Evaluation of Mandatory Testing
California Olive Oil
2015/16 Season

Submitted to the
Olive Oil Commission of California

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UC DAVIS OLIVE CENTER
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Evaluation of Mandatory Testing, California Olive Oil, 2015/16 Season

SUMMARY

The Olive Oil Commission of California (OOCC) contracted with the UC Davis Olive Center to analyze and report on 2015/16 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 180 samples collected (49 samples by the OOCC and 131 samples by 12 Handlers), 157 samples were from lots that were designated as EVOO grade prior to testing, 15 samples were designated as a lower grade, and 8 samples were unidentified by grade. Forty-one of the Handler samples were from the same lots tested by the OOCC.

All samples were analyzed based on the quality tests specified in the standards, and 20 of the OOCC samples were also analyzed for the purity tests specified in the standards. Five Handlers did not complete all of the tests required in California standards for 27 of 131 samples.

Test results showed that all samples designated as EVOO prior to testing met California standards for EVOO grade with one caveat: two samples designated and tested as EVOO by Handlers were tested as Virgin by the OOCC. For the 20 OOCC samples that were subjected to purity tests, all were within the parameters specified in the standards when the laboratory margin of error was factored in the results.

In the future the OOCC may wish to consider:

- testing samples several months after bottling and storage to assess the shelf life of California olive oils;
- requiring the third-party sampling agency to indicate the grade that the Handler has designated for each lot prior to testing, as well as the variety or varieties of olives in each lot;
- requiring Handers to retest any lot that does not include complete results for all tests required in the standard, and providing additional guidance to Handlers to increase accuracy and completeness in reporting and testing;
- clarifying the standard to ensure that Handlers use laboratories that are proficient for all tests and report the laboratory’s precision, accuracy, and margin of error with results;
- allowing DAGs and PPP tests to be optional for samples expected to be below Extra Virgin grade, so as to reduce costs to Handlers and the OOCC; and
- clarifying in the standards how laboratory margin of error should be addressed when reporting results.

INTRODUCTION

The Olive Oil Commission of California contracted with the UC Davis Olive Center to analyze the quality-testing results for oils produced during the 2015/16 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 plan 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 specify the sampling protocols or require laboratory accreditation for Handler testing. Classification of the oils is based on the quality standards and grades summarized in Table 1 and further 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
K232 Ultraviolet Absorbance (UV) $K^{1\%}_{1cm}$	≤2.40	≤2.60	>2.60
K270 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)	MeD=0.0	MeD≤2.5	MeD>2.5
Median of Fruity (MeF)	MeF>0.0	MeF>0.0	MeF: N/A

SAMPLE INFORMATION

A total of 180 samples were tested for the 2015/16 season: 49 samples were collected by the OOCC and 131 were collected by 12 Handlers. The OOCC samples were collected by CDFA officials from Handler lots and sent to the Australian Oils Research Laboratory in Wagga Wagga, New South Wales. Based on matching lot numbers, UC Davis was able to determine that 41 of the Handler samples were from the same lots tested by the OOCC. Handler sampling dates ranged from October 14, 2015 to March 1, 2016, but not all Handlers provided this information. Each Handler sent samples to a laboratory and sensory panel of their choice – California standards do not specify that the laboratory or sensory panel require accreditation.

[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.

Handler samples included information on olive varieties in the samples, but the OOCC samples did not include this information. Given that 41 of 49 OOCC samples were from lots also sampled by Handlers, the study team was 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. Taken together, 81 percent of the samples (146 of 180 samples) were single-variety, 8 percent (14 samples) were blends, 2 percent (3 samples) were vaguely identified and 9 percent (17 samples) were unidentified.

Table 2. Samples by variety or blend (180 samples)

Variety	*OOCC Samples*	*Handler Samples*	*Total # (%) Samples*
Arbequina	12	43	55 (30.5)
Arbosana	9	24	33 (18.3)
Ascolano	0	2	2 (1.1)
Barnea	0	1	1 (.06)
Coratina	1	2	3 (1.7)
Don Carlo	0	1	1 (0.6)
Favolosa	0	1	1 (0.6)
Frantoio	1	4	5 (2.8)
Hojiblanca	0	1	1 (0.6)
"Italian"	0	2	2 (1.1)
Koroneiki	6	9	15 (8.3)
Leccino	0	4	4 (2.2)
Manzanillo	0	5	5 (2.8)
Mission	2	5	7 (3.9)
Moraiolo	1	1	2 (1.1)
Pendolino	0	1	1 (0.6)
Picual	0	2	2 (1.1)
Sevillano	2	5	7 (3.9)
"Spanish"	0	1	1 (0.6)
Taggiasca	0	1	1 (0.6)
Blends	5	9	14 (7.8)
Unidentified	10	7	17 (9.4)
TOTAL	49	131	180 (100)

Fifty-nine percent of the 180 samples (106 samples) were from super-high-density varieties that are the most widely planted in the state (Arbequina, Arbosana, Koroneiki and blends); 14 percent (25 samples) were from traditional varieties that have been grown in California for more than a century (Mission, Manzanillo, Sevillano, Ascolano, and blends); 9 percent (17 samples) were from Italian varieties that have been planted in California primarily in the past 25 years (Frantoio, Leccino, Moraiolo, Pendolino, Taggiasca and blends); 5 percent (9 samples) were from varieties that have been planted in California mainly in the past few years (Coratina, Barnea, Don Carlo, Favolosa, Picual and Hojiblanca), 3 percent (6 samples) were either vaguely identified or were blends that do not fit in the above categories and 9 percent (17 samples) were unidentified.

Handlers identified 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 41 of the OOCC's 49 samples were 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 157 of the 180 samples (40 of 49 OOCC samples and 117 of 131 Handler samples) were designated as EVOO prior to testing, with 15 samples designated as a lower grade, and with 8 samples with unidentified grade.

RESULTS FOR QUALITY TESTS

Test results showed that all samples designated by Handlers as EVOO prior to testing met California standards for EVOO grade with one caveat: there were two samples that were designated and tested as EVOO grade by Handlers but the same lots were tested as Virgin grade by the OOCC. These samples are discussed later in the report.

In total, 164 of 180 samples met California standards for EVOO grade: 45 of 49 OOCC samples and 119 of 131 Handler samples. Table 3 shows the average values for the samples tested as EVOO grade and Table 4 shows the 16 samples tested as non-EVOO grade. Table 3 indicates that the EVOO samples were well within the limits of California standards, which would be expected as these oils were tested early in the season. The low standard deviations indicate that results from different producers did not deviate much from the average. Table 4 indicates that Handlers were largely accurate in their indications of non-EVOO grades prior to testing, even if several samples were indicated to be “not Virgin” or “second extraction” rather than as “Crude,” the grade identified in California standards.

Table 3. Summary of quality testing results for EVOO samples (164 of 180 samples)

Test (CA EVOO Standard)	*Average Value*	*Standard Deviation*
Free Fatty Acidity (≤0.5)	0.2	0.1
Peroxide Value (≤15.0)	5.9	2.9
UV K232 (≤2.40)	1.77	0.21
UV K270 (≤0.22)	0.12	0.03
UV ΔK (≤/0.01/)	<0.003	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)	88	6
Organoleptic (MeF>0)	4.4	0.7

Table 4. Summary of quality testing results for non-EVOO samples (16 of 180 samples)

Sample ID	*FFA ≤0.5*	*PV ≤15.0*	*K232 ≤2.40*	*K270 ≤0.22*	*ΔK ≤0.01*	*Moist. & Volatile Matter ≤0.2*	*Organo-leptic MeD=0*	*Handler Assumed Grade*	*Tested Grade*	*Possible Cause of lower grade*
OOCC SAMPLES										
15/111-01	--	--	--	--	--	--	F/MS=2.0* 0**	EVOO	Virgin* EVOO**	1
3035	0.7 *	--	--	--	--	--	--	EVOO	Virgin* EVOO**	2
803A47/48	--	--	--	--	--	--	F/MS=2.6	--	Crude	1
3145	--	20.0	--	--	--	--	--	Virgin	Virgin	3
HANDLER SAMPLES										
22929 (A)	0.7	--	--	--	--	--	2.4	Virgin	Virgin	2,4
03357 (A)	--	--	--	--	--	--	1.5	Virgin	Virgin	4
22986 (A)	0.7	--	--	--	--	--	2.3	Virgin	Virgin	2,3
22987 (A)	--	--	--	--	--	--	2.2	Virgin	Virgin	4
22921 (A)	--	--	--	--	--	--	1.7	Virgin	Virgin	4
n/a (C)	1.0	26.0	4.79	0.34	--	n/a	n/a	"Not virgin"	Crude	2,3
n/a (C)	0.8	24.0	5.95	0.37	-0.02	n/a	n/a	"Not virgin"	Crude	2,3
n/a (C)	0.6	26.6	2.68	0.29	--	n/a	n/a	"Not virgin"	Crude	2,3
n/a (C)	0.8	25.9	4.55	0.36	--	n/a	n/a	"Not virgin"	Crude	2,3
3146 (E)	--	18.7	--	--	--	--	--	Virgin	Virgin	3
3093 (E)	--	18.0	2.80	--	--	--	--	Virgin	Crude	3
15/146-01 (Q)	--	--	--	0.23	--	0.3	--	"Second extraction"	Crude	3,5

-- Data not provided
F/MS Fusty/Muddy Sediment
* When tested by OOCC
** When tested by Handler
[1] Olives had fermented or undergone hydrolysis prior to processing or oil was stored on sediment for extended period (indicated by F/MS defect)
[2] Olives had fermented or undergone hydrolysis prior to processing (indicated by elevated FFA)
[3] Oil had become oxidized (indicated by elevated PV, K232 and K270)
[4] Organoleptic defect not identified so cause of defect undeterminable
[5] Excessive moisture and volatile matter caused by improper extraction methods

There are two instances in which the test results for the OOCC and Handler did not agree for the same samples. As shown in Table 5, in both cases OOCC testing showed the sample was Virgin grade and the Handler testing showed that the sample was EVOO grade. The OOCC and Handler test results differ significantly for the two samples, with the first sample having a large discrepancy in median of defect, and the second sample having a wide difference in the FFA result. These discrepancies may relate to how California standards have different requirements for OOCC and Handlers: the OOCC must follow ISO requirements for sampling and must be tested by an accredited laboratory, while Handlers do not need to follow ISO protocols nor do Handlers need to have samples tested by an accredited laboratory and sensory panel.

Table 5. Lack of agreement in OOCC and Handler testing of samples from the same lots (2 samples)

	Sample ID	FFA (≤0.5)	Organoleptic (MeD=0)	Claimed Grade	Tested Grade
OOCC	15/111-01		Fusty/Muddy Sediment = 2.0	n/a	Virgin
Handler	Q 15/111-01		0.0	EVOO	EVOO
OOCC	3035	0.66		n/a	Virgin
Handler	D YUM 3035-2015	0.10		EVOO	EVOO

A total of 27 samples did not provide data for all of the quality tests required in California standards, as summarized in Table 6. While a Handler might be reluctant to incur the costs of all quality tests if the Handler thought a lot was below EVOO grade, Table 6 shows that Handlers had designated 23 of the 27 samples as EVOO prior to testing.

Table 6. Number of samples that were not subjected to all tests

Handler	*Samples*	*Moisture & volatile matter*	*Insoluble impurities*	*PPP*	*DAGs*	*Organoleptic*	*Designated as EVOO pre-test*
C	4	0	0	0	0	0	0
I	3	0	0	0	0	3	3
K	2	0	0	2	1	2	2
S	4	4	0	4	4	0	4
T	14	0	0	0	0	0	14
TOTAL	27	4	0	6	5	5	23

On the following pages, Charts 1-7 show the results for quality tests for the 71 samples tested in the 2015/16 Season and the 30 samples tested in the 2014/15 Season. Charts for ΔK, moisture and volatile matter and insoluble Impurities are not included because there were negligible differences among the samples. The x-axis, which is unlabeled, provides OOCC and Handler data and does not reflect dates of harvest, sampling or testing. The samples that were outside of the California standard for EVOO grade were all designated as below EVOO grade by Handlers prior to testing. While the charts suggest better quality oils in the 2015/16 Season over the 2014/15 Season, with lower FFA, lower PPP, and higher DAGs, it is not possible to draw this conclusion without knowing the harvest, sampling and testing dates of the samples.

Chart 1. Free fatty acidity results in 2015/16 season (L) and 2014/15 season (R)

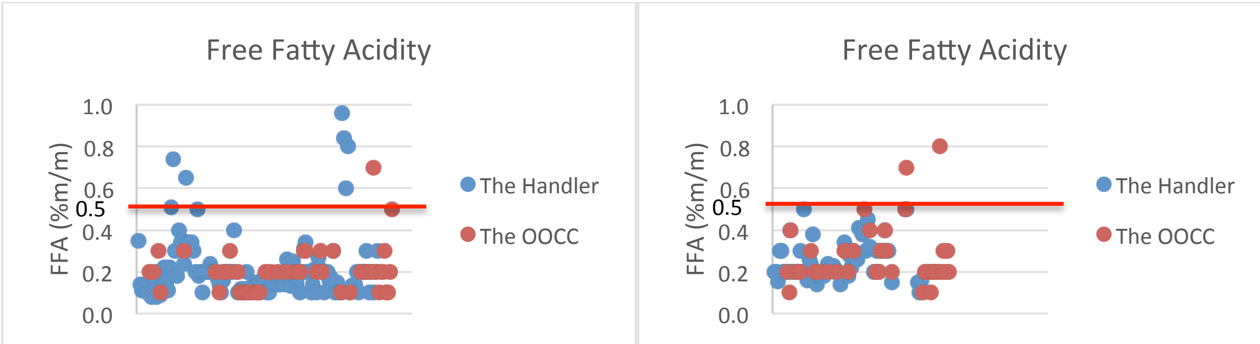


Chart 2. Peroxide values results in 2015/16 Season and 2014/15 Season

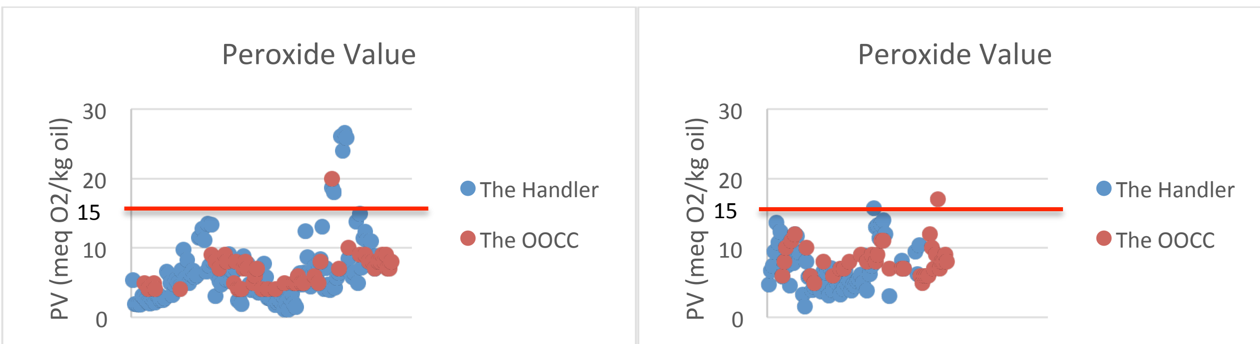


Chart 3. Ultraviolet value K232 results in 2015/16 Season and 2014/15 Season

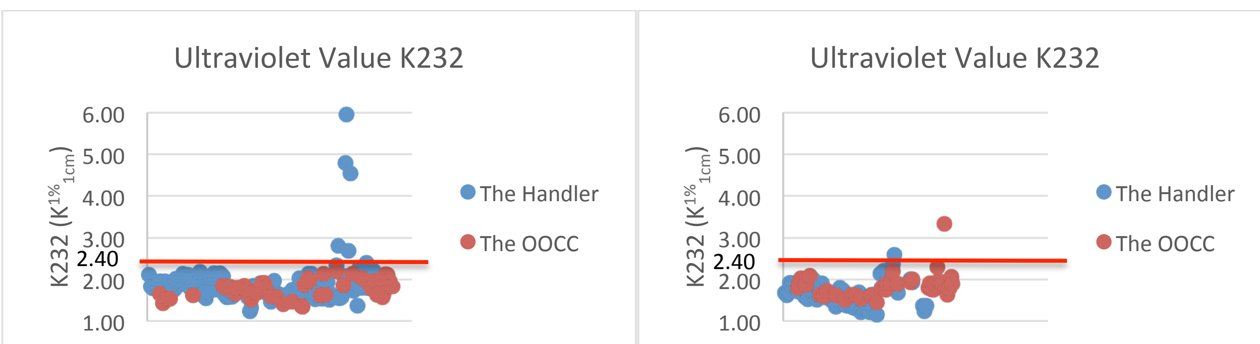


Chart 4. Ultraviolet value K270 results in 2015/16 Season and 2014/15 Season

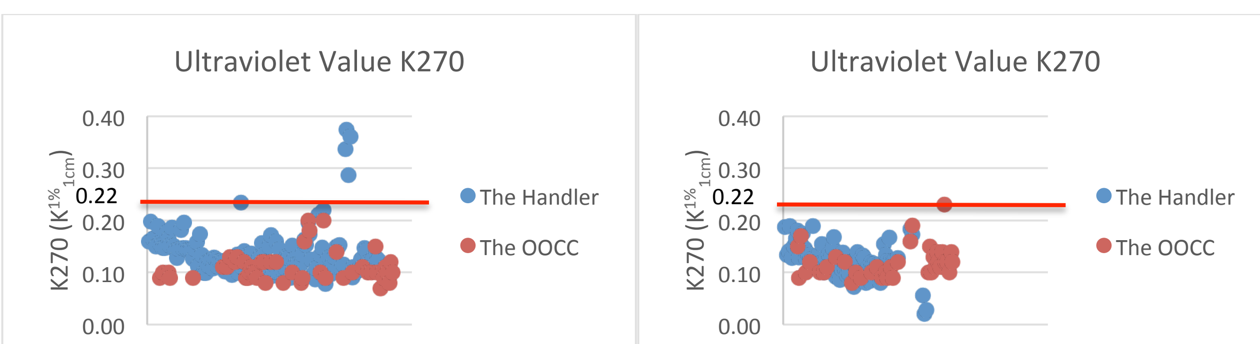


Chart 5. Pyropheophytin a results in 2015/16 Season and 2014/15 Season

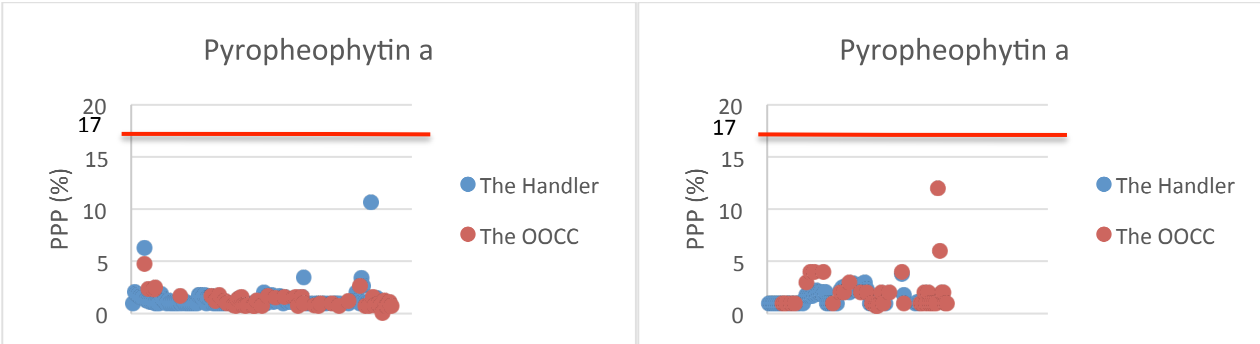


Chart 6. 1, 2 Diacylglycerols results in 2015/16 Season and 2014/15 Season

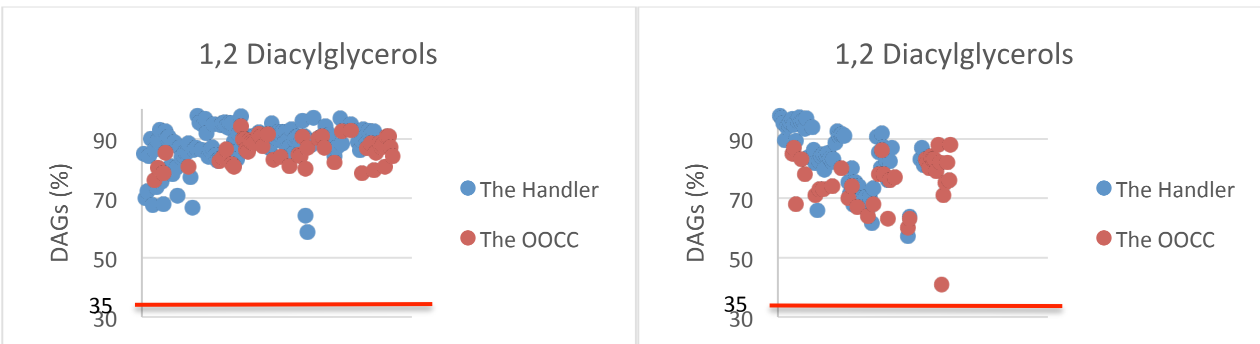
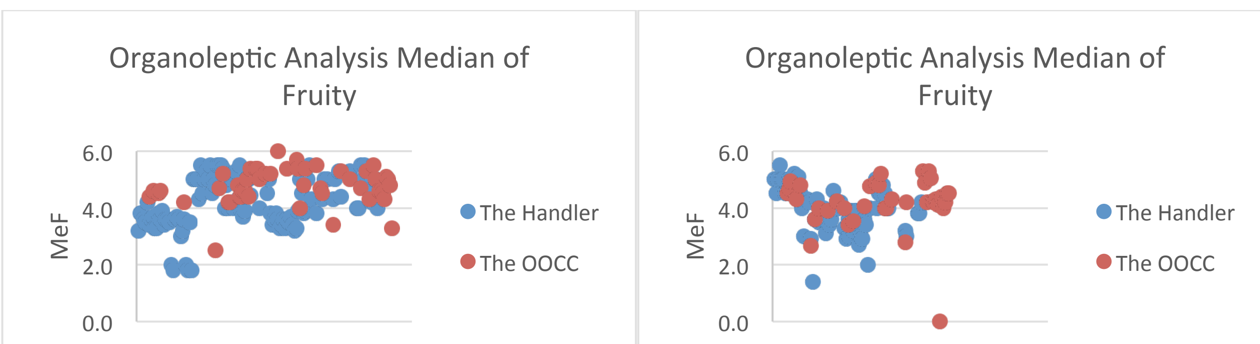


Chart 7. Organoleptic analysis (MeF) results in 2015/16 Season and 2014/15 Season



RESULTS FOR PURITY TESTS

Twenty of the 49 OOCC samples were analyzed by the Australian Oils Research Laboratory based on the purity tests required in California. All samples were within parameters in the standards for all purity tests, including in the following cases when laboratory margin of error is considered:

- 15 of the samples tested above the limit of 0.05 for trans fatty acid content (C18:2 T and C18:3 T), however the laboratory margin of error of 0.054 would permit all of these samples to conform with standards. Trans fatty acids are indication of heating or refining, however, very trace amounts can be found in extra virgin olive oil. In a survey of Australian olive cultivars meeting international standards, the average trans fatty acid content for Arbequina and Koreneiki were 0.02 and 0.01, respectively.[4]

- One sample, variety unknown, had total sterol content of 986, just below the minimum of 1000 for total sterols, however, the laboratory margin of error of 40 would permit the sample to conform to the standard. While fruit maturity can affect the total sterol content, climate and variety generally play a more influential role. Cooler climate tends to give lower level of total sterols. Koroneiki tends to have lower level of total sterols whereas Arbequina tends to have a higher level of total sterols.[5]

CONCLUSIONS AND RECOMMENDATIONS

- All samples that were designated by Handlers as EVOO prior to testing were ultimately graded as EVOO after testing. For samples graded as EVOO, the average values for the quality tests were well within the limits of California standards, which would be expected given that the oils were relatively fresh. The OOCC may wish to consider also testing oils after bottling and storage to assess the shelf life of California olive oils.

- 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 should require the third-party sampling agency to report this information in the future.

- Some Handlers did not complete all of the tests required in California standards, designate lots by the appropriate grades, or specify varieties by proper names. In addition, none of the Handlers reported harvest and processing dates and few reported sampling and testing dates, all of which would provide useful information on olive oil quality. The OOCC should require Handlers to retest any lot that does not include all tests required by the standard, and provide additional guidance to Handlers to increase accuracy and completeness in reporting and testing.

- The OOCC and Handlers received different grades for the same lots in two instances. The OOCC must clarify the standard to ensure that Handlers use laboratories that are proficient for all tests and that laboratories provide precision, accuracy and margin of error with test results.

- Handlers designated some lots as below EVOO grade prior to testing, and it may be unnecessary for Handlers to incur full testing costs for these lots. Given that California standards do not designate DAGs and PPP limits for grades below EVOO, the Commission should make DAGs and PPP optional for lots designated prior to testing as below EVOO grade, unless the lot meets EVOO standards for all other quality tests.

- All tested samples met the purity parameters in California standards when laboratory margin of error was considered. The use of margin of error is not addressed in California standards. The Commission needs to clarify in the standards how laboratory margin of error should be addressed when reporting results.

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[4]Mailer, R. J., Ayton, J. (2008) A survey of Australian olive cultivars to determine compliance with international standards, *RIRDC Pub No 08/167*.

[5]Ibid.

APPENDIX

Table 6. Quality tests in California olive oil standards

Test	Determination	Indicator
Free Fatty Acidity (FFA) *%m/m expressed as oleic acid*	Free fatty acids are formed by hydrolysis from the triacylglycerols in olives that are damaged or improperly stored before processing. Free fatty acidity is determined by a titration of sodium hydroxide solution that neutralizes the acidity.	Elevated FFA indicates poor-quality/damaged fruit, fermentation of olives prior to processing, or prolonged contact between the oil and vegetable water. A high level of FFA at bottling means shorter shelf life for the oil.
Peroxide Value (PV) *meq. O_2/kg oil*	Peroxides are primary oxidation products that form when oils are exposed to oxygen, high temperature, or light. This chemical reaction leads to rancidity in oils. However, as oxidation advances and secondary oxidation products are formed, peroxides are degraded and the level of PV decreases. Peroxide value is determined by a titration that releases iodine from potassium iodide.	Elevated PV indicates oxidized oil from oxidized and/or poor-quality fruit, prolonged fruit storage before processing, or improper storage of the oil. A high level of PV at bottling means shorter shelf life for the oil. PV decreases with time, so a low PV does not necessarily indicate the freshness of an oil.
Ultraviolet Absorbance (UV) $K^{1\%}_{1cm}$	The ultraviolet light absorbance is determined by applying UV light through the oil at specific wavelengths. Absorbance at 232 nm (K_{232}) indicates the primary oxidation level, while absorbance at 270 nm (K_{270}) indicates the secondary oxidation level. ΔK detects oil treatments with color-removing substances and the presence of refined/pomace oil.	Elevated UV indicates oxidized, poor-quality, and/or adulterated oil. Because this method measures the changes in the fatty acid structure, oxidation that occurs due to aging or refining would increase the values.
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.
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.
Pyropheophytin a (PPP) *% total pheophytins*	Pyropheophytins are the thermal degradation products of chlorophyll formed during olive oil storage, especially under elevated temperature and light exposure. Chlorophyll converts to pheophytins and ultimately to pyropheophytins. Pyropheophytin is determined by the ratio of pyropheophytin a to the sum of pheophytins and pyropheophytin a.	PPP increases with exposure of the oil to high temperature and is therefore indicative of refined and deodorized oil. PPP can be influenced by the storage conditions.
1,2–Diacylglycerols (DAGs) *% total 1,2- and 1,3-diacylglycerols*	As oil ages, or undergoes heat treatment, fatty acids on the triacylglycerol can break off from hydrolysis to form 1,2-diacylglycerols. Over time, these molecules equilibrate to form 1,3-diacylglycerols. DAGs is determined by the ratio of 1,2-diacylglycerols to the sum of 1,2- and 1,3-diacylglycerols.	DAGs decrease with time. A low ratio of 1,2-diacylglycerols to 1,2- and 1,3-diacylglycerols indicates oil that is hydrolyzed, oxidized, of poor quality, and/or adulterated with refined oil.
Organoleptic *Median of Defects (MeD) Median of Fruity (MeF)*	A trained panel of at least eight tasters determines flavor and aroma intensity of positive attributes (fruity, bitter, and pungent) and defective attributes (such as rancid, fusty, and musty.)	The absence of fruitiness and presence of defective attributes indicates oil made from substandard fruit, processing, and/or storage.