Evaluation of Mandatory Testing
California Olive Oil
2016/17 Season

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UCDAVIS
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SUMMARY

The Olive Oil Commission of California (OOCC) contracted with the UC Davis Olive Center to analyze and report on 2016/17 data produced under the mandatory sampling and testing requirements of California olive oil standards. The standards require the OOCC to take five samples for testing from each Handler, and require Handlers to separately sample and test every lot.

Of 147 samples collected (57 samples by the OOCC and 90 samples by 12 Handlers), 139 samples (95 percent) were from lots that were designated as Extra Virgin grade prior to testing, 2 samples (one percent) were designated as a lower grade, and 6 samples (four percent) were unidentified by grade. Fifty-one of the 57 OOCC samples (89 percent) were from the same lots tested by the Handlers.

All samples were analyzed based on the quality tests specified in the standards, and 25 of the OOCC samples were also analyzed for the purity tests specified in the standards. Four Handlers did not complete all of the tests required in California standards for 23 of 90 Handler samples (26 percent).

Test results showed that all samples designated as Extra Virgin prior to testing met California standards for Extra Virgin grade, with the caveat that 23 Handler samples did not have data for all the tests required under California standards. For the 25 OOCC samples that were subjected to purity tests, 23 samples (92 percent) were within the parameters specified in the standards while one Arbosana sample exceeded the limit for heptadecenoic acid (C17:1) and one Koroneiki sample exceeded the limit for campesterol.

In the future the OOCC may wish to consider:

- providing a list of required tests to Handlers prior to testing, requiring Handlers to retest any sample with incomplete data, and requiring Handlers that have been not identified samples by variety to provide the OOCC with this information; and

- requiring the third-party sampling agency to report the grade, variety or varieties of olives that the Handler has designated for each lot prior to testing.

INTRODUCTION

The Olive Oil Commission of California contracted with the UC Davis Olive Center to analyze the testing results for oils produced during the 2016/17 season. The oils were sampled and tested pursuant to California olive oil standards,[1] which require annual sampling and testing of olive oil produced in California.

The standards require the OOCC to conduct sampling and testing under the direction of the California Department of Food and Agriculture (CDFA) or by an approved independent third party. The sampling party must take five samples at random from each Handler[2] following the sampling procedures and protocols of the International Organization for Standardization (ISO),[3] and send the samples to an accredited laboratory for analysis. In addition, the standards require each Handler to sample, test, and grade all lots, although the standards do not require sampling protocols or laboratory accreditation for Handler testing. Grading is based on the quality standards summarized in Table 1 and described in the Appendix.

Table 1. Quality tests and standards for California olive oil grades

Test	Extra Virgin	Virgin	Crude
Free Fatty Acidity (FFA) %m/m expressed as oleic acid	≤0.5	≤1.0	>1.0
Peroxide Value (PV) meq. O_2/kg oil	≤15.0	≤20.0	>20.0
K_{232} Ultraviolet Absorbance (UV) $K^{1\%}_{1cm}$	≤2.40	≤2.60	>2.60
K_{270} Ultraviolet Absorbance (UV) $K^{1\%}_{1cm}$	≤0.22	≤0.25	>0.25
ΔK Ultraviolet Absorbance (UV) $K^{1\%}_{1cm}$	≤/0.01/	≤/0.01/	≤/0.01/
Moisture and Volatile Matter %m/m	≤0.2	≤0.2	≤0.3
Insoluble Impurities %m/m	≤0.1	≤0.1	≤0.2
Pyropheophytin a (PPP) %	≤17	N/A	N/A
1,2–Diacylglycerols (DAGs) %	≥35	N/A	N/A
Organoleptic Median of Defects (MeD)	0.0	≤2.5	>2.5
Organoleptic Median of Fruity (MeF)	>0.0	>0.0	N/A

SAMPLE INFORMATION

A total of 147 samples were tested for the 2016/17 season: 57 samples (39 percent) were collected by the OOCC and 90 (61 percent) were collected by 12 Handlers. The OOCC samples were collected by CDFA officials from Handler lots in January and February 2017 and sent to the Australian Oils Research Laboratory in Wagga Wagga, New South Wales, Australia. Based on matching lot numbers, we were able to determine that 51 of 57 the Handler samples (89 percent) were from the same lots tested by the OOCC. Handler sampling dates ranged from October 25, 2016 to March 6, 2017, with three of 12 Handlers not providing sampling date information. Each Handler sent samples to a laboratory and sensory panel of their choice.

[1] 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.

[2] "Handler" is defined by Section 5.13 of the California standard as "a person who engages, in this state, in the operation of marketing olive oil that he or she has produced, or purchased or acquired from an olive oil producer, or that he or she is marketing on behalf of an olive producer."

[3] ISO 5555:2001 Animal and vegetable fats and oils – Sampling.

Eighty-eight of the 90 Handler samples (98 percent) included information on olive varieties, but the OOCC samples did not include this information. Given that 51 of 57 of OOCC samples were from lots also sampled by Handlers, we were able to identify varieties in most of the OOCC samples. Table 2 summarizes the known varieties for samples collected by the OOCC and the Handlers. Overall, 118 of 147 samples (80 percent) were single-variety, 16 samples (11 percent) were blends, 3 samples (2 percent) were vaguely identified as "Spanish Blend" and "Italian Blend" and 10 samples (7 percent) were unidentified.

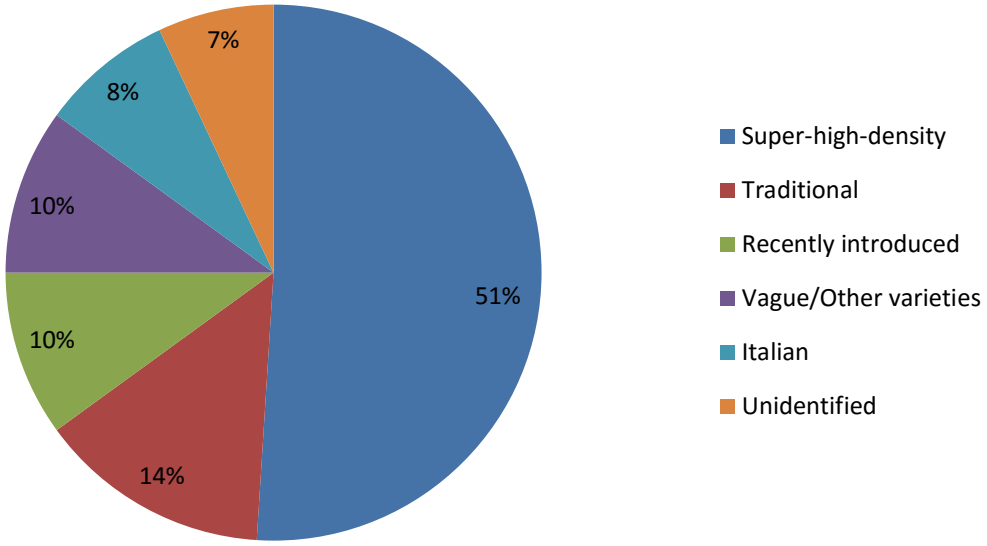
Table 2. Samples by variety or blend (147 samples)

Variety	OOCC Samples	Handler Samples	Total # (%) Samples
Arbequina	13	23	36 (24.5)
Arbosana	10	14	24 (16.3)
Ascolano	0	1	1 (0.7)
Barnea	1	1	2 (1.4)
Coratina	1	2	3 (2)
Empeltre	0	1	1 (0.7)
Favolosa	0	1	1 (0.7)
Frantoio	2	3	5 (3.4)
Hojiblanca	1	1	2 (1.4)
Italian Blend	1	1	2 (1.4)
Koroneiki	6	9	15 (10.2)
Leccino	0	2	2 (1.4)
Lunigiana	0	1	1 (0.7)
Manzanillo	1	4	5 (3.4)
Mission	2	3	5 (3.4)
Morailolo	0	1	1 (0.7)
Oliana	1	1	2 (1.4)
Pendolino	0	1	1 (0.7)
Picual	1	3	4 (2.7)
Sevillano	2	4	6 (4.1)
Spanish Blend	0	1	1 (0.7)
Taggiasca	0	1	1 (0.7)
12% Arbequina, 12% Arbosana, 5% Ascolano, 27% Frantoio, 24% Koroneiki, 8% Manzanillo, 7% Mission, 5% Picual	1	1	2 (1.4)
24% Frantoio, 19% San Felica, 15% Itrana, 15% Leccino, 13% Pendalino, 8% Kalamata, 6% Grapollo	1	1	2 (1.4)
3% Mission, 61% Arbequina, 36% Arbosana	2	1	3 (2)
3% Picual, 28% Ascolano, 27% Manzanillo, 17% Mission, 25% Sevillano	1	1	2 (1.4)
45% Frantoio, 45% Leccino, 10% Pendalino	0	1	1 (0.7)
50% Leccino, 50% Frantoio	0	1	1 (0.7)
50% Mission, 50% Manzanillo	2	2	4 (2.7)
55% Frantoio, 25% Leccino, 10% Pendolino, 10% Mission	0	1	1 (0.7)
Unidentified	8	2	10 (6.8)
Total	57	90	147 (100)

As illustrated in Chart 1, 75 of the 147 samples (51 percent) were from the major super-high-density varieties (Arbequina, Arbosana, and Koroneiki); 21 samples (14 percent) were from traditional varieties that have been grown in California for more than a century (Mission, Manzanillo, Sevillano, Ascolano, and blends of these varieties); 15 samples (10 percent) were from varieties that have been planted in California mainly in the past few years (Coratina, Barnea, Don Carlo, Empeltre, Favolosa, Hojiblanca, Oliana, and

Picual); 14 samples (10 percent) were either vaguely identified or were blends that do not fit in the above categories; 12 samples (8 percent) were from Italian varieties that have been planted in California primarily in the past 25 years (Frantoio, Leccino, Moraiolo, Pendolino, Taggiasca and blends of these varieties); and 10 samples (7 percent) were unidentified.

Chart 1. Categories of olive varieties tested



Handlers reported the assumed-grade of lots prior to testing samples from those lots, but CDFA officials did not collect this information on OOCC samples. Given that 51 of the OOCC's 57 samples had the same lot numbers as the samples also tested by the Handlers, we were able to determine the assumed-grade prior to testing for most of the OOCC lots. A total of 139 of the 147 samples (95 percent) were designated as Extra Virgin prior to testing, six OOCC samples (four percent) had no identified grade and two Handler samples (one percent) were designated as a lower grade.

RESULTS FOR QUALITY TESTS

In total, 145 of 147 samples (99 percent) met California standards for Extra Virgin grade: 57 of 57 OOCC samples and 88 of 90 Handler samples. There is a caveat in that there was incomplete data for 23 samples, and therefore it is unknown whether complete data would have shown a different passage rate. All 139 samples in which the Handler had reported an assumed grade of Extra Virgin prior to testing actually met extra virgin standards in testing. Table 3 shows the average values for the samples tested as Extra Virgin grade and indicates that the Extra Virgin samples were well within the limits of California standards. The low standard deviations indicate that results from different producers did not deviate much from the average.

Table 3. Summary of quality testing results for Extra Virgin samples (145 of 147 samples)

Test (CA Extra Virgin Standard)	Average Value	Standard Deviation
Free Fatty Acidity (≤0.5)	0.2	0.1
Peroxide Value (≤15.0)	5.5	2.5
UV K_{232} (≤2.40)	1.78	0.22
UV K_{270} (≤0.22)	0.13	0.03
UV ΔK (≤/0.01/)	0.00	0.00
Moisture and Volatile Matter (≤0.2)	0.1	0.0
Insoluble Impurities (≤0.1)	0.0	0.0
Pyropheophytins (≤17)	2	1
1,2-Diacylglycerols (≥35)	89	7
Organoleptic (MeF>0)	4.6	0.8

The two samples tested as below Extra Virgin grade came from the same Handler, who had designated the lots as below Extra Virgin grade prior to testing. Testing indicated that one of the samples met California standards for Virgin grade and the other sample met California standards for Crude grade. Table 4 indicates that the Virgin sample slightly exceeded the California standard for free fatty acidity and the Crude sample very high in free fatty acidity as well as showing organoleptic defects.

Table 4. Summary of quality testing results for non-Extra Virgin samples (2 of 147 samples)

	Sample	
Test (CA Extra Virgin Standard)	**1**	**2**
Free Fatty Acidity (≤0.5)	0.6	2.1
Peroxide Value (≤15.0)	4.8	8.4
UV K_{232} (≤2.40)	1.65	2.02
UV K_{270} (≤0.22)	0.13	0.22
UV ΔK (≤/0.01/)	0.00	<0.001
Moisture and Volatile Matter (≤0.2)	0.2	0.2
Insoluble Impurities (≤0.1)	<0.01	<0.01
Pyropheophytins (≤17)	<1.0	1
1,2-Diacylglycerols (≥35)	83	62
Organoleptic (MeD=0)	0	Rancid 1.9, Fusty 1.4
Organoleptic (MeF>0)	2.8	1.9
Handler Assumed Grade	VOO	Crude
Tested Grade	VOO	Crude

As previously indicated, 23 samples did not provide data for all of the quality tests required in California standards, as summarized in Table 5. For example, Handler C did not provide data on moisture and volatile matter, insoluble impurities, PPP, DAGs, and organoleptic for all four samples tested. While all 23 samples met extra virgin grade standards for the tests that were performed, it is not known whether all 23 samples would have met the grade standard if the samples had been subjected to all of the tests required under California standards.

Table 5. Number of samples that were not subjected to all tests

Handler	Samples	Moisture/ Volatile Matter	Insoluble Impurities	PPP	DAGs	Organoleptic	Designated as Extra Virgin pre-test
C	4	0	0	2	2	1	4
I	5	0	0	0	0	0	5
K	2	1	0	2	2	0	2
P	12	0	0	0	0	0	12
Total	23	1	0	4	2	1	23

Fifty-one lots were tested by both the OOCC and the Handlers and all 51 lots received the same grade. This 100 percent agreement is an improvement over the 2014/15 and 2015/16 seasons, which had consistent results between the OOCC and Handler testing of 85 percent and 95 percent, respectively (Table 6).

Table 6. Olive oil grading consistency for same lots from 2014/15 to 2016/17 harvest seasons

	2014/15	2015/16	2016/17
Number of lots tested by both Handlers and the OOCC	26	41	51
Number of samples in agreement	22	39	51
Percentage of grading agreement	85	95	100

Table 7 provides a summary of quality testing results for Extra Virgin samples from 2014/15 to 2016/17 harvest seasons. The average values and standard deviations indicate that the Extra Virgin samples were well within the limits of California standards and did not deviate much among different producers. The average value of peroxide value (PV), a primary oxidative parameter decreased by 25 percent, and the average value of 1,2-diacylglycerols (DAGs) increased by nine percent over three harvest seasons. This suggests that the quality of the olive fruit, post-harvest handling, and processing may have improved over three seasons. Sensory panel results showed that fruitiness increased by 10 percent. Free fatty acidity, UV, moisture and volatile matter, and pyropheophytins values remained constant in all three years.

Table 7. Summary of quality testing results for Extra Virgin samples from 2014/15 to 2016/17 harvest seasons

	2014/15		2015/16		2016/17	
Test (CA Extra Virgin Standard)	**Average Value**	**Standard Deviation**	**Average Value**	**Standard Deviation**	**Average Value**	**Standard Deviation**
Free Fatty Acidity (≤0.5)	0.2	0.1	0.2	0.1	0.2	0.1
Peroxide Value (≤15.0)	7.3	2.8	5.9	2.9	5.5	2.5
UV K_{232} (≤2.40)	1.69	0.25	1.77	0.21	1.78	0.22
UV K_{270} (≤0.22)	0.12	0.03	0.12	0.03	0.13	0.03
UV ΔK (≤/0.01/)	<0.003	0.00	<0.003	0.00	0.00	0.00
Moisture and Volatile Matter (≤0.2)	0.1	0.0	0.1	0.0	0.1	0.0
Insoluble Impurities (≤0.1)	0.0	0.0	0.0	0.0	0.0	0.0
Pyropheophytins (≤17)	2	1	2	1	2	1
1,2-Diacylglycerols (≥35)	82	10	88	6	89	7
Organoleptic (MeF>0)	4.2	0.7	4.4	0.7	4.6	0.8

RESULTS FOR PURITY TESTS

In the 2016/17 harvest season, 25 of the 57 OOCC samples were analyzed by the Australian Oils Research Laboratory based on the purity tests required by California standards. Twenty-three of the samples (92 percent) were within the limits required under California standards with two of the 25 samples (8 percent) outside the standards, both from the Central Valley: an Arbosana sample from Fresno County exceeded the limit of heptadecenoic acid (C17:1) with a value of 0.4 (California standard ≤ 0.3) and a Koroneiki sample from Yolo County exceeded the limit of campesterol content of with a value of 4.7 (California standard ≤4.5).

Similar results have been found in the Center's previous studies. Two Arbosana samples from the Central Valley (one sample from San Joaquin County in 2014 and one sample from Yolo County in 2012) exceeded the limit of 0.3 for heptadecenoic acid and three Koroneiki samples from the Central Valley exceeded campesterol limits - one sample from Madera County in 2014, one sample from Tehama County in 2014 and one sample from Yolo County in 2012.

CONCLUSIONS AND RECOMMENDATIONS

- All samples that were designated by Handlers as Extra Virgin prior to testing were ultimately graded as Extra Virgin after testing. A caveat is that a total of 23 samples did not provide data for all of the quality tests required in California standards. In addition, some Handlers did not identify the varieties in samples clearly or at all. The OOCC may wish to provide a list of required tests to Handlers prior to testing, require Handlers to retest any sample with incomplete data, and require Handlers that have been not identified samples by variety to provide the OOCC with this information.

- The third-party sampling agency did not record the grade of the lot designated by the Handler prior to testing, nor did the sampling agency record the olive varieties for each lot. The OOCC may wish to require the third-party sampling agency to report the grade, variety or varieties of olives that the Handler has designated for each lot prior to testing.

APPENDIX

Quality tests in California olive oil standards

PARAMETER	DETERMINATION	INDICATOR	CA EXTRA VIRGIN STANDARD
Free Fatty Acids (FFA)	Free fatty acids are formed by the hydrolysis of the triacylglycerols during extraction, processing and storage.	An elevated level of free fatty acid indicates hydrolyzed fruits and/or poor quality oil made from unsound fruit, improperly processed or stored oil.	≤ 0.5 % as oleic acid
Peroxide Value (PV)	Peroxides are primary oxidation products that are formed when oils are exposed to oxygen, producing undesirable flavors and odors.	An elevated level of peroxides indicates oxidized and/or poor quality oil.	≤ 15 meq. O_2/kg oil
Ultraviolet absorbance (UV)	Conjugated double bonds are formed from natural nonconjugated unsaturation in oils upon oxidation. The K_{232} measures primary oxidation products and K_{270} measures secondary oxidation products.	An elevated level of UV absorbance indicates oxidized and/or poor quality oil.	K_{232}: ≤ 2.40 $K^{1\%}_{1cm}$; K_{270} ≤ 0.22 $K^{1\%}_{1cm}$; ΔK: ≤ 0.01 $K^{1\%}_{1\ cm}$
Moisture and Volatile Matter %m/m	Olive oil retains water and volatile compounds during processing. Moisture and volatile matter are determined by the loss in mass of olive oil in an air oven at 130±2°C or in a vacuum oven at the temperature range of 20°C to 25°C under specific test conditions.	An elevated level of moisture and volatile matter could be caused by improper extraction methods, leading to poor olive oil quality, organoleptic defects, and reduced shelf life.	≤ 0.2 %
Insoluble Impurities %m/m	Insoluble impurities (meal, dirt, and other foreign matter) are determined when the impurities are insoluble in petroleum ether under specific experimental conditions.	Elevated insoluble impurities can be caused by substandard manufacturing practices, leading to poor olive oil quality, organoleptic defects and reduced shelf life.	≤ 0.1 %
1,2-Diacylglycerols (DAGs)	Fresh extra virgin olive oil contains a high proportion of 1,2-diacylglycerols to 1,2- and 1,3-diacylglycerols, while olive oil from poor quality fruits and refined olive oils have higher level of 1,3-DAGs than fresh extra virgin olive oils.	The ratio of 1,2-diacylglycerols to 1,2- and 1,3-diacylglycerols is an indicator for oil that is hydrolyzed, oxidized, and/or of poor quality.	≥ 35%
Pyropheophytins (PPP)	Chlorophyll pigments break down to pheophytins and then pyropheophytins upon thermal degradation of olive oil.	An elevated level of pyropheophytins is an indicator for oil that is oxidized and/or adulterated with refined oil.	≤ 17%
Sensory	Sensory refers to taste, odor and mouthfeel	Sensory assessment can help identify oils that are of poor quality, oxidized, and/or adulterated with other oils.	Median of defects=0.0; median of the fruity>0.0