Heptadecenoic Acid (C17:1) in California Olive Oil: A Review

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SUMMARY

The UC Davis Olive Center was requested by the Olive Oil Commission of California to review the scientific literature on heptadecenoic acid (C17:1) in olive oil; to summarize the C17:1 data of 275 California single-variety olive oil collected by the UC Davis Olive Center over six harvest seasons; and to provide recommendations on the established limit.

C17:1 is one of the fatty acids in olive oil. To prevent adulteration, olive oil standards establish limits for each fatty acid, and oils that fall outside these limits are often devalued in the marketplace. The United States Department of Agriculture (USDA) olive oil standards limit C17:1 to 0.3%, which is the limit that applies in California. The USDA limit was based on International Olive Council (IOC) trade standards published in 2003.

Our review of 275 California single-variety olive oil samples collected over a six-year period found that 80 samples (29 percent) had a C17:1 content that was equal to or exceeded the California limit (11 samples at 0.4% and 69 samples at 0.3%.)

Given the high percentage of authentic olive oil samples that equal or exceed the California C17:1 limit, the Olive Oil Commission of California may want to recommend that the CDFA modify the limit consistent with the value adopted by the International Olive Council and the European Union in 2016.

BACKGROUND

The fatty acid profile is useful in trade standards for determining the authenticity of the oil, given that different oils are comprised of distinctive ratios of fatty acids. California olive oil observes standards for fatty acid profiles set by the California Department of Food and Agriculture (CDFA) and the United States Department of Agriculture (USDA).

USDA standards for olive oil fatty acid profile are based on the IOC trade standard published in 2003[1,2]. In September 2014, the CDFA adopted olive oil standards for some, but not all, fatty acids. For those components of fatty acid profile not in the CDFA standards, California producers observe USDA standards, which are referenced in California law[3]. The USDA standard for heptadecenoic acid (C17:1) observed by California olive oil producers is 0.3%.

The Olive Oil Commission of California, noting that California olive oils often reach or exceed the USDA limit for C17:1, requested that the UC Davis Olive Center review the literature in this area, summarize analytical data on California olive oil, and provide recommendations.

OLIVE OIL FATTY ACIDS AFFECTED BY SEVERAL FACTORS

Research studies have shown that factors such as olive variety[4-6]; geographical origin[7-9]; climate; soil quality[10-11]; growing conditions such as harvest timing[12-13] and irrigation strategies[14-15]; and processing variables including malaxation conditions[16-17] and centrifugation systems[18] can lead to an olive oil failing to meet one or more limit values of fatty acid standards. Table 1 summarizes the standards for olive oil fatty acids among seven regulatory bodies.[19]

Table 1. The limit values of olive oil fatty acids composition (% m/m methyl esters) in the current national and international standards for olive oil (year of most recent version)

	IOC (2016)	European Union (2016)	Codex Alimentarius (1981)	USDA (2010)	CDFA (2014)	Australia (2011)	South African National Standard (2015)
Myristic acid (C14:0)	≤0.03	≤0.03	≤0.05	≤0.05	≤0.05	≤0.05	≤0.05
Palmitic acid (C16:0)	7.50-20.00	7.50-20.00	7.5-20.0	7.5-20.0	7.5-20.0*	7.0-20.0	7.0-20.0
Palmitoleic acid (C16:1)	0.30-3.50	0.30-3.50	0.3-3.5	0.3-3.5	0.3-3.5*	0.3-3.5	0.3-3.5
Heptadecanoic acid (C17:0)	≤0.40	≤0.40	≤0.3	≤0.3	≤0.3	≤0.3	≤0.3
Heptadecenoic acid (C17:1)	≤0.60	≤0.60	≤0.3	≤0.3	≤0.3*	≤0.4	≤0.4
Stearic acid (C18:0)	0.50-5.00	0.50-5.00	0.5-5.0	0.5-5.0	0.5-5.0	0.5-5.0	0.5-5.0
Oleic acid (C18:1)	55.00-83.00	55.00-83.00	55.0-83.0	55.0-83.0	55.0-83.0*	53.0-85.0	53.0-85.0
Linoleic acid (C18:2)	2.50-21.00	2.50-21.00	3.5-21.0	3.5-21.0	3.5-21.0*	2.5-22.0	2.5-22.0
Linolenic acid (C18:3)	≤1.00	≤1.00	-	≤1.5	≤1.5*	≤1.5	≤1.5
Arachidic acid (C20:0)	≤0.60	≤0.60	≤0.6	≤0.6	≤0.6	≤0.6	≤0.6
Gadoleic acid (C20:1)	≤0.50	≤0.50	≤0.4	≤0.4	≤0.4*	≤0.5	≤0.5
Behenic acid (C22:0)	≤0.20	≤0.20	≤0.2	≤0.2	≤0.2	≤0.2	≤0.2
Lignoceric acid (C24:0)	≤0.20	≤0.20	≤0.2	≤0.2	≤0.2	≤0.2	≤0.2

* Values adopted from the USDA standards

As shown in Table 1, the IOC/EU limit for C17:1 is 0.6%, which is double the USDA/CDFA limit of 0.3%. The IOC and EU increased the limit in 2016 with the goal of permitting olive oil produced from certain varieties (e.g. Carolea and Coratina) to be correctly classified as olive oil without facilitating fraud, given that C17:1 is "practically absent" from other oils.[20]

C17:1 IN OLIVE OIL OUTSIDE OF CALIFORNIA

The 2016 IOC increase of the C17:1 limit to 0.60% follows several studies indicating that C17:1 values in olive oil often were equal to or exceeded the old IOC limit of 0.3%.

Tunisia Dabbou et al. found in 2009 that Ascolana Tenera had a significantly higher value of C17:1 (0.3%) compared to that of other varieties (0.1% on average) in North Tunisia. [21] In a 2010 study, Dabbou et al. found that three different irrigation treatments: 50% evapotranspiration (ETc), 75% ETc, and 100% ETc in an Arbequina orchard produced olive oil with C17:1 values that were above 0.30% in each treatment area.[22]

Spain Aranda et al. reported in 2004 that the C17:1 values of Arbequina VOO samples were 0.26%, which would be equal to the CDFA limit of 0.3% when rounded up by the lab.[23] Reboredo-Rodriguez et al. measured the quality and authenticity parameters of two single-variety olive oil samples (Brava and Mansa) and found C17:1 value of 0.4%.[6]

Italy A 2004 study by Poiana and Mincione, in which olive samples of nine varieties were analyzed every four to 16 days from the beginning of October to the middle of January for three consecutive crop seasons found maximum values of C17:1 of 0.34% for Itrana, 0.38% for Ottobratica, and 0.30% for Sinopolese.[24] Piscopo, A. et al., found in a 2016 study of 151 Carolea olive oil samples from five areas within the Calabria found mean values of C17:1 of 0.31%.[25]

Greece Stefanoudaki et al. studied four sampling locations based on their geographical (altitude) and climatic traits (relative humidity) in 1999. Samples from three ripening stages and collected from five trees on each stage found that the mean value of C17:1 of Koroneiki oils was 0.07% while that of Mastoides oils was around 0.30% from the same Chania region.[26]

France In 2003, Ollivier et al. published a study on the fatty acid profile and triacyglycerols data of 564 French virgin olive oil samples from four olive harvest seasons. Results showed that 88 samples had C17:1 values higher than 0.3%, of which 54 samples were from the Aglandau variety (mean value 0.38%).[27] In a follow-up study conducted by the same research group in 2006, 72 of 85 samples from the Haute-Provence region had C17:1 values in excess of 0.3%. The highest C17:1 value found in the region was 0.53%. Aglandau is considered the major variety in the region.[28]

Australia Mailer et al. analyzed the fatty acid profile of 556 olive oil samples collected from farmers and processers throughout the Australian olive growing regions in 2002 and 2003. In the 2002 season, 32 of 250 samples had C17:1 values in the range of 0.31% to 0.4% and in 2003, 22 of 316 samples exceeded 0.3%.[29]

Table 2 summarizes the studies discussed above.

Table 2. Summary of scientific literature on olive oil C17:1 studies

Country	Objective	Variety	Results of C17:1	Reference
Tunisia	The influence of the genetic characteristics of olive varieties and the climatic and edaphic factors on olive oil	Three European varieties Ascolana Tenera, Koroneiki, Picholine, and an autochthonous Chetoui grown in the north of Tunisia	Ascolana Tenera olive oil had a significantly higher value of C17:1 (0.3%) compared to that of other varieties (0.1% by average) in North Tunisia	Dabbou et al. (2009)[21]
Tunisia	The effect of different irrigation treatments: 50% evapotranspiration (ETc), 75% ETc, and 100% ETc	Arbequina	C17:1 value at 50% ETc was 0.34±0.01; 75% ETc was 0.35±0.00; 100% ETc was 0.34±0.00	Dabbou et al. (2010)[22]
Spain	Characterization of olive oils extracted from different olive cultivars using fatty acid composition	Cornicabra, Arbequina, Hojiblanca, and Picual	1) C17:1 played the most important role in characterizing the four Spanish varieties studied 2) C17:1 values of Arbequina VOO samples were 0.26%	Aranda et al. (2004)[23]
Spain	Characterization of olive oils from two autochthonous cultivars from north-western Spain using fatty acid composition and minor compounds	Brava and Mansa	Brava olive oils had C17:1 values of 0.40%	Reboredo-Rodriguez et al. (2018)[6]
Italy	Fatty acids evolution and composition of olive oils extracted from different olive cultivars grown in Calabrian area	Itrana, Cassanese, Coratina, Pendolino, Leccino, Picholine, Nociara, Ottobratica, and Sinopolese	The maximum values of C17:1 were 0.34% (Itrana), 0.38% (Ottobratica), and 0.30% (Sinopolese)	Poiana and Mincione (2004)[24]
Italy	Characterization of olive oils from five areas in the Calabria region	Carolea, Ottobratica, and Sinopolese	1) The mean values of C17:1 were 0.31% (Carolea), 0.22% (Ottobratica), and 0.17% (Sinopolese) 2) The high value of C17:1 in Carolea oils seemed more generic-dependent	Piscopo et al. (2016)[25]
Greece	Classification of olive oils of two major Cretan cultivars based on their fatty acid composition	Koroneiki and Mastoides	1) The mean values of C17:1 are 0.07% (Koroneiki) and 0.30% (Mastoides) from the same Chania region 2) C17:1 values were able to differentiate olive oils of different cultivars from different regions or the same region with different microclimates	Stefanoudaki et al. (1999)[26]
France	Characterization of French olive oils by triacylglycerol, fatty acid compositions, and chemometrics	Aglandau, Cailletier, Picholine, Salonenque, Nyons (cv. Tanche), Vallee des Baux, and a few unknowns	1) 88 out of 564 samples had C17:1 values higher than 0.3% 2) Aglandau oils had the highest C17:1 mean value of 0.38%, including 54 samples higher than 0.3%	Ollivier et al. (2003)[27]
France	Characterization of French olive oils RDOs by sensory characteristics, fatty acid and triacylglycerol compositions and chemometrics	539 samples from five French RDOs	1) 72 out of 85 samples were found with C17:1 values higher than 0.3% in Haute-Provence 2) The highest C17:1 value found in samples from Haute-Provence was 0.53%	Ollivier et al. (2006)[28]
Australia	Variation in olive oil quality and fatty acid profiles resulting from Australia's diverse environments and cultivars	Over 800 samples from Australian olive growing regions	1) In 2002, 32 of 250 oil samples had C17:1 values in the range of 0.31% to 0.40% 2) In 2003, 22 of 316 samples exceeded 0.3%	Mailer (2005)[29]

C17:1 IN CALIFORNIA OLIVE OIL

The UC Davis Olive Center analyzed fatty acid profiles of 275 single-variety California olive oils collected over six harvest seasons from 2010/11 to 2016/17 (no samples were collected in 2011/12 season). The samples were of single varieties, some produced by UC Davis using Abencor lab-scale processing equipment, and some were collected from producers who had processed the olives with their own equipment. Table 3 and Table 4 summarize the sample information by season and variety, respectively.

Table 3. Sample information by season

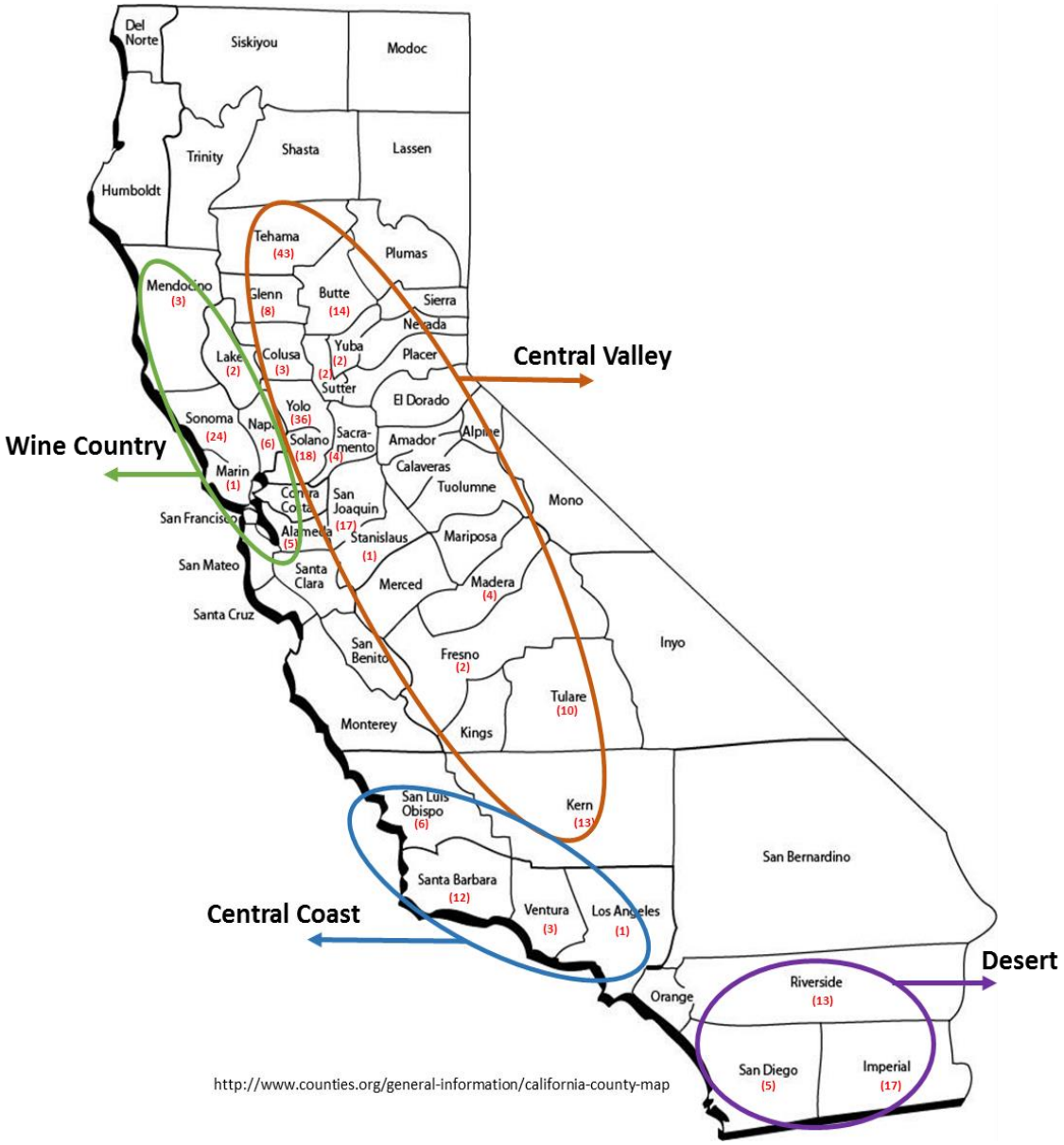
Season	Samples	Varieties	Counties	Processing Method
2010/11	57	14	15	Commercial
2012/13	14	7	4	Abencor
2013/14	13	7	4	Abencor
2014/15	50	14	12	Abencor and Commercial
2015/16	71	24	20	Commercial
2016/17	70	22	18	Commercial

Table 4. Sample information by variety

Variety	Samples	Percentage	Variety	Samples	Percentage
Arbequina	52	18.9	*Barnea*	4	1.5
Koroneiki	34	12.4	*Nocellara del Belice*	3	1.1
Arbosana	27	9.8	*Chemlali*	2	0.7
Mission	22	8.0	*Grignon*	2	0.7
Leccino	17	6.2	*Picholine*	2	0.7
Picual	17	6.2	*Dolce*	2	0.7
Frantoio	14	5.1	*Aglandau*	1	0.4
Pendolino	13	4.7	*Allegra*	1	0.4
Manzanillo	12	4.4	*Barouni*	1	0.4
Ascolano	11	4.0	*Chiquetita*	1	0.4
Taggiasca	8	2.9	*Favolosa*	1	0.4
Coratina	7	2.5	*Grapolo*	1	0.4
Sevillano	7	2.5	*Hojiblanca*	1	0.4
Maurino	5	1.8	*Kalamata*	1	0.4
Moraiolo	5	1.8	*Lucca*	1	0.4
			TOTAL	275	100

Figure 1 shows the distribution of the samples, with the number from each county indicated in red. A total of 41 samples (15%) were collected from the Wine Country region, 22 samples (8%) from the Central Coast region, 177 samples (64%) from the Central Valley region (where most olive trees in California are planted), and 35 samples (13%) from the Desert region.

Figure 1. Sample distribution by California counties and regions over six years



Of the 275 samples analyzed, a total of 80 samples (29 percent) were greater than or equal to the California limit of 0.3%: 11 samples had C17:1 levels of 0.4% and 69 samples had levels of 0.3%. Of the 11 samples at 0.4%, seven were collected from the Central Valley region, nine were collected from the harvest season of 2010/11, and four were collected from Tehama County.

Some varieties showed consistently high values for C17:1:

- Aglandau: Consistent with the results of French studies, [27-28] the only Aglandau sample collected (2016/17) showed a high C17:1 value of 0.3%.
- Arbequina: 20 of 52 samples had values of 0.3% regardless of season or altitude.
- Arbosana: 24 of 27 samples had high values. In the seasons of 2012/13 and 2014/15, two samples from the Central Valley region had of 0.4%.
- Ascolano: 10 of 11 samples had high values. In the 2010/11 harvest season, a Central Valley sample and Wine Country sample had C17:1 values of 0.4%.
- Manzanillo: 7 of 12 samples had high values of 0.3% and two had values of 0.4%.
- Sevillano: 3 of 7 samples had high values of 0.3% and three had values of 0.4%.

CONCLUSION

Our review of the scientific literature found that olive oil fatty acids can be influenced by genetic, environmental, agronomic and processing factors. In light of these factors, the IOC modified the C17:1 standard in 2016 to 0.60%, replacing the previous value of 0.3%.

Our review of six years of data found that legitimate California olive oil samples are often equal to or greater than the California C17:1 limit of 0.3%. Given that the existing California standard for C17:1 was based on an older IOC standard that existed prior to July 2016, it is appropriate for CDFA to consider modifying the C17:1 standard.

RECOMMENDATION

The Commission may wish to recommend to the CDFA that the C17:1 limit be consistent with the value recently adopted by the IOC and the European Union.

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