Off-the-Shelf Survey of California Olive Oil in the Marketplace 2020

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UC DAVIS
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Off-the-shelf survey of California olive oil in the marketplace

SUMMARY

To differentiate California olive oil from competitors and encourage transparent communication with consumers, the Olive Oil Commission of California (OOCC) has made the declaration of a use-by-date on olive oil packaging mandatory for its members and requested the use-by-date must be supported by technical evidence since the 2019-20 harvest[1]. The OOCC contracted with the UC Davis Olive Center to collect 50 California extra virgin olive oil samples from retail outlets, analyze the laboratory results and prepare this report, and with Eurofins Central Analytical Laboratories (ECAL) to perform chemical and sensory tests of the samples.

All 50 samples were labelled Extra Virgin from the 2019 harvest except for two from the 2018 harvest. Of the samples collected (42 samples from 12 mandatory members; four samples from four voluntary members; and four private label samples), 36 samples (72 percent) met Extra Virgin grade, 13 samples (26 percent) were tested as Virgin grade, and one sample (2 percent) was tested as Crude grade. Of the 14 non-extra virgin samples, 11 virgin samples did not meet California Extra Virgin grade solely because the samples had sensory defects (nine had rancid defects and two had both rancid and fusty/muddy-sediment defects); two virgin samples failed both chemistry and sensory standards; and one sample was tested crude because of the high K_{232} value.

Forty-seven samples (94 percent) had use-by-date information on the label, one sample (2 percent) from a voluntary member purchased in a tasting room was missing use-by-date information on the label but a tasting room staff confirmed the use-by-date onsite, and two samples (4 percent) from a mandatory member collected in two traditional stores did not have any use-by-date listed on the label. Of the 48 samples that had use-by-date information, three samples (two from a mandatory member and one from a voluntary member) had no harvest year information but the study team was able to collect this information by contacting the specific OOCC members.

Samples were in dark glasses (42 samples), clear glasses with large wrap labels (2 samples), tinplate containers (2 samples), bag-in-boxes (2 samples) or pantry pouches (2 samples), which were favorable containers that protected the oil from light and oxygen permeation.

According to the recommendation by the OOCC for shelf-life prediction, the estimated use-by-date of each sample during its stated shelf life was calculated based on the Modern Olives model[2]. Of the 36 extra virgin samples (excluding two samples missing use-by-dates), the month difference between the calculated and the labeled shelf life ranged from -15.4 to 18.0 months. Ten of the 36 samples (28 percent) had the month difference in the positive range, indicating these oils would likely remain Extra Virgin grade beyond their labeled use-by-dates under proper storage conditions while 24 extra virgin samples (67 percent) that were in the negative month difference range would likely not meet Extra Virgin grade by their labeled use-by-dates. Of the 14 non-extra virgin samples, 11 samples (79 percent) had the month difference in the negative range between -0.2 and -19.7 months, suggesting the quality would continue to fall further from extra virgin before their labeled use by dates.

[1] Olive Oil Commission of California (2020). Guidance Document for Determining Best By Date.

[2] Guillaume, C., & Ravetti, L. (2016). Shelf-life prediction of extra virgin olive oils using an empirical model based on standard quality tests. *Journal of Chemistry*, *2016*.

In future off-the-shelf surveys, the OOCC may wish to consider:

- continuing sampling OOCC-member oils so a consistent methodology is carried out to ensure proper evaluations of samples in the marketplace;

- communicating with the specific member whose samples failed Extra Virgin grade in multiple years' surveys and require records of fruit conditions and storage conditions showing the oil lots were properly conserved prior to being released into the supply chain to help the member assess the possible cause(s) for quality degradation;

- immediately alerting an OOCC member when a sample collected from the member through the commission's mandatory government sampling and testing program does not meet or have abnormal value(s) which are too close to the lower/upper limits of California olive oil standard for Extra Virgin grade so the member can adjust the sample's shelf life accordingly; and

- ensuring the inclusion of lot numbers on packaging for the purpose of tracking product quality. This information was missing on samples from two mandatory members and all four voluntary members. Half of the voluntary members had oils that failed Extra Virgin grade this year.

METHODOLOGY

In the 2019/20 season, there were 14 mandatory members[3] and six voluntary members[4] participating in the OOCC's mandatory government sampling and testing program. For the 2020/21 off-the-shelf survey, the OOCC Grades & Standards Committee and Subcommittee requested sampling 50 extra virgin olive oil (on label) produced by OOCC members and from private labels that were likely or confirmed to be produced by OOCC members.

In November 2020, the study team went to various types of retail outlets in the Bay Area (California, US) and nearby cities to collect as many OOCC-member olive oil samples as possible. Forty-six samples produced by 11 mandatory members and four voluntary members were collected from 10 traditional grocery stores, three specialty stores, two tasting rooms, two supercenters, and one café on November 7 and November 14, respectively. Three OOCC-member samples and one private label sample were ordered online and via Instacart from a club/warehouse store in Southern California, respectively, due to their lack of availability in the stores visited.

Of the 50 olive oil samples, 42 samples were from 12 mandatory members, four samples were from four voluntary members, and four samples came from private labels that were likely or confirmed to be produced by OOCC members (one sample had an OOCC logo on the label). The number of samples collected from each OOCC member was estimated proportionally to their 2019/20 annual production reported to the OOCC mandatory government sampling and testing program. For members who carried multiple stock-keeping units (SKU), the study team tried to include different SKUs to ensure relatively

[3] California producers of 5,000 gallons or more of olive oil per year are required to participate in the OOCC mandatory government sampling and testing program by testing all lots of oil through a certified laboratory.

[4] Producers' annual olive oil volume does not exceed 5,000 gallons per year are technically exempt from the mandatory OOCC testing requirement but they can opt in the OOCC program on a voluntary basis.

comprehensive sampling. Samples from two mandatory and two voluntary members were not available in any retail outlet during the sampling. During the sample collection, the study team minimized the impact of heat and light by covering collected samples, parking in the shade and checking temperature inside the vehicle in between stops – the temperature did not exceed 74°F (23°C) during the two days of collection.

Depending on sample packaging size, which varied from 100 mL to 1 L containers, at least 600 mL of each sample from the same lot was obtained for chemical and sensory tests. Forty-six samples collected from physical stores were shipped overnight to ECAL by Eurofins Test America Laboratory in West Sacramento within 48 hours of collection while three online-ordered samples were delivered to the UC Davis Olive Center first, clearly labeled, and shipped overnight to ECAL. The sample obtained from Southern California was dropped off at Eurofins Microbiology Laboratories, Inc. in Garden Grove and overnighted to ECAL. All samples were stored below 65°F (18°C) at all locations prior to shipping.

ECAL holds International Organization for Standardization (ISO) 17025 Chemical Field of Testing accreditation, and is American Oil Chemists' Society (AOCS) approved for olive oil chemical and sensory tests. ECAL is also an International Olive Council (IOC) chemistry-approved laboratory for 2020/21[5]. Upon sample receipt in November, ECAL stored samples in an environmental chamber at approximately 65°F (18°C) until tests were conducted. Samples were tested based on California olive oil standards (Appendix Table 1). All chemical tests were completed within 14 days after receipt while sensory test completion time varied from seven days to 30 days due to sensory panel's in-person gathering being disrupted by COVID-19. Chemical and sensory retests were done on unopened retention samples within 21 days after the first round of test results when failed Extra Virgin standards were reported.

Comparisons of sampling from the off-the-shelf surveys in 2016/17, 2017/18 and 2020/21 are summarized in Table 1[6]. The number of OOCC members sampled (16 members) in the current study was significantly higher than that in previous studies (up to 8 members). The increased number of non-traditional stores in the 2020/21 study was due to limited availability or absence of certain OOCC members' products in traditional stores.

Table 1. Comparison of three studies in 2016/17, 2017/18 and 2020/21

STUDY SEASON	**2016/17**	**2017/18**	**2020/21**
NUMBER OF SAMPLES	50	50	50
NUMBER OF BRANDS	18	23	20
NUMBER OF OOCC MEMBERS SAMPLED[1]	8	7	16
NUMBER OF TRADITIONAL GROCERY STORES	7	7	10
NUMBER OF NON-TRADITIONAL STORES[2]	5	7	11
PERIOD OF SAMPLE COLLECTION	Nov 2016	Oct - Nov 2017	Nov 2020
LOT NUMBER VERIFICATION	Yes	Yes	Yes
RETESTING OF FAILED SAMPLES	Yes	Yes	Yes

[1] This number may not reflect OOCC members responsible for private label samples; [2] non-traditional stores include warehouse clubs, supercenters, and online stores, tasting rooms, café, delicatessens and specialty food stores.

[5] https://www.eurofinsus.com/food-testing/our-company/accreditations-programs/ecal/.

[6] (a) UC Davis Olive Center (2017). Evaluation of 50 California Olive Oil at Marketplaces 2016. (b) UC Davis Olive Center (2018). Evaluation of 50 California Olive Oil Samples at Least One Year after Harvest 2017.

STORE INFORMATION

In each store, the study team recorded the top, bottom, and sample shelf temperatures and illuminances using a hand-held Etekcity infrared thermometer and a LUX LED light meter[7], respectively, which provided a snapshot of the sample storage condition at the time of sampling. Temperatures and illuminances from two online stores and one warehouse in Southern California where the study team did not have physical access were not reported. As shown in Figure 1, the highest top shelf temperature was detected in café #1 at 75.9°F, followed by the second and the third highest top shelf temperatures found in two tasting rooms at 75.5°F and 72.5°F, respectively. Of the other 15 physical stores the study team visited, minimum temperatures at the bottom shelves ranged from 58.9°F to 71.6°F and maximum temperatures from the top shelves ranged from 60°F to 72.2°F. Lower illuminances were observed in retail outlets such as café, some specialty food stores, and tasting rooms where incandescent and fluorescent lamps are usually installed. Higher illuminances were detected in traditional stores and supercenters where LED lighting sources are more common. Illuminances highly depended on lighting source, height differences between store ceiling and shelves, and angles of lighting source to specific shelf locations. Thus, a much wider illuminance range was found from as low as 80 Lux (bottom shelf) to as high as 1436 Lux (top shelf) throughout sampled retail outlets. However, it is worth mentioning that compared to other lighting resources such as incandescent and fluorescent lamps, LEDs emit no infrared light and only small amount of ultraviolet (UV) which potentially reduce heat from lighting fixtures on food products[8].

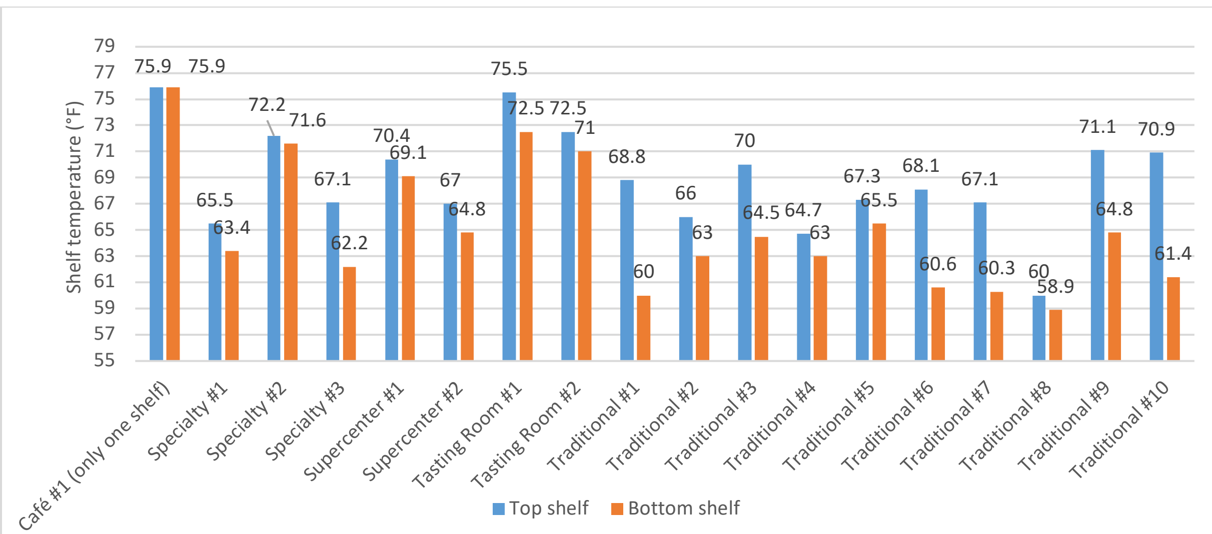

FIGURE 1. Temperature at shelf (°F)

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[7] A LUX LED light meter converts light to an electrical current. Measuring this current allows the device to calculate the lux value of the light it captured.

[8] ConTech Lighting (2018). Supermarket lighting design guide.

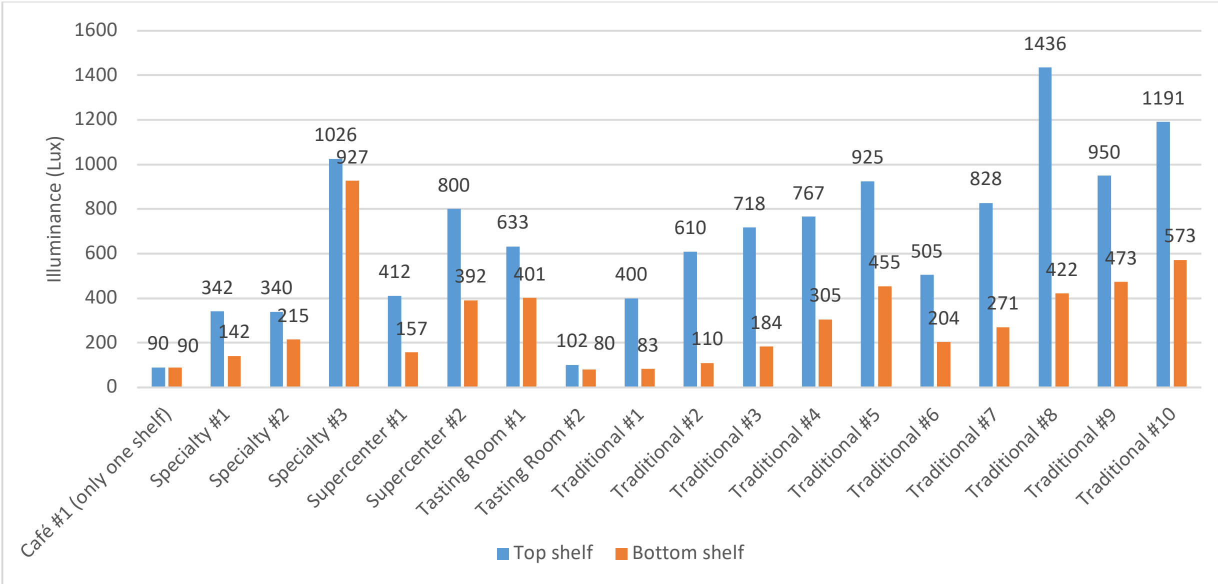

FIGURE 2. Illuminance at shelf (Lux)

Additionally, traditional grocery stores #1 and #6, #2 and #7, #3 and #9, and #5 and #8 were from the same supermarket chains located in different cities, respectively. As indicated in Figure 1, the shelf temperature ranges were mostly comparable between the two stores from the same chain. However, the minimum and maximum temperatures differed drastically between stores #5 and #8. Few olive oils, including two from an OOCC mandatory member, were displayed in the Produce section in a traditional supermarket chain where the temperatures were supposed to be lower. However, only one store location (traditional #7) had a lower temperature range of 54.9 to 56.6°F in the Produce section while the other location (traditional #2) had a temperature range of 65 to 66.7°F in the Produce section which was slightly higher than its normal shelf temperature range (63 to 66°F) for storing most olive oil products.

Within the same store, the higher the shelf, the higher the temperature and illuminance. Placement on the top shelf is undesirable because it typically has the highest temperature and the greatest exposure to light, which can hasten oil oxidation. Placement on the bottom shelf attracts the least consumer attention because it is physically difficult to reach, which can also lead to slower product turnover. Other than café #1 which only had one tall shelf, and two online stores and one warehouse club that the study team did not have store data, the number of shelves in each store bay varied between three and seven (Figure 3). Overall, 26 out of 45 samples (58 percent) were displayed on shelving locations at adult eye-level that was defined as the top two or three shelves in three- to six-shelf bays that were considered prominent[9].

[9] Young, L., Rosin, M., Jiang, Y., Grey, J., Vandevijvere, S., Waterlander, W., & Mhurchu, C. N. (2020). The effect of a shelf placement intervention on sales of healthier and less healthy breakfast cereals in supermarkets: A co-designed pilot study. Social Science & Medicine, 266, 113337.

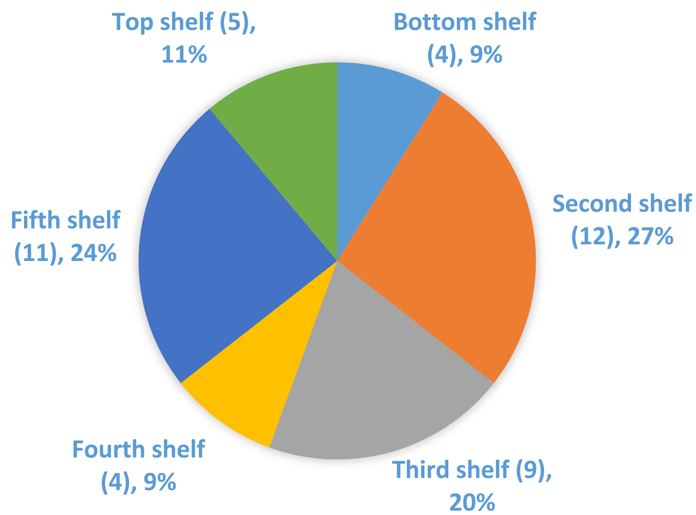

FIGURE 3. Shelving location where purchased samples (45 samples shown) were placed; number of samples in parentheses

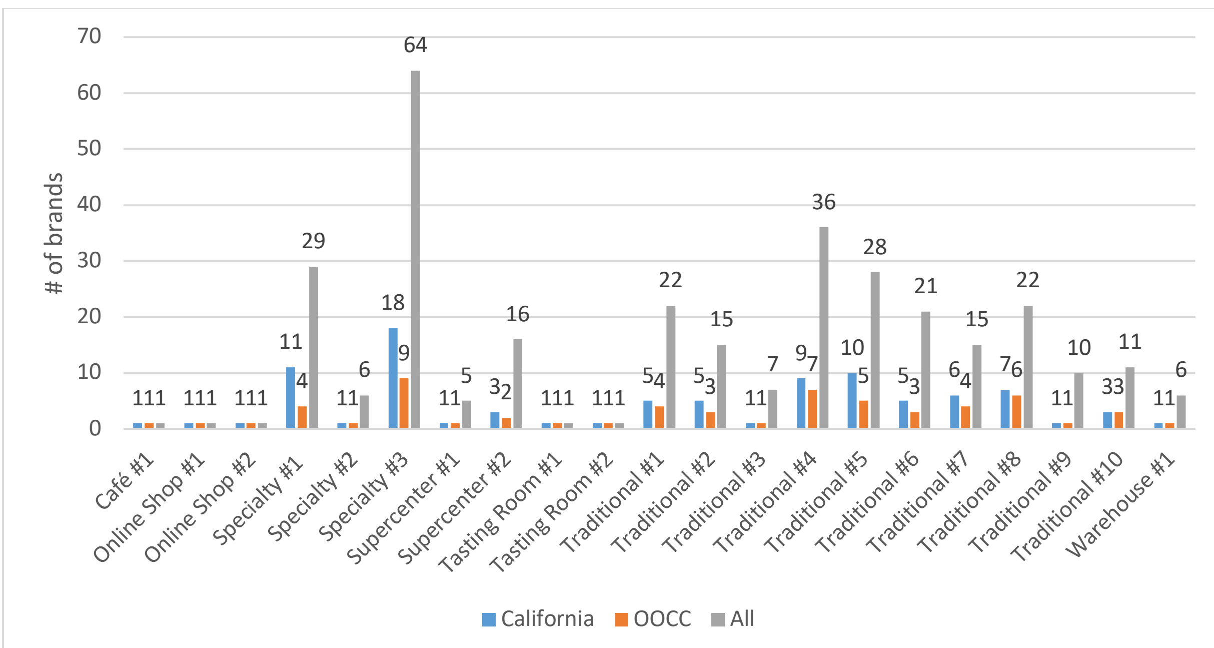

FIGURE 4. Number of olive oil brands at each store

Due COVID-19 constraints, the study team did not measure shelf inches in certain stores but was able to count the number of all olive oil brands, California-produced olive oil brands (including OOCC-member brands), and OOCC-member brands (including private labels that were likely or confirmed to be produced by OOCC members) at each store. As shown in Figure 4, specialty food stores usually carry a larger number of California and imported olive oil brands. Of the 64 olive oil brands found in specialty food store #3, there were nine OOCC brands and 18 California-produced olive oil brands (including OOCC-member brands), which were the highest numbers of California and OOCC brands among all the sampled stores. Traditional grocery stores which price on the higher end and promote healthy food purchase (e.g. traditional #4, #5, and #8) also provide a broader selection of olive oil brands. Overall, OOCC-member brands comprised 36 to 86 percent of California-produced brands and 10 to 27 percent of all olive oil brands, respectively, in stores that carried more than one olive oil brand.

CHEMISTRY AND SENSORY RESULTS

Of the 50 samples, including four private label samples, 72 percent (36 samples) met California Extra Virgin grade standards, 26 percent (13 samples) met the standards for Virgin grade while two percent (one sample) was tested as Crude grade.

Forty-eight samples were from the 2019 harvest year (one-year-old) while the remaining two samples were from the 2018 harvest year (two-year-old). The Extra Virgin rate for the 2019 harvest samples was 73 percent (35 of 48 samples) - highly comparable to those in previous studies: 77 percent in the 2017/18 study and 73 percent in the 2016/17 study[6ab].

Figure 5 summarizes the Extra Virgin passage rates for chemical and sensory tests of the 50 samples, indicating samples under OOCC brands and private labels (likely or confirmed to be produced by OOCC members) separately. Four private label samples (2019 harvest) passed all chemical tests at a 100 percent rate but two of them failed sensory test yielding a passage rate of 50 percent. Forty-six OOCC-brand samples passed chemical tests at rates exceeding 96 percent while passed the sensory test at a 76 percent rate.

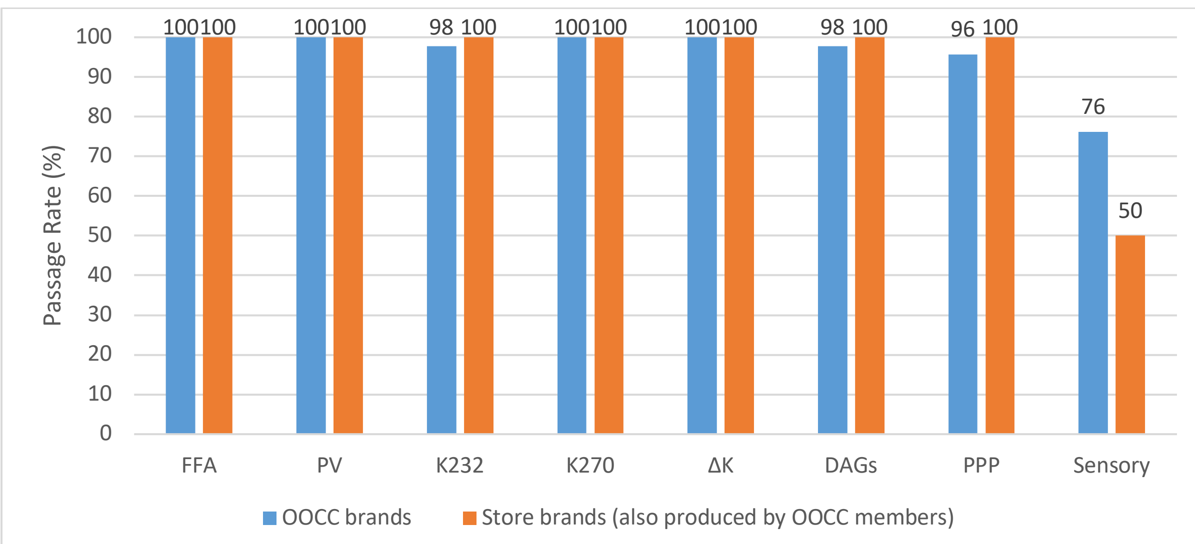

FIGURE 5. Passage rate for OOCC members and private labels (likely produced by OOCC members); CA EVOO standards (%)

The percentage of samples passing or failing each test is summarized in Figure 6. One-hundred percent of samples passed Extra Virgin standards for FFA, PV, K_{270} and ΔK; 98 percent passed the standards for K_{232} and DAGs and 96 percent passed the standard for PPP. The 74 percent sensory passage rate is similar to the 2016/17 study (80 percent) and the 2017/18 study (74 percent). Eleven of the 14 non-extra virgin samples did not meet California Extra Virgin grade solely because the samples did not pass the sensory test.

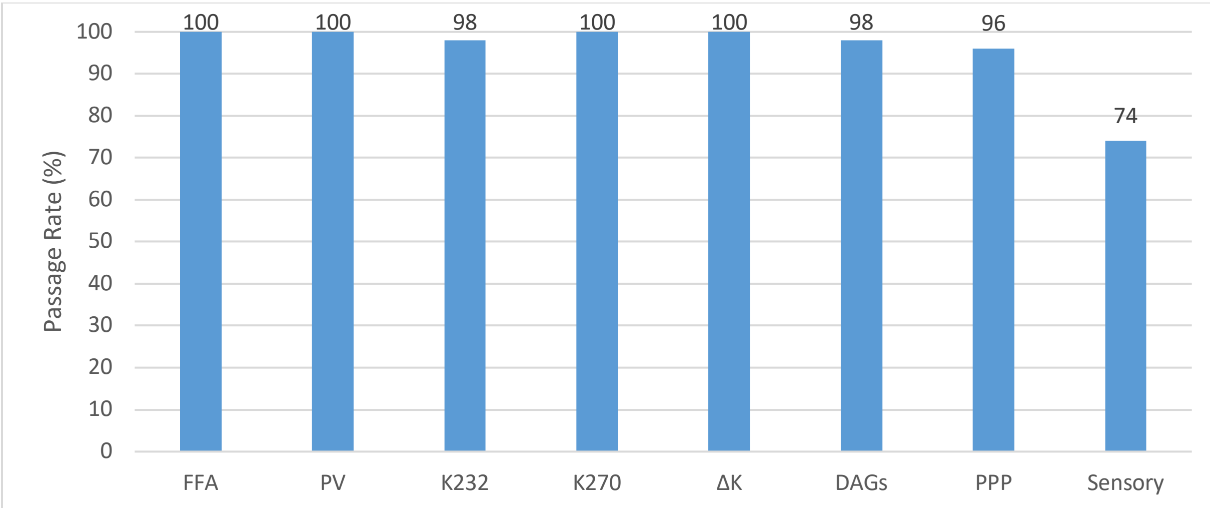

FIGURE 6. Passage rate for the 50 samples; CA EVOO standards (%)

Table 2 summarizes the shelving information in each store, and chemistry and sensory data for the 50 samples. Of the 14 samples not categorized as Extra Virgin grade, 13 met the California standard for Virgin grade (Samples 1, 2, 4, 7, 9, 13, 25, 27, 33, 37, 38, 41 and 49) and one was tested as Crude grade (Sample 46). Samples were in dark glasses (42 samples), clear glasses with large wrap labels (2 samples), tinplate containers (2 samples), bag-in-boxes (2 samples) or pantry pouches (2 samples), which were favorable containers that protected the oil from light and oxygen permeation. Lot numbers were missing from two mandatory members (five samples) and all four voluntary members (four samples). The distribution of chemistry results is summarized in Figures 7 – 11 and analyzed below. Sensory attributes are shown in Figure 12 and induction time is in Figure 13. The red line on each figure indicates the lower/upper limits of California olive oil standard for Extra Virgin grade.

TABLE 2. Store shelving information, and chemistry and sensory data for 50 samples

SAMPLE #	STORE CODE	SHELF POSITION	HARVEST YEAR	SHELF TEMPERATURE (F)	SHELF ILLUMINANCE (LUX)	FFA	PV	K_{232}	K_{270}	ΔK	DAGs	PPP	INDUCTION TIME	SENSORY DEFECTS	GRADE
						≤0.5	*≤15*	*≤2.40*	*≤0.22*	*≤0.01*	*≥35*	*≤17*	*N/A*	*MeD=0.0*	*Extra Virgin*
						≤1.0	*≤20*	*≤2.60*	*≤0.25*	*≤0.01*	*N/A*	*N/A*	*N/A*	*0.0<MeD≤2.5*	*Virgin*
						>1.0	*>20*	*>2.60*	*>0.25*	*≤0.01*	*N/A*	*N/A*	*N/A*	*MeD>2.5*	*Crude*
1	Traditional #1	6/6	2019	68.8	270	0.2	4	1.57	0.11	0.00	68	8	21.7	Rancid: 1, 0.8	Virgin
2	Traditional #1	5/6	2019	66.0	244	0.2	4	1.55	0.12	0.00	58	11	24.5	Rancid: 1.1, 0.5; Fusty/Muddy: 0.5, 1	Virgin
3	Traditional #1	5/6	2019	65.9	123	0.2	8	2.03	0.14	0.00	66	11	21.2		Extra virgin
4	Traditional #2	5/6	2019	66.0	341	0.1	4	1.62	0.10	0.00	65	9	20.6	Rancid: 0.9, 0.5	Virgin
5	Traditional #2	5/6	2019	66.0	293	0.2	4	1.69	0.11	0.00	59	11	22.4		Extra virgin
6	Traditional #2	2/7[1]	2019	66.7	201	0.2	6	1.82	0.16	0.00	74	7	38.5		Extra virgin
7	Traditional #3	1/4	2019	64.5	184	0.3	6	1.77	0.13	0.00	47	11	23.9	Rancid: 1, 0.8	Virgin
8	Specialty #1	3/5	2019	64.5	224	0.3	4	1.65	0.11	0.00	55	9	21.3		Extra virgin
9	Specialty #1	5/5	2019	65.5	156	0.2	7	1.76	0.11	0.00	65	11	19.2	Rancid: 0.9, 0.8	Virgin
10	Specialty #1	3/5	2019	64.7	230	0.1	8	1.96	0.13	0.00	73	9	21.8		Extra virgin
11	Specialty #1	3/5	2019	66.2	208	0.1	3	1.67	0.14	0.01	91	3	20.6		Extra virgin
12	Specialty #1	1/5	2019	64.6	142	0.2	6	1.81	0.12	0.00	58	10	20.0		Extra virgin
13	Specialty #1	1/5	2018	64.3	142	0.4	4	1.55	0.11	0.00	32	23	23.9	Rancid: 1.2, 0.5	Virgin
14	Traditional #4	2/6	2019	62.9	249	0.1	10	2.21	0.13	0.00	70	3	16.8		Extra virgin
15	Traditional #4	2/6	2019	64.0	314	0.4	6	1.90	0.15	0.00	43	8	32.2		Extra virgin
16	Traditional #4	5/6	2019	64.6	470	0.2	5	1.67	0.09	0.00	64	10	15.5		Extra virgin
17	Traditional #4	6/6	2018	64.6	750	0.1	7	2.10	0.14	0.00	74	6	30.9		Extra virgin
18	Traditional #4	5/6	2019	63.9	575	0.2	4	1.71	0.11	0.00	56	15	20.2		Extra virgin
19	Traditional #4	3/6	2019	64.5	311	0.2	5	1.89	0.12	0.00	58	10	20.3		Extra virgin
20	Traditional #4	5/6	2019	66.7	445	0.2	4	1.63	0.12	0.00	56	9	21.0		Extra virgin
21	Traditional #4	2/6	2019	62.8	344	0.2	8	1.91	0.11	0.00	59	15	17.8		Extra virgin
22	Traditional #4	3/6	2019	63.3	417	0.3	8	2.05	0.15	0.00	51	4	35.4		Extra virgin
23	Traditional #4	3/6	2019	63.5	318	0.2	7	1.84	0.12	0.00	58	17	21.7		Extra virgin
24	Supercenter #1	3/6	2019	69.7	233	0.2	6	1.71	0.11	0.00	59	12	15.7		Extra virgin
25	Specialty #2	3/6	2019	75.6	220	0.2	6	1.74	0.10	0.00	55	18	11.7	Fusty/Muddy: 1.8, 2	Virgin

26	Traditional #5	2/6	2019	66.0	709	0.2	7	1.74	0.12	0.00	58	14	20.8		Extra virgin
27	Traditional #5	2/6	2019	66.0	673	0.3	5	1.64	0.12	0.00	54	15	24.6	Rancid: 0.5, 0.5; Fusty/Muddy: 0.5, 0.5	Virgin
28	Traditional #5	6/6	2019	66.5	925	0.2	10	2.16	0.12	0.00	68	7	18.1		Extra virgin
29	Traditional #5	3/6	2019	66.3	915	0.3	7	1.89	0.14	0.00	50	11	31.6		Extra virgin
30	Traditional #5	5/6	2019	66.4	1036	0.2	6	1.83	0.12	0.00	58	10	21.8		Extra virgin
31	Traditional #5	2/6	2019	65.0	585	0.1	7	1.96	0.11	0.00	72	8	19.9		Extra virgin
32	Traditional #6	5/6	2019	67.3	346	0.1	7	2.06	0.12	0.00	62	13	21.3		Extra virgin
33	Traditional #7	4/6	2019	64.2	495	0.2	10	2.16	0.12	0.00	60	13	15.1	Rancid: 1.2, 0.5	Virgin
34	Traditional #7	3/3[1]	2019	56.6	463	0.1	6	1.82	0.16	0.00	74	9	38.9		Extra virgin
35	Specialty #3	2/5	2019	62.7	914	0.1	4	1.56	0.11	0.00	58	9	23.9		Extra virgin
36	Specialty #3	2/5	2019	62.7	918	0.2	4	1.64	0.12	0.00	53	10	21.4		Extra virgin
37	Specialty #3	4/5	2019	65.7	994	0.2	10	2.18	0.12	0.00	61	4	16.6	Rancid: 0.9, 0.5	Virgin
38	Specialty #3	4/5	2019	64.9	900	0.2	6	1.80	0.11	0.00	59	14	19.8	Rancid: 1.3, 0.5	Virgin
39	Traditional #8	4/6	2019	59.7	800	0.1	4	1.61	0.12	0.00	58	13	31.1		Extra virgin
40	Traditional #9	2/4	2019	66.2	330	0.2	4	1.61	0.11	0.00	57	12	23.6		Extra virgin
41	Traditional #10	5/6	2019	67.7	744	0.1	5	1.66	0.11	0.00	70	7	22.7	Rancid: 0.9, 0.5	Virgin
42	Supercenter #2	5/6	2019	66.3	455	0.2	7	1.79	0.15	0.00	63	12	21.9		Extra virgin
43	Tasting Room #1	2/3	2019	75.1	504	0.1	12	2.21	0.13	0.00	75	9	21.1		Extra virgin
44	Tasting Room #1	1/3	2019	72.5	401	0.1	7	2.05	0.13	0.00	77	9	26.6		Extra virgin
45	Tasting Room #2	2/4	2019	71.3	92	0.1	7	2.24	0.17	0.00	74	8	27.4		Extra virgin
46	Café #1	1/1[2]	2019	75.9	90	0.1	12	2.80	0.15	0.00	72	3	15.0		Crude
47	Online store #1	N/A[3]	2019	N/A	N/A	0.1	5	1.88	0.12	0.00	86	5	28.1		Extra virgin
48	Online store #2	N/A	2019	N/A	N/A	0.1	10	2.29	0.15	0.01	80	5	23.8		Extra virgin
49	Online store #2	N/A	2019	N/A	N/A	0.1	9	2.32	0.14	0.01	79	5	22.8	Rancid: 0.6, 0.5	Virgin
50	Warehouse #1	N/A	2019	N/A	N/A	0.1	3	1.50	0.10	0.00	68	8	24.6		Extra virgin

[1] Samples were displayed in the Produce section; [2] only one tall shelf for displaying olive oil; [3] N/A: information not available/not recorded.

Free fatty acids (FFA), which are flavorless, come from the breakdown of triacylglycerols through a chemical reaction called hydrolysis. Factors that can lead to a high FFA in an oil include poor quality of fruit, fruit fly infestation, diseases, delays between harvesting and milling, poor extraction methods and improper storage of the oil (such as on sediment).

As indicated in Figure 7, all 50 samples had FFA values within the California Extra Virgin grade of 0.5. Seven samples (Samples 7, 8, 13, 15, 22, 27 and 29) had FFA values equal to or greater than 0.3. Three (Samples 15, 22 and 29) of the seven samples were unfiltered and produced by the same OOCC member while another two samples (Samples 8 and 13) - also unfiltered and produced in two harvest years (2018 and 2019 harvests) - were from a different OOCC member. Oil stability highly depends on an oil's initial quality and its storage conditions. Filtration removes suspended solids and moisture in olive oil before storage and can help avoid excessive hydrolysis which increases FFA[10]. Generally, FFA values do not change substantially under proper storage conditions during natural aging of the oil.

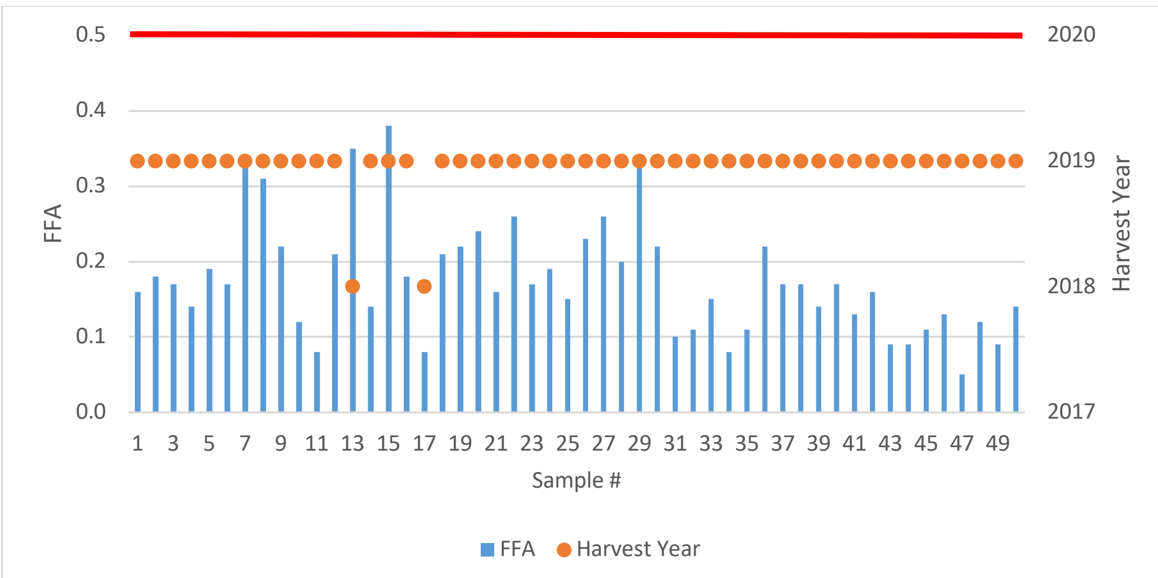

FIGURE 7. FFA (CA EVOO ≤ 0.5% as oleic acid)

Peroxide value (PV) is a crude measurement of initial oxidation in the oil. Oxidation can cause peroxides to transform into aldehydes and other compounds that are responsible for rancid flavors. Oxidation is a natural process and PV is expected to increase as the oil ages, although PV can later decrease as the primary oxidation products transform during secondary oxidation. High storage temperature and excessive light exposure can greatly hasten oil oxidation.

Figure 8 shows that all samples had PV below the California Extra Virgin grade of 15. The highest value of 12 was detected in Sample 46, and this sample also failed another oxidative parameter K_{232} at 2.80 thus was categorized as Crude grade. This 2019 harvest sample was exposed to the highest room temperature of 75.9°F (24.4°C) under fluorescent lights in the café among all sampled stores. Eight 2019 harvest samples (Samples 14, 28, 33, 37, 43, 46, 48 and 49) with PV over 9 also had K_{232} greater than 2.16 (CA EVOO K_{232} ≤ 2.40) and three of them (Samples 33, 37 and 49) had rancid defects. Six out of 12 rancid

[10] Ngai, C., & Wang, S. (2015). A Review of the Influence of Filtration on Extra Virgin Olive Oil.

samples had PV below 6 (usually found in relatively fresh olive oil less than six months old under proper storage conditions), which indicates the limitations of using PV alone for oil quality assessment.

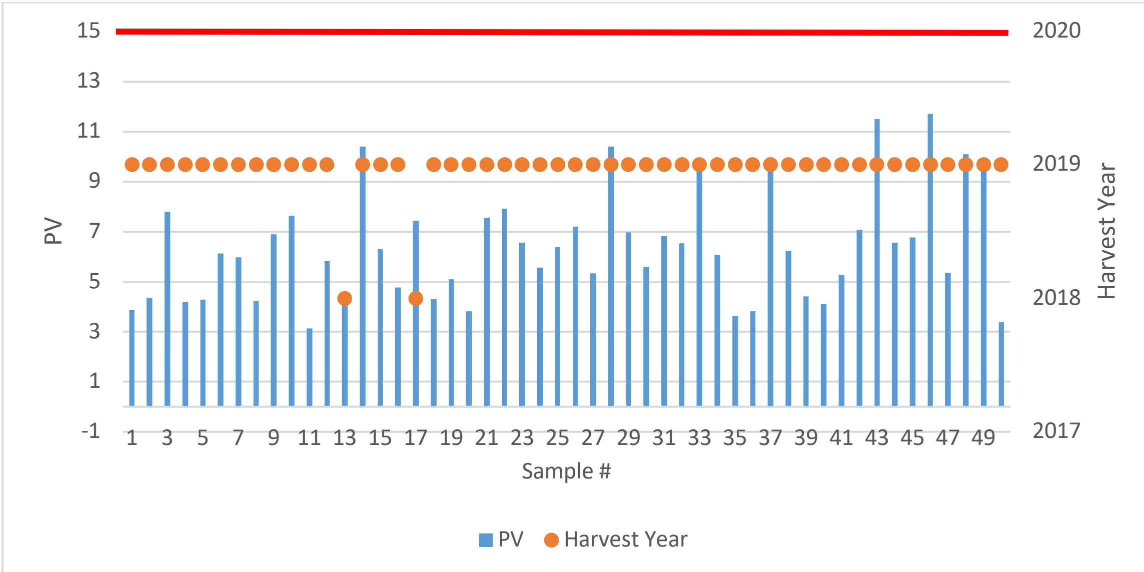

FIGURE 8. PV (CA EVOO ≤ 15 meq O_2/kg oil)

Ultraviolet Absorbance (UV) UV absorbance is used to identify oils that are oxidized (K_{232} and K_{270} /K_{268}) or contain refined/pomace oil (ΔK); it measures changes in the structure of fatty acids that occur during aging or heating of oil. K_{232} measures initial oxidation products in the oil, similar to PV. K_{270} (or K_{268}) measures secondary oxidation products when oxidation has advanced past initial oxidation. ΔK measures the difference between the absorbance at 270 nm and 266-274 nm, and is a useful indicator in detecting the presence of refined/pomace oil.

As shown in Figure 9B, all samples were well below the California Extra Virgin grade for K_{270} (or K_{268}) at 0.22, indicating overall a low level of secondary oxidation had occurred for all 50 samples. Nine samples (Samples 14, 28, 33, 37, 43, 45, 46, 48 and 49) had K_{232} greater than 2.15 (Figure 9A), including Sample 46 that had a K_{232} value of 2.80 which placed the sample in Crude grade. Seven of these nine samples (2019 harvest) also had PV over 10 which well correlated with their relatively high K_{232} values; both oxidative parameters primarily measure initial oxidation in the oil. Of the nine samples, three were from a mandatory member whose oils had constantly shown elevated K_{232} and PV in previous years[6]; two were from another mandatory member whose oils were included in the off-the-shelf survey for the first time; and the remaining four samples were from tasting rooms, café, and private labels. As shown in Figure 1 and Table 2, tasting rooms and café generally had higher temperatures compared to other retail outlets. The K_{232} results suggested that these samples had undergone elevated oxidation than other samples that may be caused by suboptimal storage or transportation conditions. All samples were within the California Extra Virgin standard for ΔK at 0.01 (Table 2), suggesting no refined oil found in collected samples.

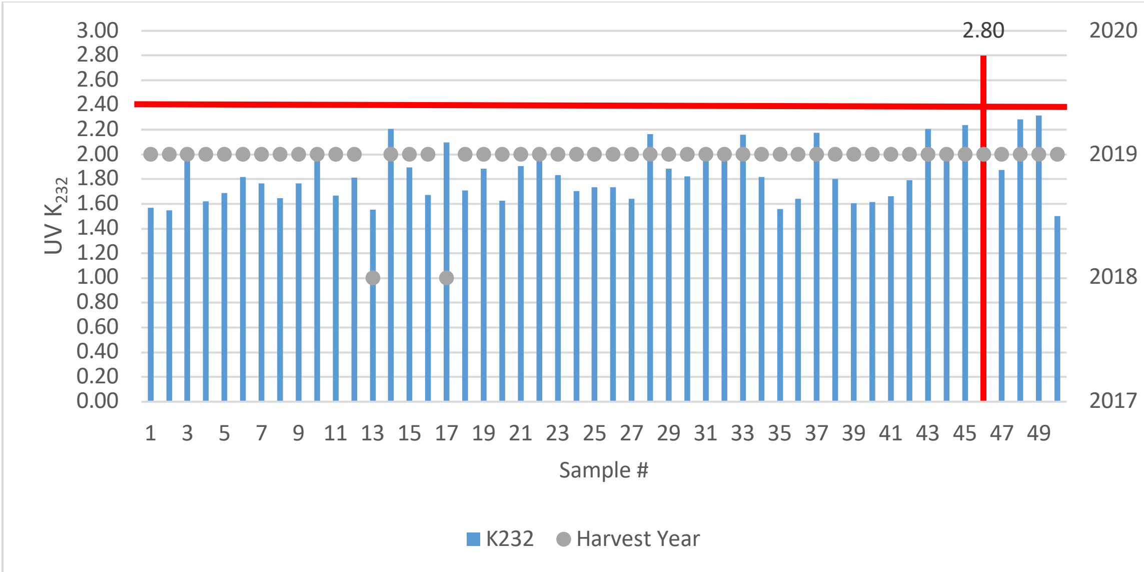

FIGURE 9A. UV K_{232} (CA EVOO ≤ 2.40 $K^{1\%}_{1cm}$)

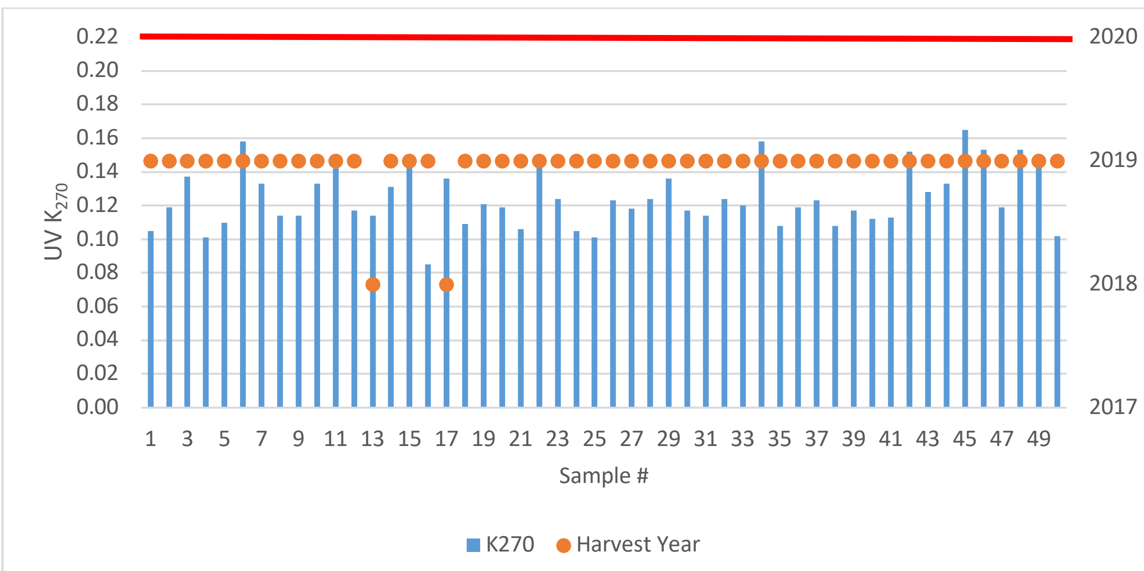

FIGURE 9B. UV K_{270} (CA EVOO ≤ 0.22 $K^{1\%}_{1cm}$)

Diacyglycerols (DAGs) are formed when a triacylglycerol molecule undergoes hydrolysis. The resulting DAG contains two fatty acids on a glycerol backbone in a 1,2 position. As oil ages or is heated, these molecules equilibrate, in a predictable and linear manner, to a 1,3 position. The DAGs test assesses the extent of aging or heating by analyzing the ratio of 1,2 and 1,3 DAGs. DAGs are also related to the hydrolysis reaction, in a manner similar to FFA, and therefore can be affected by the quality of olives and post-harvest practices. A fresh high-quality oil typically has a DAGs ratio above 90 percent, and this percentage decreases as the oil ages.

As shown in Figure 10, all samples passed the California Extra Virgin grade for DAGs except Sample 13 from the 2018 harvest (DAGs = 32). This Virgin sample also had the highest FFA at 0.4 and a rancid defect. Being in a bag-in-box and stored on the bottom shelf with a shelf temperature at 64.3°F (17.9°C) and a low illuminance at 142 Lux at the store, it was unlikely that the oil quality degradation was mainly caused by suboptimal retail store conditions. Producers reported difficulties related to the 2018 harvest where large amount of material-other-than-olives (MOO) and mummified fruit were found during production that led to decreased DAGs and increased FFA in the produced oil. Elevated FFA also promotes oil oxidation which consequently causes oil rancidity.

Other than Sample 13, there were seven unfiltered samples and one filtered sample (Sample 27) from the 2019 harvest that had DAGs between 43 and 55 with six of them having FFA equal to or greater than 0.3 (Samples 7, 8, 15, 22, 27 and 29). In spite of being filtered prior to bottling, Sample 27 (Arbosana variety) had both rancid and fusty/muddy-sediment defects, indicating the fruit was fermented (usually associated with higher initial FFA and lower initial DAGs) before milling. On the other hand, 25 samples had DAGs over 60 with the highest DAGs of 91 found in a filtered sample in a tinplate container from a voluntary member; all of the remaining 24 samples were unfiltered but properly racked prior to bottling. Under proper storage conditions, DAGs decrease at an average rate of 23% annually and are influenced by the oil's initial quality. Higher FFA in the oil also catalyze the hydrolysis of triacyglycerols thus further decrease DAGs in the oil[11].

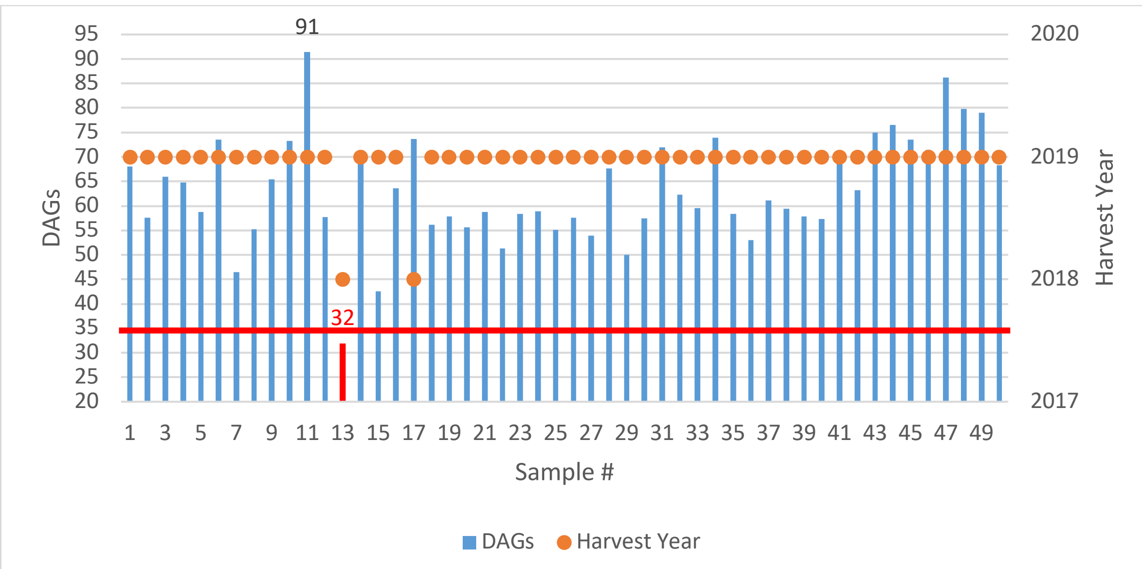

FIGURE 10. DAGs (CA EVOO ≥ 35%)

Pyropheophytins (**PPP)** are degradation products of chlorophyll *a* as a result of aging and/or heating. Chlorophyll *a* converts to pheophytins *a* and then to pyropheophytins *a*. The ratio of pyropheophytin *a* to the total pheophytins is useful to detect oils that are aged or have been heated in the refining process as this ratio increases linearly with time. A fresh high-quality oil starts with a PPP value close to zero and this value increases with aging, light exposure and/or excessive heating.

[11] Guillaume, C., Gertz, C., & Ravetti, L. (2014). Pyropheophytin a and 1, 2-diacyl-glycerols over time under different storage conditions in natural olive oils. *Journal of the American Oil Chemists' Society*, *91*(5), 697-709.

As shown in Figure 11, Sample 13 from the 2018 harvest and Sample 25 from the 2019 harvest failed the PPP standard (CA EVOO ≤ 17) with values of 23 and 18, respectively. The PPP value typically increases on an average of seven percent annually under proper storage conditions and is not influenced by the initial quality of the oil, cultivar or growing environments. Sample 25 was stored under 75.6°F (24.2°C) with incandescent lighting which generated more heat compared to LED lighting during the same storage period. On the other hand, Sample 17, which was also from the 2018 harvest, had a low PPP value of 6, indicating a favorable storage condition (i.e. minimized heat and light exposure) was achieved. Overall, 25 samples had PPP equal to or greater than 10 and eight of them (Samples 2, 7, 9, 13, 25, 27, 33 and 38) also had sensory defects. It is worth mentioning that the Crude grade Sample 46 had the lowest PPP value of 3 despite the unfavorable storage condition observed in the café. In an Australian study investigating different storage conditions on extra virgin olive oil quality[12], PPP disappeared completely when oil was exposed to intensive light. The Australian study also suggested that it may be useful to use this information along with the measurement of K_{268}/K_{270} to indicate the exposure of oil to light. If PPP and pheophytins are absent in the chromatogram while the K_{268}/K_{270} value is high, it is likely that the oil has been exposed to excessive light.

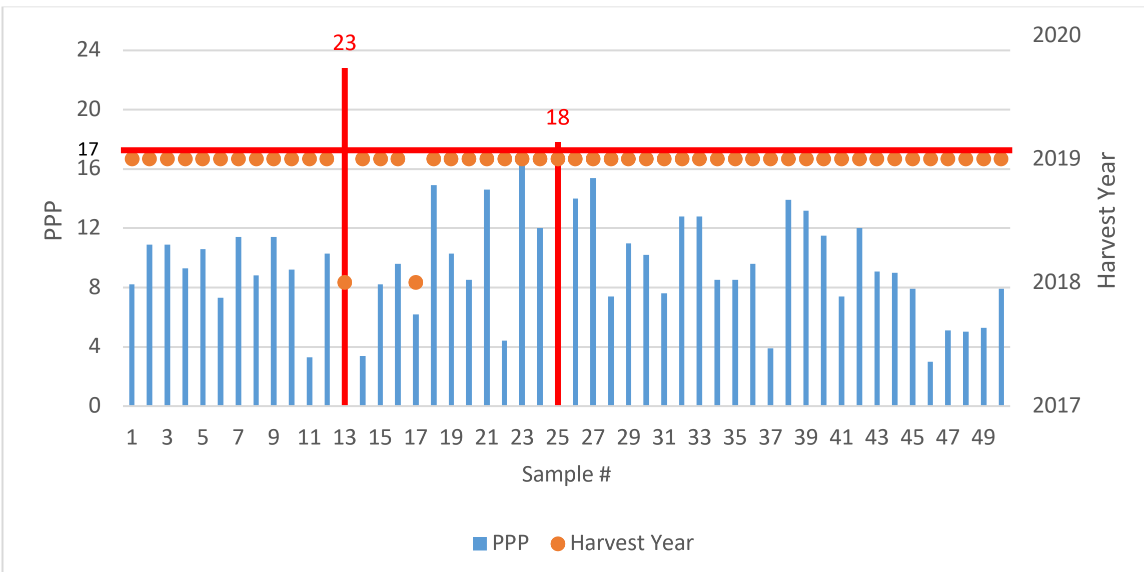

FIGURE 11. PPP (CA EVOO ≤ 17%)

Sensory analysis is conducted by a certified panel consists of at least eight tasters to characterize an olive oil based on olfactory and tasting factors. The sensory panel evaluates the positive and negative attributes of an olive oil, many of which cannot be picked up by chemical tests directly. An extra virgin olive oil should have a median value for defects of zero and a median value for fruitiness greater than zero.

Of the 50 samples, 13 samples (Samples 1, 2, 4, 7, 9, 13, 25, 27, 33, 37, 38, 41 and 49) were categorized as Virgin grade from both sensory panel evaluations. One Arbequina and Koroneiki blend sample (Sample 25) from a voluntary member had a fusty/muddy-sediment defect at a median of 2.0, two samples (Samples 2 and 27) of the same variety (Arbosana) from a mandatory member had both rancid and fusty/muddy-sediment defects, and the remaining 10 samples had rancid defects with a median of 0.5. The fusty/muddy-sediment defect suggested that substandard/fermented fruit was used prior to

[12] Ayton, J., Mailer, R. J., & Graham, K. (2012). *The effect of storage conditions on extra virgin olive oil quality*. RIRDC.

processing. Processors and literature also reported that Arbosana variety generally has lower harvesting efficiency compared to common varieties like Arbequina due to different detachment force[13]. This may result in a higher percentage of MOO (e.g. leaves, stems, knots) with the harvested Arbosana fruit, which could hasten fruit fermentation prior to oil production and shortens oil shelf life.

For the 10 virgin samples from the 2019 harvest that had a low median of rancid defects at 0.5, seven of them were displayed on the top or the second to the top shelf in different stores, which was closer to lighting sources and accelerated oil photooxidation. Their average PPP and DAGs values were at 12 and 59, respectively, indicating a moderate level of light/heat exposure had occurred during the storage although all the samples were stored in preferable containers such as dark glasses. For Sample 13 (2018 harvest) that was in a 3L bag-in-box and stored on the bottom shelf, a lower product-turnover rate might also have contributed to the quality degradation.

The median scores of fruitiness, bitterness and pungency of 50 samples were 3.8, 2.0 and 2.0, respectively, with the highest scores found in Sample 11 - a 2019 Picual sample produced by a voluntary member who filtered and stored oils in tinplate containers – at 4.5, 4.2 and 3.2, respectively. An Arbequina sample (Sample 43) that was also stored in a tinplate container had median scores of fruitiness, bitterness and pungency at 4.2, 2.7 and 2.6, respectively. Given these two varieties' intrinsic sensory characteristics that oils from Picual variety being bitter-pungent with a strong fruity odor and oils from Arbequina variety being sweet-fruity[14], it seemed the tinplate container helped to preserve the positive sensory attributes in spite of incandescent/fluorescent light exposure and higher storage temperature observed from retail outlets. Tinplate container not only grants protection to the oil from sunlight, oxygen, humidity and microorganisms, the inside of the container also protects iron from the corrosiveness of the oil[15].

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[13] Camposeo, S., & Vivaldi, G. A. (2016, October). Yield, harvesting efficiency and oil chemical quality of cultivars' Arbequina'and'Arbosana'harvested by straddle machine in two Apulian growing areas. In *VIII International Olive Symposium 1199* (pp. 397-402).

[14] Aparicio, R., Calvente, J. J., & Morales, M. T. (1996). Sensory authentication of European extra-virgin olive oil varieties by mathematical procedures. *Journal of the Science of Food and Agriculture*, *72*(4), 435-447.

[15] Tsimis, D. A., & Karakasides, N. G. (2002). How the choice of container affects olive oil quality—a review. *Packaging Technology and Science: An International Journal*, *15*(3), 147-154.

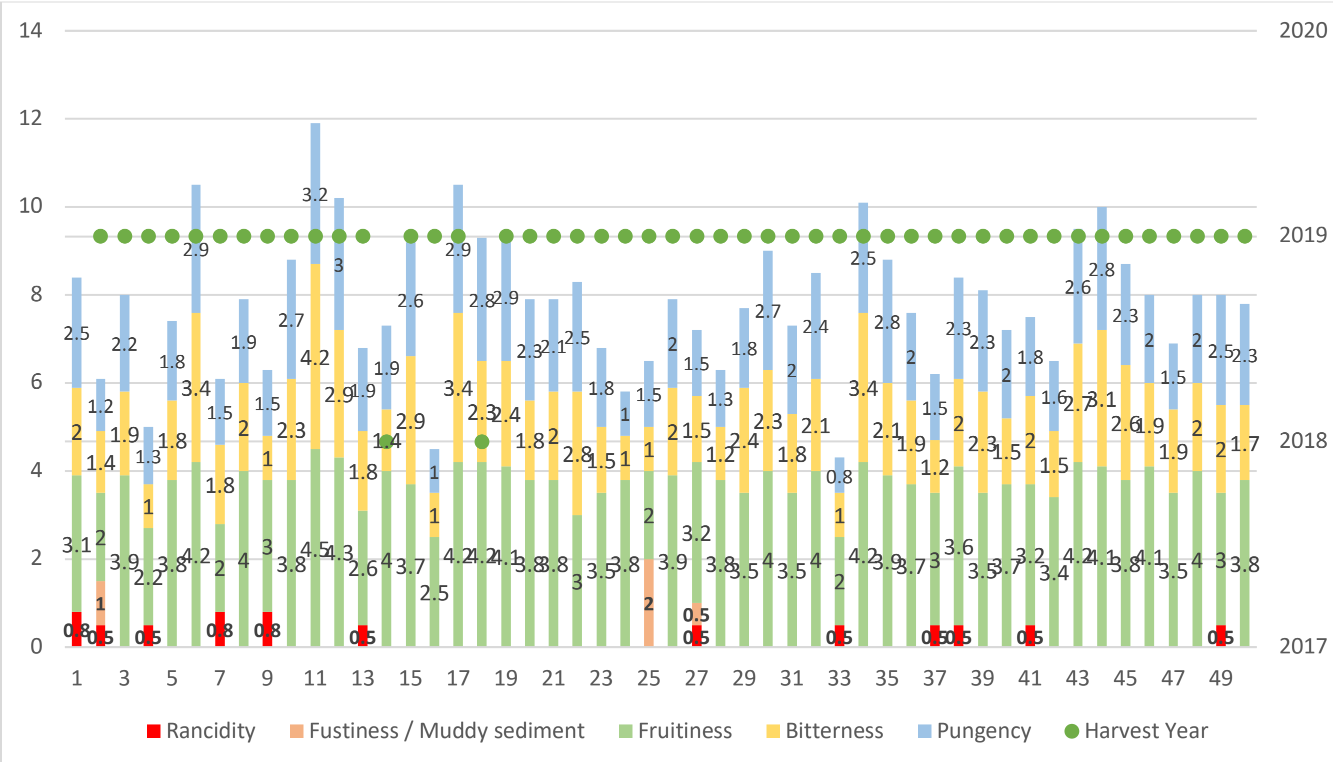

FIGURE 12. Medium scores of sensory attributes on rancidity, fustiness/muddy sediment, fruitiness, bitterness and pungency (MeD=0.0; MeF>0.0)

Induction time Induction time is determined by an instrument, usually a Rancimat[16], which accelerates the aging process of the sample by exposing it to excessive heat and increased volumes of air, and it measures the time that passes until oxidation takes place at a high rate – the induction time or oxidation stability index (OSI). Theoretically, the longer the induction time, the more stable the oil, although the method does not by itself provide an accurate assessment of shelf life due to the complex chemical reactions that occur during the natural aging process. Induction time is not required in California olive oil standards but has been widely used to estimate an oil's oxidative stability and predict shelf life.

Figure 13 shows that induction time for the 50 samples ranged from 11.7 hours to 38.9 hours. Non-extra virgin samples were highlighted in red. Among them, 12 samples with mild rancidity medians below 1.0 had an average induction time of 21.3 hours. Sample 25 which had the highest median score of fusty/muddy-sediment defect and a high PPP at 18 yielded the shortest induction time of 11.7 hours while two Koroneiki samples (Samples 6 and 34) from a mandatory member had the longest induction time at an average of 38.7 hours. Crude sample 46 also had a shorter induction time of 15.0 hours which correlated well with its oxidative parameter K_{232} at 2.80. In the Center's 2016/17 study[6a], induction time and other chemical tests' correlation results suggested that induction time is related to primary oxidation markers but high induction time does not necessarily indicate freshness and therefore should not be used as the sole tool for shelf-life prediction.

In general, samples of the same variety/SKU and harvest year (although differed in lot numbers and retail

[16] https://www.metrohm.com/en-us/products-overview/stability-measurement/rancimat/

outlets) from the same producer tended to have similar quality profile at the time of testing and yielded similar induction time.

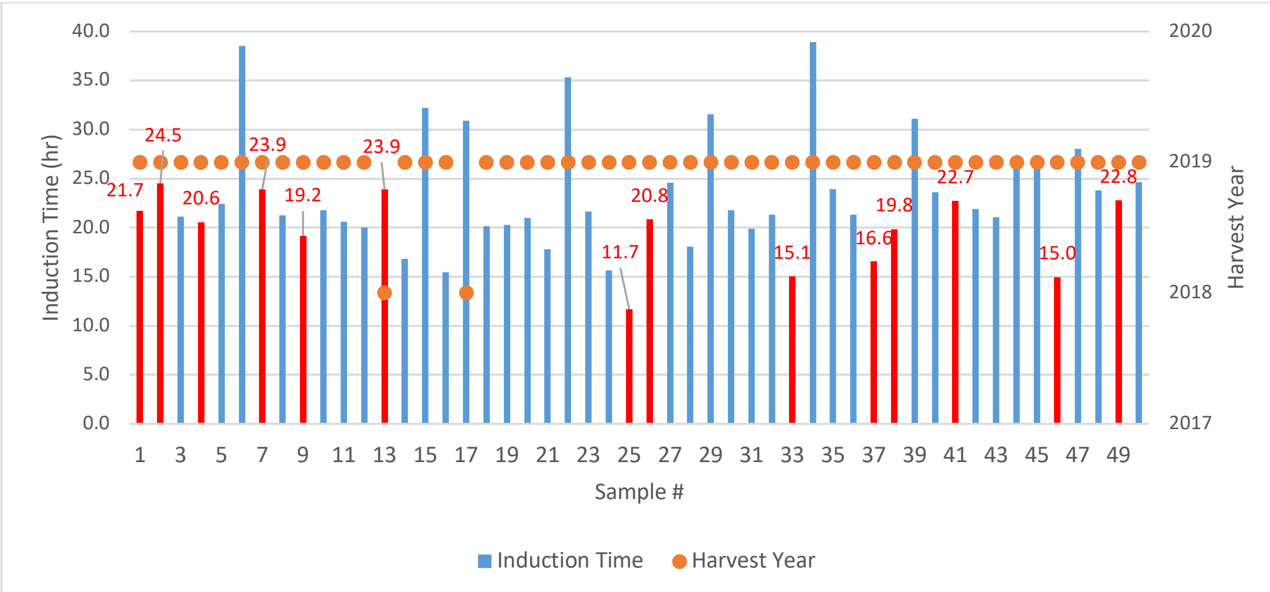

FIGURE 13. Induction time of olive oil samples (red bar indicates non-EVOO grade samples)

USE-BY-DATES CALCULATION

Beginning with the 2019 harvest, declaration of a use-by-date is mandatory for OOCC members and must be supported by technical evidence, usually based on chemical quality results at the time of harvest or bottling[1]. Technical evidence is information showing that the olive oil in question is very likely to retain its grade according to California olive oil standards until its stated use-by-date. As shown in Table 3, of the 50 extra virgin olive oil (on label) collected, 47 samples (94 percent) had use-by-date information stated on the label as "best by", "best if used by", or "best consumed within". One 2019 sample (2 percent) from a voluntary member purchased from a tasting room did not have use-by-date information on the label but a tasting room staff confirmed the use-by-date onsite. Two 2019 samples (4 percent) from a mandatory member collected in two traditional stores did not have any use-by-date information on the label.

According to the recommendation by the OOCC, the updated use-by-date of each sample during its stated shelf life was calculated based on the prediction model published by Modern Olives[2]. This model uses the results of chemical tests that are already required by the OOCC – FFA, DAGs and PPP – plus induction time on a Rancimat following the AOCS official method (Cd 12b-92)[17]. Specifically, the use-by-date is determined by the lowest of the following three estimations:

1) *Hours of induction time at 110°C x 1 = expected shelf-life (in months).*
2) *(17.0% - PPP)/0.6% = expected shelf-life (in months).*
3) *(DAGs – 35.0%)/FFA factor = expected shelf-life (in months).*

FFA factor = 1.7% (if FFA < 0.4%); 2.1% (if 0.4% < FFA < 0.6%); or 2.5% (if FFA > 0.6%).

[17] AOCS. (Reapproved 2017). Method Cd 12b-92. *Official Methods and Recommended Practices of the American Oil Chemists' Society*.

TABLE 3. Calculating use-by-dates of 50 samples using the Modern Olives model

SAMPLE #	HARVEST YEAR	USE-BY-DATE	INDUCTION TIME ESTIMATION	PPP ESTIMATION	FFA/DAGS ESTIMATION (FFA FACTOR 1.7%)	UPDATED SHELF LIFE ESTIMATED BY THE MODERN OLIVES MODEL (IN MONTHS)	TIME LEFT BEFORE USE-BY-DATES ON THE LABEL (IN MONTHS; FROM DEC 1, 2020)	DIFFERENCE BETWEEN THE ESTIMATED AND THE LABELED USE-BY-DATES (IN MONTHS)
1	2019	4/19/2022	21.7	14.7	19.4	14.7	16.6	-2.0 (Virgin)
2	2019	4/18/2022	24.5	10.2	13.3	10.2	16.6	-6.4 (Virgin)
3	2019	Nov 2021	21.2	10.2	18.2	10.2	11.0	-0.8
4	2019	3/10/2022	20.6	12.8	17.5	12.8	15.3	-2.5 (Virgin)
5	2019	2/26/2022	22.4	10.7	13.9	10.7	14.9	-4.3
6	2019	N/A[1]	38.5	16.2	22.6	16.2	N/A	N/A
7	2019	June 2021	23.9	9.3	6.8	6.8	6.0	0.8 (Virgin)
8	2019	Aug 2022	21.3	13.7	11.9	11.9	20.0	-8.1
9	2019	July 2022	19.2	9.3	17.9	9.3	19.0	-9.7 (Virgin)
10	2019	11/20/2021	21.8	13.0	22.5	13.0	11.7	1.3
11	2019	Dec 2021	20.6	22.8	33.2	20.6	12.0	8.6
12	2019	11/16/2021	20.0	11.2	13.4	11.2	11.5	-0.4
13	2018	Oct 2021	23.9	-9.7	-1.8	-9.7	10.0	-19.7 (Virgin)
14	2019	July 2022	16.8	22.7	20.8	16.8	19.0	-2.2
15	2019	12/31/2021	32.2	14.7	4.5	4.5	13.0	-8.5
16	2019	5/21/2022	15.5	12.3	16.8	12.3	17.7	-5.3
17	2018	Nov 2020	30.9	18.0	22.7	18.0	0	18.0
18	2019	6/26/2022	20.2	3.5	12.5	3.5	18.9	-15.4
19	2019	11/16/2021	20.3	11.2	13.5	11.2	11.5	-0.4
20	2019	May 2022	21.0	14.2	12.1	12.1	17.0	-4.9
21	2019	3/10/2022	17.8	4.0	13.9	4.0	15.3	-11.3
22	2019	10/31/2021	35.4	21.0	9.6	9.6	11.0	-1.4
23	2019	3/14/2022	21.7	0.2	13.8	0.2	15.5	-15.3
24	2019	8/13/2022	15.7	8.3	14.1	8.3	20.4	-12.1
25	2019	Dec 2021	11.7	-1.3	11.8	-1.3	12.0	-13.3 (Virgin)
26	2019	6/26/2022	20.8	5.0	13.3	5.0	18.9	-13.9
27	2019	6/26/2022	24.6	2.7	11.1	2.7	18.9	-16.2 (Virgin)
28	2019	July 2022	18.1	16.0	19.2	16.0	19.0	-3.0
29	2019	12/31/2021	31.6	10.0	8.8	8.8	13.0	-4.2
30	2019	11/16/2021[2]	21.8	11.3	13.2	11.3	11.5	-0.2
31	2019	2/4/2022	19.9	15.7	21.7	15.7	14.1	1.5
32	2019	Nov 2021	21.3	7.0	16.1	7.0	11.0	-4.0
33	2019	4/17/2022	15.1	7.0	14.4	7.0	16.6	-9.6 (Virgin)
34	2019	N/A	38.9	14.2	22.9	14.2	N/A	N/A
35	2019	4/22/2022	23.9	14.2	13.8	13.8	16.7	-3.0
36	2019	Aug 2022	21.4	12.3	10.6	10.6	20.0	-9.4
37	2019	Sep 2022	16.6	21.8	15.4	15.4	21.0	-5.6 (Virgin)
38	2019	2/24/2022	19.8	5.2	14.4	5.2	14.9	-9.7 (Virgin)
39	2019	June 2022	31.1	6.3	13.5	6.3	18.0	-11.7
40	2019	June 2021	23.6	9.2	13.1	9.2	6.0	3.2
41	2019	4/6/2022	22.7	16.0	20.6	16.0	16.2	-0.2 (Virgin)
42	2019	3/9/2022	21.9	8.3	16.6	8.3	15.3	-7.0
43	2019	Jan 2022	21.1	13.2	23.5	13.2	13.0	0.2
44	2019	Jan 2022	26.6	13.3	24.4	13.3	13.0	0.3
45	2019	Nov 2022[3]	27.4	15.2	22.6	15.2	23.0	-7.8
46	2019	3/1/2021	15.0	23.3	21.5	15.0	3.0	12.0 (Crude)
47	2019	Nov 2021	28.1	19.8	30.1	19.8	11.0	8.8
48	2019	Nov 2021	23.8	20.0	26.4	20.0	11.0	9.0
49	2019	Nov 2021	22.8	19.5	25.9	19.5	11.0	8.5 (Virgin)
50	2019	3/3/2022	24.6	15.2	19.6	15.2	15.1	0.1

[1] N/A: information not available; [2] two out of three bottles from the same lot did not have expiration date stickers; [3] confirmed by a tasting room staff onsite.

One deviation in the induction time measurement performed in this study from the Modern Olives model was that the Rancimat airflow rate was set at 9 L/h at ECAL while the Modern Olives model uses 20 L/h. Previous studies showed that at a sample size of 3 g for ghee and soybean oil, the decrease in airflow rate from 20 L/h to 10 L/h at 110°C would also slightly decrease induction time[18]. On the other hand, the airflow rate of 9 L/h was recommended in the AOCS official method (Cd 12b-92)[17] and it has been widely used for induction time/OSI measurement in edible oils. As indicated in Table 3, only three samples (Samples 11, 14 and 46; sample 46 being Virgin grade) had estimated shelf life from induction time estimation while the rest of the sample had the lowest values from either PPP or FFA/DAGs estimations. Thus, the majority of the estimated shelf-life results were still valid from the Modern Olives model in the current study. Overall, 38 samples (76 percent) had estimated shelf life from PPP, nine samples (18 percent) had estimated shelf life from FFA/DAGs, and only three samples (6 percent) had estimated shelf life from induction time.

The Modern Olives model was developed based on Extra Virgin grade samples at the point of production or bottling but here we applied to these 50 samples in the marketplace that were at least one-year-old to see how the model would perform. All 50 samples had FFA values below 0.4 so the FFA factor of 1.7% was used in the FFA/DAGs estimation. Tests on FFA, PPP, DAGs and induction time were conducted between November 13 and December 4, 2020 with the majority of the induction time test done between November 23 and December 4, 2020. Thus, December 1, 2020 was selected as the new starting date for the ease of calculating shelf life left before the labeled use-by-date. On the other hand, since some members labeled use-by-dates with specific dates (e.g. 4/19/2022 for Sample 1) while some only listed a month and a year (e.g. Nov 2021 for Sample 3), the first day of the labeled month was used for calculation. For example, Sample 3 had a use-by-date of "Nov 2021" on the label so November 1, 2021 was used for its use-by-date in the calculation. The lowest shelf-life estimation was 10.2 months from its PPP estimation, which meant under proper storage conditions, Sample 3 would maintain its Extra Virgin grade for 10.2 months starting from December 1, 2020 (testing date). In the meanwhile, the label showed under proper storage conditions there were 11 months left before Sample 3 would no longer be in Extra Virgin grade. As a result, the difference between the estimated/updated and the labeled shelf life (abbreviated as "month difference") was -0.8 month, which indicated that 0.8 month earlier than the labeled use-by-date, Sample 3 would likely be non-extra virgin.

Of the 36 extra virgin samples, the month difference ranged from -15.4 months (Sample 18) to 18.0 months (Sample 17) although use-by-dates of two extra virgin samples (Samples 6 and 34 from the same mandatory member) that had the longest induction time (an average of 38.7 hours) were missing on the label. Ten of the 36 samples (28 percent) had the month difference in the positive range, indicating these oils would likely remain Extra Virgin grade beyond their labeled use-by-dates under proper storage conditions while 24 extra virgin samples (67 percent) that were in the negative month difference range would likely not meet Extra Virgin grade by their labeled use-by-dates. Sample 17, an extra virgin olive oil from the 2018 harvest, which was expiring (on label) by the time it was tested but turned out to have another 18-month shelf life according to the Modern Olives model. This is an example of a high quality oil when produced in the 2018 harvest and had been stored under optimal storage conditions (production facility, transportation, warehouse and retail store) until being tested. When applying the Modern Olives

[18] (a) Pawar, N., Purohit, A., Gandhi, K., Arora, S., & Singh, R. R. B. (2014). Effect of operational parameters on determination of oxidative stability measured by Rancimat method. *International Journal of Food Properties*, *17*(9), 2082-2088. (b) Farhoosh, R. (2007). The effect of operational parameters of the Rancimat method on the determination of the oxidative stability measures and shelf-life prediction of soybean oil. *Journal of the American Oil Chemists' Society*, *84*(3), 205-209.

model to 14 non-extra virgin samples, 11 samples (79 percent) had the month difference in the negative range between -0.2 and -19.7 months, suggesting these samples would not maintain Extra Virgin grade by their labeled use-by-dates. Two negative shelf-life estimations were found in Sample 13 and Sample 25 at -9.7 and -1.3 months, respectively, correctly indicating these two samples were already non-extra virgin by the time they were tested. On the other hand, Crude Sample 46 had a month difference of 12 because other than its high K_{232} at 2.80, the rest of the chemistry and sensory results were still well within Extra Virgin standards while the Modern Olives model does not use oxidative parameters such as PV and UV.

When month difference values were negative, the larger discrepancies (absolute value > 5 months) were mainly from samples that had over 30-month shelf life estimated between the harvest date and the use-by-date. Overall, seven out of 12 mandatory members (58 percent) and three out of four voluntary members (75 percent) listed shelf life between 16 and 24 months (from harvest date to use-by-date) on the label. The Modern Olives model also suggested that an additional time of 1-2 months may have to be deducted from the initial shelf-life estimation to compensate for negative impact on oil quality from suboptimal storage conditions during transportation and warehouse/store handling[16]. Lastly, the chemistry results used in the Modern Olives model for estimating use-by-dates are usually generated at the time of bottling, which could be months after harvest and milling depending on an OOCC member's production capacity, although bottling date information is not required on the label.

CONCLUSIONS

Fifty California extra virgin olive oil samples, including four private labels, from OOCC members were collected from retailers and analyzed for their quality. As shown in Table 4, OOCC-member oils achieved an Extra Virgin passage rate of 72 percent in 2020/21. This rate was comparable to that from the 2017/18 study at 75 percent but lower than the 90 percent from the 2016/17 study. The main differences between the 2016/17 study and the 2020/21 study might explain the lower passage rate found this year:

- Eleven more OOCC samples (22 percent of the entire sample size) were collected in the 2020/21 study.
- At least 16 OOCC members (members responsible for private label samples were unknown) were sampled in the 2020/21 study while only eight OOCC members were sampled in the 2016/17 study.
- A total of 21 stores, including 11 non-traditional stores who carried OOCC-member oils, were visited and sampled in the 2020/21 study whereas 12 stores (including 7 traditional and 5 non-traditional stores) were sampled in the 2016/17 study.
- Different sensory panels were used in the two studies. In the 2020/21 study, nine samples were categorized as Virgin grade by the sensory panel at ECAL solely because of rancid defects (MeD ≤ 0.8) while most of the rancid samples in the 2016/17 study had prominent rancid defects at MeD greater than 1.0 determined by the Applied Sensory panel in California and/or the Australian Oils Research Laboratory. This year, there were also some delays (up to 30 days) between the sample receipt and the sensory evaluation due to COVID-19 which might have slightly affected the oil quality. Additionally, when MeD is below 1.0 for specific defect(s) the evaluated oil could be on

the borderline and yield different grade categorizations from different sensory panels[19]. For easier comparison, the Extra Virgin grade passage rates for non-OOCC member oils were also given in Table 4.

TABLE 4. Comparison of Extra Virgin grade passage rates for OOCC, non-OOCC, and private label samples (presumably produced by OOCC members) in 2016/17, 2017/18 and 2020/21

STUDY SEASON	**2016/17**	**2017/18**	**2020/21**
OOCC	90% (28 of 31 samples)	74% (23 of 31 samples)	74% (34 of 46 samples)
NON-OOCC	18% (2 of 11 samples)	50% (7 of 14 samples)	0 samples
PRIVATE LABEL	88% (7 of 8 samples)	80% (4 of 5 samples)	50% (2 of 4 samples)
COMBINED EVOO GRADE FOR OOCC SAMPLES*	**90% (35 of 39 samples)**	**75% (27 of 36 samples)**	**72% (36 of 50 samples)**

*OOCC samples include OOCC-member oils and private label oils that were presumably also produced by OOCC members

Overall, 48 samples had use-by-date information available on the label and one sample from a tasting room had use-by-date information provided by a staff onsite. The two remaining samples were from the same OOCC mandatory member who only printed harvest month and year on the label. Of the 48 samples that had use-by-date information, three samples (two from a mandatory member and one from a voluntary member) had no harvest year information but the study team was able to collect this information by contacting the specific OOCC members. One mandatory member had missing use-by-date stickers on two out of the three bottles collected for Sample 30 although all three bottles were from the same lot.

The Modern Olives model for shelf-life prediction was applied to the study samples of at least one-year-old in the marketplace. This information can be useful for a discussion amongst the OOCC members regarding their extra virgin olive oils' use-by-dates labeled at the time of bottling in the production facility where is more desirable and well-regulated, and updated use-by-dates during oils' stated shelf life in the marketplace where various post-production factors such as light, heat, air, and moisture play more significant roles on oil quality once oils leave the production facility.

[19] Circi, S., Capitani, D., Randazzo, A., Ingallina, C., Mannina, L., & Sobolev, A. P. (2017). Panel test and chemical analyses of commercial olive oils: A comparative study. *Chemical and Biological Technologies in Agriculture*, *4*(1), 1-10.

RECOMMENDATIONS

- The OOCC may wish to continue sampling OOCC-member oils in future off-the-shelf surveys so a consistent methodology is carried out to ensure proper evaluations of samples in the marketplace. The results and analysis presented here as well as the individual reports (with lot numbers, locations of the purchasing store etc.) shared with the OOCC member privately should be helpful to the producers. The Grades & Standards Committee may use the data from these surveys and mandatory testing program for the consideration of modifying the chemistry standards so they accommodate the natural aging patterns of extra virgin oil while having a better alignment with sensory results.

- For samples from the same OOCC members that failed Extra Virgin grade in multiple years' surveys, the OOCC may wish to communicate with the specific member and inquire records of fruit conditions prior to processing and storage conditions showing the oil lots were properly conserved prior to being released into the supply chain to help the member assess the possible cause(s) for quality degradation.

- The OOCC may wish to immediately alert an OOCC member when a sample collected from the member through the commission's mandatory sampling and testing program does not meet or have abnormal value(s) which are too close to the lower/upper limits of California olive oil standard for Extra Virgin grade. While the oil may still be tested as Extra Virgin grade (may be on the borderline) from the mandatory testing program, oil made from suboptimal fruit will have reduced shelf life and become more prominent in defects such as fusty/muddy-sediment - although unlike rancid defects that will keep developing during storage - when positive sensory attributes weaken over time.

- The OOCC may want to ensure the inclusion of lot numbers on packaging for the purpose of tracking product quality. This information was missing from samples from two mandatory members and all four voluntary members while half of the voluntary members had oils failed Extra Virgin grade this year.

Appendix

TABLE 1. Chemical and sensory tests for olive oil quality analysis.

PARAMETER	DETERMINATION	INDICATOR	METHODOLOGY	CA EVOO 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 stored oil. High FFA accelerates oxidation.	AOCS Ca 5a-40 Analytical Titration	≤ 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.	AOCS Cd 8b-90 Analytical Titration	≤ 15 meq O_2/kg oil
Ultraviolet absorbance (UV)	UV absorbance provides three different measurements: K_{232} measures primary oxidation products (similar to PV); K_{270} measures secondary oxidation products; ΔK detects presence of refined or pomace oil.	An elevated level of UV absorbance indicates oxidized and/or poor quality oil.	AOCS Ch 5-91 UV spectrophotometry	K_{232}: ≤ 2.40 $K^{1\%}$1cm; K_{270}: ≤ 0.22 $K^{1\%}$1cm; ΔK: ≤ 0.01 $K^{1\%}$1cm
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.	A low 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.	ISO 29822:2009 Gas Chromatography (GC)	≥ 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.	ISO 29841:2012 High performance liquid chromatography (HPLC)	≤ 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.	COI/T.20/Doc. 15 IOC-recognized panel of 8-12 people evaluates oils for sensory characteristics.	Median of defects = 0.0; median of fruity > 0.0
Induction Time	The aging process is accelerated by means of heating up the reaction vessel and by passing air continuously through the sample.	Oxidative stability (in hours) denotes the resistance of oils to oxidation. The longer the induction time, the more stable the sample is.	AOCS Cd 12b-92: 1997 Rancimat (110°C, 2.5±0.2 mL/sec, 2.5±0.2 g)	Not required in California olive oil standards