara	South Coast
	Solano	Central Valley
	Tehama	Central Valley
	Yolo	Central Valley

Mission (4)	Butte	Central Valley
	Solano	Central Valley
	Tehama	Central Valley
	Tehama	Central Valley
Moraiolo (2)	Solano	Central Valley
	Sonoma	Wine Country
Nocellara del Belice (2)	Kern	Central Valley
	San Diego	South Coast
Pendolino (3)	Kern	Central Valley
	Solano	Central Valley
	Solano	Central Valley
Picholine (1)	Los Angeles	South Coast
Picual (5)	Kern	Central Valley
	San Diego	South Coast
	Tehama	Central Valley
	Tehama	Central Valley
	Yolo	Central Valley
Sevillano (2)	Napa	Wine Country
	Tehama	Central Valley
Taggiasca (2)	Napa	Wine Country
	Solano	Central Valley

Table 6 shows sample information from three consecutive harvest seasons (2014/15 to 2016/17). In the 2014/15 harvest season, the Center's research team processed 20 single-variety samples on Abencor equipment at UC Davis due to the unavailability of samples from specific locations (e.g. desert region) and collected 30 commercial samples from seven California olive oil producers. There were 14 varieties from 12 counties analyzed in the 2014/15 harvest season. Eight of the 20 Abencor samples (40 percent) were outside the USDA standard for fatty acid and/or sterol profile. Of those eight Abencor samples, six were from the desert region (Imperial and Riverside Counties). In spite of the variety, lower oleic acid values and higher linoleic acid values were observed. Moreover, higher campesterol and lower apparent B-sitosterol values were detected among SHD varieties from desert region (Table 7).

In the 2015/16 harvest season, 71 commercial samples (23 varieties from 20 counties) were collected with the goal of maximizing diversity in varieties and California counties. Only three samples (4 percent) were outside the USDA standard for fatty acid and/or sterol profile (Table 7).

In the 2016/17 harvest season, the Center continues seeking for the diversity of sample variety and harvest region. A total of 70 commercial samples (22 varieties from 20 counties) were collected and analyzed. Nine of the 70 samples (13 percent) were found to be outside at least one parameter in the USDA fatty acid/sterol standard. Seven of the nine samples were of SHD varieties including six Koroneiki and one Arbequina. An Arbequina sample from Imperial County had high levels of palmitic acid and linoleic acid; low level of oleic acid, while three Koroneiki samples from the same region had high level of campesterol and low apparent B-sitosterol values which was also in agreement with previous years' data of the same variety from the same county (Table 7). Another three Koroneiki samples from other three different counties (Tehama, Yolo, and Napa) had low total sterols values in the 2016/17 harvest season.

Table 7. Samples outside the USDA Standard of fatty acid and/or sterol profile from 2014/15 to 2016/17 harvest seasons

Harvest Season	Variety	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)	Campesterol	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	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	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	Arbequina	Imperial	21.2 (0.01)			49.3 (0.02)	23.0 (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)			

CONCLUSIONS AND RECOMMENDATIONS

- The commission may wish to work with the research team to identify samples and develop a standardized information sheet in order to obtain meaningful and consistent data from producers of all varieties from all regions. In order to confirm the variety/climate influence, it is critical that several olive oil samples of same variety are collected each year.

- Our finding that some legitimate olive oil is outside fatty acid or sterol profile standards is consistent with California data from previous seasons,[9] as well as similar research in Australia, Chile, Argentina, New Zealand, Italy, Spain and Tunisia.[11, 12] The fatty acid and sterol profile of SHD oil varieties from Imperial Valley (desert region) have been consistently outside the current California olive oil standards. The commission may wish to recommend modifications to California olive oil standards so that fatty acid and sterol profile standards accommodate all olive oil produced in California.

[1] CDFA has adopted standards for some, but not all, olive oil fatty acids and sterols. For those elements of fatty acid and sterol profiles not in CDFA standards, California producers observe USDA standards, which are referenced in California state law. See California Department of Food and Agriculture, "Grade and Labeling Standards for Olive Oil, Refined-Olive Oil and Olive-Pomace Oil", Effective September 26, 2014, Incorporating Amendments Since February 15, 2015; California Health and Safety Code, Division 104, Part 6, Chapter 9; and United States Department of Agriculture (2010), United States Standards for Grades of Olive Oil and Olive-Pomace Oil, *Federal Register.*

[2] 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.

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