Evaluation of Fatty Acid and Sterol Profiles
California Olive Oil
2014/15 Season

Submitted to the
Olive Oil Commission of California

January 2016

UC DAVIS OLIVE CENTER
at the Robert Mondavi Institute

Evaluating Fatty Acid and Sterol Profiles, California Olive Oil, 2014/15 Season

SUMMARY

California's olive oil industry observes standards for fatty acid and sterol profiles of the California Department of Food and Agriculture (CDFA and the United States Department of Food and Agriculture (USDA). The UC Davis Olive Center analyzed the fatty acid and sterol profiles of 50 single-variety olive oil samples for the 2014/15 season, a research project funded by the Olive Oil Commission of California (OOCC).

The Center extracted 20 of the oil samples on Abencor equipment from fresh olives, and sourced 30 oil samples from commercial producers in California. Samples that were outside a fatty acid or sterol standard at UC Davis were sent to Modern Olives laboratory (Lara, Victoria, Australia) for retesting. In this report we consider a sample to be outside of standards only when the sample is outside of the same parameter in both laboratories.

Our results show that eight of 20 Abencor-extracted samples (40 percent) and two of 30 commercial samples (7 percent) were outside standards for at least one fatty acid or sterol parameter, for an overall rate of 10 of 50 samples (20 percent) outside the standards. These findings, which are consistent with data the Olive Center has collected on California olive oil in previous years, indicate that existing standards could prevent authentic California olive oil from being graded as olive oil, through no fault of the producer.

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, ensure that commercial samples from desert regions are included in the commission's future testing of California olive oils, and assess new and advanced methods to analyze olive oil authenticity.

BACKGROUND

California olive oil observes standards for fatty acid and sterol profiles set by the California Department of Food and Agriculture (CDFA) and the United States Department of Agriculture (USDA)[1]. Two of the key tests for determining olive oil authenticity are fatty acid profile and sterol profile. 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 oil's *sterol profile*.

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 authenticity, including geographical origin[2], climate and altitude[3], cultivar and harvest timing[4,5], irrigation strategies[6], and processing techniques[7]. These factors can lead to an authentic olive oil being outside the standards for fatty acid and sterol profiles.

The official method for sterols composition takes about 10 hours for sample preparation and analysis by gas chromatography (GC), and there are large amounts of organic solvents (e.g., ethyl ether, ethyl acetate, hexane) consumed in sample preparation. The method for fatty acids profile analysis takes about three hours to complete with less solvent consumption.

In this report, we summarize the results of 50 single-variety California olive oil from the 2014/15 season and compare them with findings from the Center's research from previous years[8], as well as research from the other olive-growing regions around the world.

SAMPLE INFORMATION

The UC Davis Olive Center analyzed the fatty acid and sterol profiles of 50 single-variety olive oil samples for the 2014/15 season. Oil was extracted from fresh olives (20 samples) using a Abencor laboratory-scale olive oil extraction system. The olives generally were shipped to the laboratory with cold gel packs and held at 38 °F (3 °C) upon arrival at the campus until the olives could be processed. The fresh olive samples were processed between one and three days after harvest. All fruit was harvested and processed between November 5 and November 25, 2014. In addition, 30 single-variety commercial samples were collected from seven California olive oil producers between December 4, 2014 and January 5, 2015.

Samples that were outside a fatty acid or sterol standard at the UC Davis laboratory were sent to Modern Olives laboratory (Lara, Victoria, Australia) for retesting, except for two samples that had insufficient amounts for retesting.

The Abencor-extracted samples are summarized by harvest location in Table 1. The harvest locations selected in the study sought geographic and climatic diversity where little commercial olive oil was available for the varieties selected. As shown in Table 1, fresh olive samples were selected from one cool coastal area (Petaluma); three Central Valley locations with hot summers, moderate rainfall, and winter minimum temperatures that may dip below freezing (Red Bluff, Corning and Davis/Winters); and two desert zones with early ripening, low rainfall, and very hot summer temperatures (Imperial Valley and Temecula). Table 2 shows the Abencor-extracted samples by variety, with the widely planted super-high-density varieties; Arbequina, Arbosana, and Koroneiki; comprising 11 of the 20 samples (55 percent).

Table 1. Abencor-extracted samples by harvest location

Code	Variety	Harvest Location	Total by Location
A	Leccino	Petaluma (cool coastal)	2
B	Pendolino		
C	Arbequina	Imperial Valley (hot, dry desert)	5
D	Arbosana		
F	Picual		
G	Koroneiki		
H	Leccino		
I	Barnea	Davis/Winters (Central Valley)	7
J	Arbequina		
K	Leccino		
L	Picual		
M	Arbosana		
N	Pendolino		
O	Koroneiki		
P	Picual	Corning (Central Valley)	1
Q	Koroneiki	Temecula (hot, dry desert)	3
R	Arbosana		
S	Arbequina		
T	Arbequina	Red Bluff (Central Valley)	2
U	Koroneiki		

Table 2. Abencor-extracted samples by variety

Code	Variety	Harvest Location	Total by Variety
C	Arbequina	Imperial Valley	4
J		Davis	
S		Temecula	
T		Red Bluff	
D	Arbosana	Imperial Valley	3
M		Davis	
R		Temecula	
G	Koroneiki	Imperial Valley	4
O		Davis	
Q		Temecula	
U		Red Bluff	
F	Picual	Imperial Valley	3
L		Davis	
P		Corning	
A	Leccino	Petaluma	3
H		Imperial Valley	
K		Davis	
B	Pendolino	Petaluma	2
N		Davis	
I	Barnea	Winters	1

The Center also sourced 30 single-variety oil samples from commercial producers, summarized by harvest location in Table 3 and by variety in Table 4. Table 3 shows that, except for five samples from Sonoma County, the harvest locations were from Central Valley counties where more than 80 percent of California olive oil is grown. Table 4 shows that 17 commercial samples (57 percent) were from the main super-high-density varieties of Arbequina, Arbosana, and Koroneiki, which comprise a large portion of California olive oil.

Table 3. Commercial samples by harvest location

Code	Harvest County	Variety	Total from Location
1	Butte County	Mission	2
4		Manzanillo	
12	Glenn County	Arbequina	3
13		Arbequina	
16		Arbequina	
7	Madera County	Koroneiki	1
2	Sacramento County	Frantoio	3
3		Pendolino	
5		Leccino	
10	San Joaquin County (Linden)	Arbosana	4
23	San Joaquin County (Lodi/Stockton)	Arbequina	
24	San Joaquin County (Lodi)	Arbequina	
25	San Joaquin County (Lodi)	Koroneiki	
8	Solano County	Arbequina	1
26	Sonoma County	Picual	5
27		Arbequina	
28		Koroneiki	
29		Picholine	
30		Sevillano	
18	Sutter County	Chiquetita	1
20	Tehama County (Gerber)	Ascolano	5
21		Arbequina	
22		Mission	
11	Tehama County (Corning)	Ascolano	
17	Tehama County	Arbosana	
6	Yolo County	Picual	4
9		Arbosana	
14		Arbequina	
15		Koroneiki	
19	San Joaquin and Yolo Counties	Koroneiki	1

Table 4. Commercial samples by variety

Code	Variety	Harvest Location	Total by Variety
8	Arbequina	Solano County	9
12		Glenn County	
13		Glenn County	
14		Yolo County	
16		Glenn County	
21		Tehama County (Gerber)	
23		San Joaquin County (Lodi/Stockton)	
24		San Joaquin County (Lodi)	
27		Sonoma County	
7	Koroneiki	Madera County	5
15		Yolo County	
19		San Joaquin and Yolo Counties	
25		San Joaquin County (Lodi)	
28		Sonoma County	
9	Arbosana	Yolo County	3
10		San Joaquin County (Linden)	
17		Tehama County	
11	Ascolano	Tehama County (Corning)	2
20		Tehama County (Gerber)	
1	Mission	Butte County	2
22		Tehama County (Gerber)	
6	Picual	Yolo County	2
26		Sonoma County	
2	Frantoio	Sacramento County	1
3	Pendolino	Sacramento County	1
4	Manzanillo	Butte County	1
5	Leccino	Sacramento County	1
18	Chiquetita	Sutter County	1
29	Picholine	Sonoma County	1
30	Sevillano	Sonoma County	1

RESULTS AND DISCUSSION

Abencor-extracted Samples

The Center analyzed the oil samples based on methods and standards required in California for fatty acid and sterol profiles[1]. Table 5 shows, by harvest location, that Abencor-extracted samples (40 percent) were outside one or more parameters at both UC Davis and Modern Olives laboratories.

Six of the eight samples came from the hot desert regions of Imperial Valley and Temecula:

- Samples C, D, R, and S: Arbequina and Arbosana samples that generally showed high levels of palmitic acid and palmitoleic acid, a low level of oleic acid, a high level of campesterol, and a low level of apparent beta-sitosterol. These results for Arbequina are consistent with Center's research from previous years[8] and other independent research in Australia and Argentina[9]. Hot climates seem to correlate with lower levels of oleic acid while cooler climates promote higher levels of oleic acid[9b]. Hot climates also seem to correlate with elevated palmitic acid and polyunsaturated linoleic acid[9b].

- Sample F: Picual had a high level of palmitioleic acid.

- Sample H: Leccino, a cold-hardy variety from Tuscany, had a low levels of oleic acid, and high levels of linoleic and linolenic acid.

Two of the eight samples (L and U) were from outside the desert areas:

- Sample L: a Picual sample from Davis had a linoleic acid content that was less than the minimum allowed under standards. Australian survey showed that Picual and Arbequina from cooler climates can have low level of linoleic acid[9b].

- Sample U: a Koroneiki sample from Red Bluff had a low level of total sterols, which is consistent for this variety with previous research in the United States and Australia[8,9b].

Commercial Samples

As noted earlier the Center analyzed data on fatty acid and sterol profiles for 30 commercial samples collected from seven California olive oil producers. Table 6 shows that two of the 30 samples (7 percent) were outside standards for one or more parameters at UC Davis and Modern Olives laboratories: Sample 7, a Koroneiki sample from Madera County, was below the minimum value in the standard for apparent beta-sitosterol; and Sample 10, an Arbosana sample from San Joaquin County, was above the maximum value in the standard for heptadecenoic acid (C17:1).

The fewer outliers for commercial samples compared to Abencor-extracted samples likely is due to the absence of commercial samples available from hot desert regions, as well as the common commercial practice of blending multiple single-varietal batches from several areas. Research suggests that olive oil extraction via laboratory-scale Abencor equipment compared to an industrial-size mill does not have a large effect on the fatty acid and sterol profiles[7a].

Table 5. Abencor samples that were outside fatty acid and sterol profile standards

Sample Information			Laboratory	Fatty Acid Parameter					Sterol Parameter		
Code	Harvest Location	Variety		Palmitic acid (C16:0)	Palmitoleic acid (C16:1)	Oleic acid (C18:1)	Linoleic acid (C18:2)	Linolenic acid (C18:3)	Total sterols	Campesterol	Apparent beta-sitosterol
Standard				7.5 – 20.0 %	0.3 – 3.5 %	55.0 – 83.0 %	3.5 – 21.0 %	≤1.5 %	>1000 mg/kg	≤ 4.5 %	≥ 93.0 %
C	Imperial Valley	Arbequina	UC Davis	26.7	4.1	44.7				5.2	91.9
			Modern Olives	22.7	4.0	44.0				5.6	91.9
D		Arbosana	UC Davis			54.0				4.6	90.9
			Modern Olives			53.3				4.8	92.2
F		Picual	UC Davis		3.9						
			Modern Olives		3.8						
H		Leccino	UC Davis			46.5	27.3	1.7			
			Modern Olives			46.6	27.6	2.3			
L	Davis/ Winters	Picual	UC Davis				2.9				
			Modern Olives				3.4				
R	Temecula	Arbosana	UC Davis	24.5	4.1	43.5	23.5				
			Modern Olives	22.0	4.0	44.3	24.8				
S		Arbequina	UC Davis	26.1	4.5	37.1	28.6			5.0	92.2
			Modern Olives	23.4	4.6	37.7	30.3			5.0	92.8
U	Red Bluff	Koroneiki	UC Davis						683		
			Modern Olives						791		

Table 6. Commercial samples that were outside fatty acid and sterol profile standards

Sample Information			Laboratory	Fatty Acid Parameter	Sterol Parameter
Code	Harvest Location	Variety		Heptadecenoic acid (C17:1)	Apparent beta-sitosterol
Standard				≤0.3 %	≥ 93.0 %
7	Madera County	Koroneiki	UC Davis		90.9
			Modern Olives		92.7
10	San Joaquin County (Linden)	Arbosana	UC Davis	0.4	
			Modern Olives	0.4	

CONCLUSIONS AND RECOMMENDATIONS

- Of the 50 samples that were analyzed by UC Davis and Modern Olives for fatty acid and sterol profiles, 10 samples were outside standards for at least one parameter at both laboratories. Thus, 20 percent of the 50 olive oil samples could be prevented by standards from being graded as olive oil, based solely on the oil's natural chemistry and through no fault of the producer. Six of the 10 samples came from the emerging desert regions of Imperial Valley and Temecula. Four of the 10 samples came from the Central Valley, California's core olive-growing region, and three out of these four samples were produced from commonly planted super-high-density varieties. Our finding that a significant amount of legitimate olive oil is outside fatty acid or sterol profile standards is consistent with California data from previous seasons[8], as well as similar research in Australia, Chile, Argentina, New Zealand, Spain and Tunisia[9,10]. 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.

- Fewer commercial samples were outside standards than the Abencor-extracted samples, which is probably due to the lack of commercial samples produced from desert regions and the common practice of combining several batches from multiple areas for commercial sale. The commission may wish to ensure that commercial samples from desert regions, which are expected to be available beginning with the 2015/16 season, are included in the commission's future testing of California olive oils.

- Fatty acid and sterol profile analyses have shortcomings as tools for assessing olive oil purity. These tests are time-consuming and expensive, and cannot reliable prove olive oil authenticity. The commission may wish to investigate new and advanced methods with the potential to cost less, be more accurate, and minimize laboratory variability.

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[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.*

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