Biology Internal Assessment

Chlorophyll in Olive Oil

0

Aim

The aim of this experiment is to determine the varying levels of chlorophyll in different grades of olive oils, and hence the oil's grade. The greater the absorption peak of the olive oil on a spectrometer, the greater is the chlorophyll content, and the better the quality of the olive oil.

Ex
Topic identified
When the aim is combined with the research question (p 2) it is adequately focused.

Motivations

I first became interested in spectrometers when the science teachers showed a demonstration of how a solution's concentration could be found just by passing white light through it, sparking passing my interest for the device. As its use isn't covered in the syllabus, I realized the IA would be the perfect chance to use a spectrometer. I only realized the spectrometer's wide range of applications upon my research, like finding that there was a way to test an olive oil's quality using the oil's absorbance patterns. Having an Italian background, my family has always been adamant about the quality of ingredients in the Italian dishes we make. This, of course, includes olive oil. Thus I was quickly enticed by the idea of using a spectrometer to examine olive oils in a biological context.

PE
Personal significance.

Background

Chlorophyll is a green pigment found in photosynthetic organisms that absorb light energy for the purpose of photosynthesis.[1] In green plants, it is found in the chloroplasts of the cells. There are several forms of chlorophyll (a, b, c, d, and e), but chlorophyll a and b are the ones found in green plants.[2] They absorb largely red and blue light, or light in the 400-500 nm and 600-700 nm wavelength range in the visible light spectrum.[3]

Ex
Relevant background.

Olive oil is made by pressing olives (*Olea europaea*[4]) to extract the oils from the fruit. Olives contain chlorophyll that is extracted when producing olive oil, giving most oils a green color. Chlorophyll levels in olive oil vary with the extraction process of the oil, the type of olives used, the time the olives were pressed, weather conditions in the olives' place of growth, etc. Many oils are made with pressing some olive leaves with the fruits, which adds more chlorophyll to the oil and gives it a "grassy" flavor.[5]

Following its processing, olive oil is categorized in grades as an expression of its quality. Extra virgin has the highest quality, as it is usually pressed from fresh olives, has not been refined, and contains no additives. It has a green-gold color and can be clear or cloudy. It is characterized by its relatively fruity aroma due to the high levels of volatile material extracted from the olives. Regular olive oil is extracted with the use of liquid additives to increase yield. It has a pale yellow-green color and is clear, refined, and usually contains preservatives. It only has a slight aroma due to the lower quantity of volatile material in the oil. Light or cooking olive oil has a yellow color and no aroma, as it is pressed under pressure to remove all volatile compounds. It is the least expensive, and is often used in cooking.[6]

By measuring the absorption spectrum of a substance, or all the wavelengths that it absorbs, it is possible to recognize and categorize it, as substances have characteristic wavelengths. *Figure 1* shows the absorbance spectra of the three central pigments found in plants (including olives); chlorophyll a and b, and carotenoids. From this graph we can see that chlorophyll produces two blue absorbance peaks at approximately425 and 450 nm, and red absorbance peaks at approximately 630 and 670 nm. As a result, it absorbs blue and red light and reflects green light, giving chlorophyll-containing plants their characteristic green color.

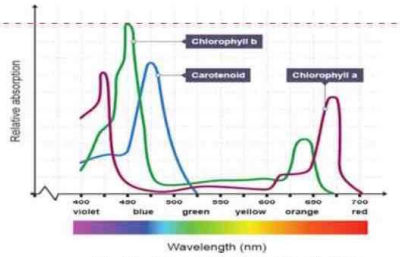


Figure 1 – Chlorophyll a, b and carotenoid relative absorption per wavelength graph[5]

Ex
Dependent variable explained in the context of the investigation.

[1] http://www.biology-online.org/dictionary/Chlorophyll
[2] http://www.britannica.com/science/chlorophyll
[3] http://www.vernier.com/innovate/determination-of-chlorophyll-in-olive-oil
[4] http://www.jstor.org/stable/4110824?origin=crossref&seq=1#page_scan_tab_contents
[5] http://www.oliveoilsource.com/definition/chlorophyll
[6] http://www.vernier.com/innovate/determination-of-chlorophyll-in-olive-oil
[7] http://www.bbc.co.uk/education/guides/z23ggk7/revision/2

Research Question

How do chlorophyll levels vary according to the grade of the olive oil(oil of *O. europaea*), as judged by their absorbance found through a spectrometer?

Variables

Variables Type	Variable	Range
Independent	Olive Oil grade	Light/Cooking → Extra Virgin
Dependent	Absorbance	≈-0.2 – 2.5 Au

Table 1

Controls	Method of Control	Why?
Concentration of Olive Oil	No additives added to the samples, oils used as bottled	An olive oil whose concentration is altered would have a lighter/darker color, thus altering results
Volume of Olive Oil	Same cuvettes used, each 4/5 filled with respective sample	To make sure it is the sample, not the air above it, that the spectrometer finds the absorbance of
Spectrometer	Same spectrometer used throughout experiment	Different spectrometers can have different levels of accuracy
Calibration	Each test performed with same calibration	Comparing samples to the same calibration allows us to compare the results side-by-side
Time & External Light	Each data collection performed after 30 seconds in spectrometer, for each sample	Experiment carried out in one span of time, allowing external light to remain constant.

Table 2

Ex
Appreciates principle variables that require control.

Hypothesis

If the olive oil is of a higher grade (i.e. Extra Virgin), then it will have a greater chlorophyll content.

Null Hypothesis

If the olive oil is of a higher grade, then the chlorophyll content will not be affected.

Materials

- Laptop with LoggerPro Application
- Vernier ™ Spectrometer
- Approx. 100 mL of five olive oils of varying standards
- 31 cuvettes
- Distilled water
- 5 x 10 mL pipettes
- Hot dish soap solution
- 1 x 500 mL Beaker

The experiment used 5 olive oils of varying grades, presented in *Table 3* below.

Sample Name	Olive Oil 1	Olive Oil 2	Olive Oil 3	Olive Oil 4	Olive Oil 5
Grade	Extra Virgin	Light/Cooking	Extra Virgin	Virgin	Extra Virgin
Picture of Bottle					

Table 3 – Olive oil samples

Procedure

1. Connect the spectrometer to the USB Port of your laptop computer. Open LoggerPro, and calibrate the spectrometer by filling a cuvette with distilled water and placing it in the Spectrometer.
2. Go to Calibrate → Spectrometer from Experiment Menu. Place the blank cuvette in the spectrometer, making sure clear side/side with arrow is facing the light source of the spectrometer.
3. Prepare 5x5 cuvettes of each olive oil sample using pipettes, making each cuvette 4/5 full. Label the first set of cuvettes filled with the Olive Oil 1 all "1," the second set of cuvettes with Olive Oil 2 all "2," and the other sets "3", "4", and "5", respectively. Within each set of the five cuvettes, label the first cuvette "a" (so its full label is i.e. "1a"), the second cuvette "b" (so its full label is i.e. "1b"), and continue this process for the rest of the cuvettes in the set, so that no oil sample is tested twice.
4. Conduct a full spectrum analysis of the first olive oil sample by placing cuvette 1a in spectrometer, and clicking "Collect."
5. Wait 30 seconds for the analysis to be carried through, and go to "Experiment → Store Last Run." Repeat step 4 for all cuvettes in set 1.
6. Now we attain a table with all the absorbance patterns of the sample at each wavelength for each trial, or run, for our Olive Oil 1, as well as a graph of the absorption pattern across the visible spectrum. Save this data, and go to "New."
7. Repeat steps 4-6 for the other sets of olive oil samples.
8. Collect expended olive oil for later reuse. Clean up materials by placing hot water and dish soap in a large beaker, and submerging all materials with oil on them such as the cuvettes, in the beaker.

Ex
Safety issue? Reuse of oil? I think the student is referring to the cuvettes not the oil.

Lab Diagram *(Not all materials used included)*

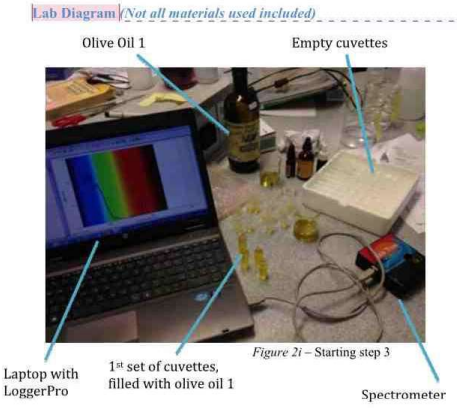


Figure 2i – Starting step 3

Figure 2ii – Step 8

Risk Assessment

No chemicals were used in this experiment. The olive oil used in the experiment was poured out of the cuvettes and given to the science teachers for later use. The soiled cuvettes were mixed with hot water and dish soap and then disposed of, to help the breakdown of the oils. No notable risks are involved in the experiment.

Ex
Safety and environmental issues addressed.

3

Data Collection

Qualitative Data

Figure 3 – Image showing samples of each olive oil side by side to see color difference

Olive Oil	Olive Oil 1	Olive Oil 2	Olive Oil 3	Olive Oil 4	Olive Oil 5
Color difference (on a scale of + to ++++ with the latter being the most deeply colored)	++++	+	++++	+++	+++

Table 4 – Observations from Figure 3

An
Qualitative observations recorded.

Quantitative Data

Raw Data

Through conducting a full spectrum analysis on Olive Oil 1, the data shown in Table 5 was obtained with this raw data being collected from LoggerPro. This table has been shortened to include the absorbance for only the wavelengths within the visible spectrum that are a multiple of 10.

Olive Oil 1

Wavelength (nm)	Absorbance(Au)				
	Run 1	Run 2	Run 3	Run 4	Run 5
390	1.654	1.639	1.692	1.631	1.554
400	2.015	2.017	2.012	1.992	1.962
410	2.401	2.419	2.268	2.310	2.340
420	2.402	2.378	2.359	2.358	2.316
430	1.983	1.985	1.985	2.007	1.975
440	1.734	1.758	1.719	1.749	1.718
450	1.786	1.791	1.771	1.790	1.75
460	1.723	1.745	1.714	1.751	1.698
470	1.435	1.450	1.429	1.449	1.425
480	1.441	1.448	1.433	1.455	1.430
490	1.318	1.317	1.307	1.324	1.294
500	0.935	0.948	0.935	0.945	0.928
510	0.560	0.563	0.559	0.564	0.552
520	0.259	0.258	0.257	0.261	0.254
530	0.203	0.199	0.202	0.202	0.196
540	0.190	0.182	0.189	0.185	0.184
550	0.100	0.092	0.099	0.096	0.096
560	0.099	0.091	0.098	0.092	0.095
570	0.080	0.072	0.081	0.073	0.077
580	0.067	0.057	0.065	0.057	0.063

Table 5 - Absorbance per wavelength for Olive Oil 1

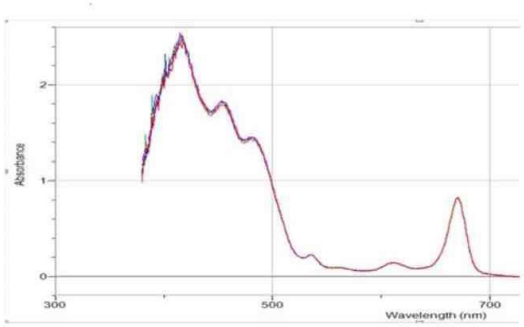
An
Sample of raw data presented and an example of a graphical readout given later.

Com
Would have been better for the table to be all on one page. At least the table headers are repeated on the next page.

Wavelength (nm)	Absorbance (Au)				
	Run 1	Run 2	Run 3	Run 4	Run 5
590	0.067	0.058	0.067	0.059	0.063
600	0.100	0.090	0.099	0.091	0.095
610	0.145	0.138	0.148	0.139	0.141
620	0.119	0.112	0.122	0.111	0.116
630	0.088	0.079	0.088	0.080	0.084
640	0.098	0.089	0.098	0.089	0.093
650	0.156	0.148	0.158	0.148	0.151
660	0.427	0.418	0.426	0.416	0.420
670	0.827	0.821	0.830	0.819	0.819
680	0.338	0.328	0.338	0.326	0.331
690	0.060	0.051	0.059	0.050	0.055
700	0.029	0.021	0.030	0.021	0.026
710	0.015	0.006	0.017	0.006	0.011

Table 5 - Absorbance per wavelength for Olive Oil 1(*continued*)

Below are the graphs attained from LoggerPro for the spectral analysis of each sample. All graphs have the range of -0.2 to 2.6 Au, and domain of 390nm to 710nm, as to be better able to compare results. Graph 1 shows the data collected in Table 5.



Graph 1 - Wavelength vs absorbance for Olive Oil 1

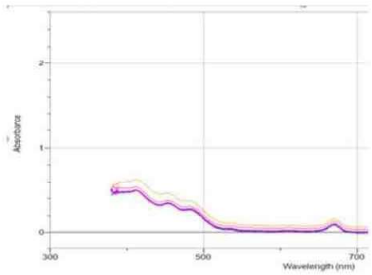
Observations for *Graph 1*:

Graph 1 shows the absorbance spectrum of Olive Oil 1 and contains four peaks at 417, 453, 481, and 670 nm. Compared to the standard chlorophyll peaks in *Figure 1* which are at approximately 425,450, 630, and 670 nm, the first peak is within the 8 nm, the second within 3 nm, the fourth matching the standard.

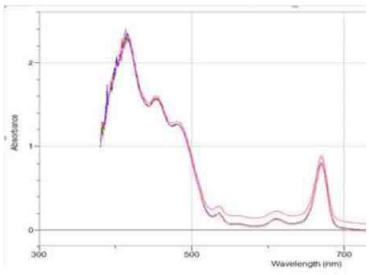
Graphs 2, 3, 4, and 5, display the Wavelength vs. Absorbance graphs for Olive Oils 2, 3, 4, and 5, respectively. Their table can be found in the appendix.

An Interpretation

5



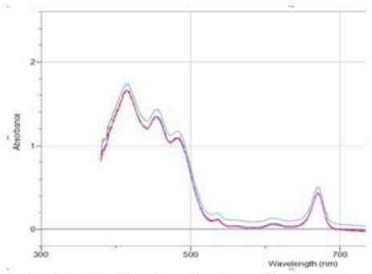
Graph 2 - Wavelength vs absorbance for Olive Oil 2



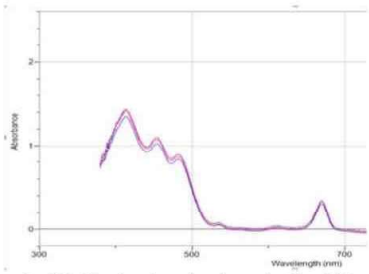
Graph 3 - Wavelength vs absorbance for Olive Oil 3

Observations for *Graph 2:*
There are four minor peaks, at on average, 406, 453, 480, and 670 nm. Compared to the standard, the first peak is within 19 nm, the second within 3 nm, and the fourth matching the standard. HOwever, the absorbance per wavelength for Oil 2 is generally much lower than for Oil 1, as can be seen by the lower range.

Observations for *Graph 3:*
There are four peaks, at 415, 454, 480, and 670nm. Compared to the standard, the first peak is within 10 nm, the second within 4 nm, and the fourth matching the standard. The range of absorption for this oil is greater than Olive Oil 2, resembling Oil 1 more than Oil 2.



Graph 4 - Wavelength vs absorbance for Olive Oil 4



Graph 5 - Wavelength vs absorbance for Olive Oil 5

Observations for *Graph 4:*
There are four minor peaks, at 416, 455, 483, and 670 nm. Compared to the standard, the first peak is within 10 nm, the second within 4 nm, and the fourth within 1 nm. The range absorption for this oil is less than that for Oil 1 and 3, but more than for Oil 2.

Observations for *Graph 5:*
There are four minor peaks, at 413, 455, 483, and 670 nm. Compared to the standard, the first peak is within 12 nm, the second within 4 nm, and the fourth within 1 nm. The range absorption for this oil is less than that for Oil 1 and 3, but more than for Oil 2, resembling most Oil 4.

6

These observations can be organized in the following table:

Sample	**Wavelength at Peak Absorbance (nm)**				**Relative Nature of Absorbance Range**
	1st Peak	*2nd Peak*	*3rd Peak*	*4th Peak*	
Chlorophyll Standard	425	450	630	670	Wide
Olive Oil 1	417	453	481	670	Wide
Olive Oil 2	406	453	480	670	Low
Olive Oil 3	415	454	480	670	Wide
Olive Oil 4	416	455	483	670	Moderate
Olive Oil 5	413	455	483	670	Moderate

Table 6 – Wavelength at which absorbance peaks were located for each Olive Oil sample, nature of absorbance range for

Observations for *Table 6*:
The third peaks in the olive oils, rather than being similar to the chlorophyll standard, deviate greatly. Returning to *Figure 1* allows us to see that at the wavelength 480 nm, it is carotenoids' absorbance that peaks. 630 nm, at the red end of the visible spectrum, is where chlorophyll b peaks mildly. Thus we can conclude that the 3rd peak of the olive oil samples can be neglected as it pertains to carotenoid, rather than chlorophyll, content.

The fourth peaks of the olive oil samples constantly matched the fourth peak of the chlorophyll standard. The first and second peaks varied more from the chlorophyll standard, but the general shape of the graph was maintained in all samples, whether the absorbance range was greater or lesser. The fact that all the samples' peaks remained close to the chlorophyll standard's peaks to retain the general shape of the chlorophyll graph confirms all samples contain chlorophyll.

An
Good argument.

Processed Data

Sample	**1st Peak (Highest Peak)**		**4th Peak (Lowest Peak)**	
	Mean Absorbance (Au) [to 3 decimal places]	*Standard Deviation*	*Mean Absorbance (Au) [to 3 decimal places]*	*Standard Deviation*
Olive Oil 1	2.464	0.052	0.823	0.005
Olive Oil 2	0.515	0.059	0.113	0.032
Olive Oil 3	2.300	0.037	0.818	0.040
Olive Oil 4	1.682	0.041	0.452	0.032
Olive Oil 5	1.407	0.033	0.333	0.017

Table 7 – Mean & standard deviation at highest and lowest peak for each olive oil sample

Calculations were only performed for the 1st(highest) and 4th(lowest) peaks, because this was the absorbance data the software was able to give accurately.

Variables for sample calculations: x is the absorbance at the peak 1 for each trial, and n is the total number of trials per sample, or 5.

7

Sample Calculation for Mean Value:

$$\bar{x} = \frac{\sum x}{n}$$

$$\bar{x}_{Olive\ Oil\ 1} = \frac{2.489 + 2.518 + 2.481 + 2.449 + 2.382}{5}$$

$$\bar{x}_{Olive\ Oil\ 1} = 2.4638$$

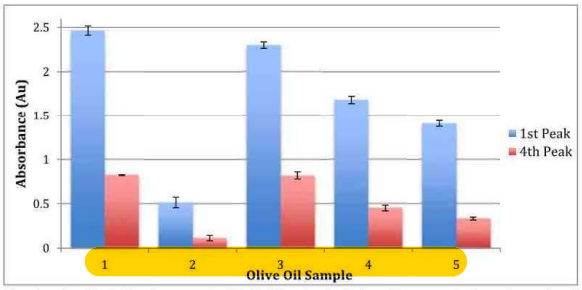
An/Com
Processing can be followed.

Sample Calculation for Standard Deviation:

$$\sigma = \sqrt{\frac{\sum(x - \bar{x})^2}{n}}$$

$$\sigma_{Olive\ Oil\ 1} = \sqrt{\frac{(2.489 - 2.4638)^2 + (2.518 - 2.4638)^2 + (2.481 - 2.4638)^2 + (2.449 - 2.4638)^2 + (2.382 - 2.4638)^2}{5}}$$

$$\sigma_{Olive\ Oil\ 1} = 0.0518$$



Com
The names of the oils would have been more user friendly.

Graph 6 –Sample vs Peak Absorbance *graph of Table 7*showing the highest & lowest peaks for each sample, with standard deviation error bars

Com
Error bars identified.

Observations for *Graph 6:*
Graph 6 shows the absorbance levels at two different peaks for each olive oil sample. What we can see is a strong positive correlation between grade and absorbance. Samples 1 & 2, which are Extra Virgin, have the greatest overall peak absorbance. Sample 4, the Regular sample, still had a relatively high absorbance. Sample 2, the cooking olive oil, had by far the lowest absorbance. Sample 5 was a slight outlier, or exception, as although it was labeled as Extra Virgin, with the results I would classify it as Regular olive oil.

An
A very optimistic interpretation given the range and number of samples.

The error bars allow us to see the variability of data for each sample. Due to their relatively small size, we can conclude that even accounting for errors or uncertainties would not affect our conclusions, i.e. when ordering which samples had the highest absorption.

An
This is correct.

An
Error: 1, 3 and 5 are extra virgin.
Com
Probably a typo.

An
Better to call it an exception rather than an outlier.

8

Ev
The support for this is not strong given the limited data (only 3 grades of oil and all from different brands).

Conclusions

Overall, my hypothesis that chlorophyll content increases as the grade of the olive oil increases can be judged as true due to the positive correlation between these variables, as suggested by the data. Consequently, the null hypothesis can be judged as false. The positive correlation between range of absorbance and grade of olive oil can be seen prominently for Olive Oil 1, 2, 3, and 4. Oil 5 claims to be Extra Virgin, yet its range of absorbance is moderate and only has a higher overall absorbance than Oil 2, the Light/Cooking grade olive oil. From the data from this experiment, we can conclude it should have been graded as Regular olive oil. Using the mean absorbance at the highest peak in *Table 7* we can see that, Olive Oil 1 has the most chlorophyll content, followed by Olive Oil 3, 4, 5, and 2. Relatively, Olive Oil 1 (the Extra Virgin grade) has nearly twice as much chlorophyll content as Olive Oil 4 (the Regular grade), and almost four times the chlorophyll content of Olive Oil 2 (the Light/Cooking grade).

In the Wavelength vs absorbance graphs of each olive oil sample, the general wavelengths at which chlorophyll peaks seem to be the same as that of the olive oils on the visible light spectrum (as seen in *Table 6*), which merely confirm that the olive oils do contain chlorophyll. The slight irregularities of the first and second peaks could most likely be seen as a natural variance arising from differences in location and subspecies of *O. europaea* grown. For example, Olive Oil 1 and 5 are made from olives from the Italian region, while Olive Oil 3 and 4 cite the origin of their olives as various countries in the European Union. Additionally, the way the olive oil was processed (and if additives were used) would be at least slightly different for each olive oil, which could have lead the oil olive to take on a color whose absorbance pattern does not match exactly with chlorophyll or carotenoid absorbance patterns. Furthermore, as we did not isolate chlorophyll in the olive oil samples, other compounds could have influenced the oils' absorbance. These factors all create limitations on the extent that we can claim our data to show a particular conclusion or not. Also, the fact that the *Figure 1* does not show the exact wavelength where the chlorophyll peaks as our data does, and the ability to only relatively examine the relative chlorophyll content of each olive oil sample, could all add to the limitations on the interpretation of the experiment.

Ev
Relevant limitation discussed

Ev
Strengths discussed

Evaluation& Improvements

The experiment was successful to the extent that I was able to find relative differences in chlorophyll in the different grades of olive oil, and thus, was not exact, but certainly demonstrates the varying levels of chlorophyll in the grades. Limitations include that some of the raw data shows greater deviance from the mean than others, which could be attributed to the cuvettes' varying sterility (as these are cuvettes my school's lab reuses), making them have mildly different levels of transparency even before the experiment began [this is also what accounts for the negative absorbance rates in the raw data].Or it could be accounted for by the device's photometric accuracy, which its website states to be ±5.0%.[8] Or, the light constancy might have been inconstant; as there was also natural light in the room and often, this can change moderately as clouds pass. Though, greater irregularity can be attributed to the cuvettes than the light change as the latter was relatively minimal during the duration of the experiment, and I was not close to the windows. Realistic improvements could be to use newly unboxed or thoroughly cleaned cuvettes that will for certain have no smudges on them, and just in case, to perform the experiment in a room with only artificial light that can be held at a constant brightness. Nevertheless, these deviations do not expressively hamper the results, so it can still be resolved that the conclusions stand true.

Ev
Sterility is not the issue. Reused cuvettes will be optically compromised.

Ev
Not really relevant. The readings are taken inside a spectrometer.

One component I was expecting was for the third peak in chlorophyll to show up also in the olive oils. The fact that it didn't is likely due to the variance of chlorophyll types *a* and *b* in different plants. If I had more time, I would look into the chlorophyll composition in various *O. europaea* subspecies. Additionally, I would have created my own chlorophyll wavelength vs absorbance graph by creating an analysis with the spectrometer of a spinach dilute. Another interesting investigation would be extracting carotene from different grades of olive oil, and comparing it to carotene in carrots. The central fallback of my experiment is really that this chlorophyll test is also not the only way that olive oil quality is measured. Thus, it cannot be conclusively said if one olive oil is better than the other (in every way). However, there is a strong correlation between an oil's chlorophyll aggregate and its grade, so generally, my conclusions stand true. To conclusively guarantee my conclusions, I would look into the other ways in which olive oil quality and purity is assessed. However this can become very complex and requires extensive knowledge of chemistry and biochemistry[9], and thus is neither a realistic nor relevant improvement to the experiment.

[8] http://www.vernier.com/products/sensors/spectrometers/visible-range/v-spec/
[9] http://www.internationaloliveoil.org/estaticos/view/224-testing-methods

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Appendix

Olive Oil 2					
Wavelength (nm)	Absorbance (Au)				
	Run 1	Run 2	Run 3	Run 4	Run 5
390	0.467	0.520	0.462	0.466	0.589
400	0.479	0.522	0.472	0.465	0.606
410	0.498	0.536	0.486	0.484	0.625
420	0.457	0.495	0.447	0.449	0.593
430	0.373	0.408	0.363	0.367	0.511
440	0.327	0.362	0.317	0.321	0.453
450	0.341	0.371	0.330	0.334	0.461
460	0.329	0.360	0.320	0.323	0.440
470	0.272	0.308	0.264	0.269	0.381
480	0.276	0.306	0.264	0.269	0.376
490	0.247	0.278	0.236	0.240	0.340
500	0.172	0.200	0.156	0.160	0.255
510	0.103	0.134	0.088	0.093	0.182
520	0.059	0.089	0.043	0.049	0.130
530	0.048	0.077	0.031	0.035	0.115
540	0.038	0.072	0.022	0.027	0.106
550	0.027	0.061	0.012	0.016	0.092
560	0.026	0.061	0.012	0.016	0.092
570	0.021	0.053	0.005	0.008	0.085
580	0.018	0.053	0.004	0.009	0.082
590	0.017	0.051	0.003	0.008	0.080
600	0.019	0.052	0.006	0.010	0.081
610	0.024	0.058	0.012	0.013	0.085
620	0.021	0.053	0.009	0.011	0.084
630	0.017	0.050	0.003	0.006	0.078
640	0.017	0.050	0.003	0.006	0.079
650	0.022	0.055	0.009	0.011	0.083
660	0.052	0.084	0.039	0.041	0.113
670	0.100	0.131	0.087	0.087	0.160
680	0.044	0.075	0.031	0.033	0.104
690	0.012	0.045	-0.001	0.001	0.072
700	0.007	0.039	-0.007	-0.005	0.067
710	0.003	0.035	-0.011	-0.007	0.063

Table 8 - Absorbance per wavelength for Olive Oil 2

Olive Oil 3					
Wavelength (nm)	Absorbance				
	Run 1	Run 2	Run 3	Run 4	Run 5
390	1.550	1.450	1.519	1.444	1.522
400	1.883	1.880	1.825	1.872	1.868
410	2.210	2.195	2.173	2.161	2.176
420	2.227	2.198	2.183	2.176	2.196
430	1.771	1.735	1.730	1.720	1.720
440	1.543	1.507	1.509	1.507	1.497
450	1.576	1.550	1.551	1.539	1.537
460	1.524	1.506	1.502	1.500	1.496
470	1.298	1.263	1.264	1.258	1.254
480	1.300	1.258	1.259	1.252	1.253
490	1.190	1.149	1.148	1.139	1.140
500	0.880	0.831	0.828	0.822	0.824
510	0.551	0.493	0.492	0.486	0.490
520	0.291	0.222	0.219	0.209	0.215
530	0.256	0.178	0.173	0.162	0.174
540	0.251	0.166	0.164	0.150	0.165
550	0.173	0.082	0.077	0.063	0.081
560	0.172	0.081	0.078	0.062	0.082
570	0.158	0.066	0.062	0.047	0.066
580	0.146	0.054	0.050	0.035	0.054
590	0.149	0.056	0.054	0.038	0.057
600	0.181	0.087	0.084	0.070	0.090
610	0.225	0.136	0.133	0.117	0.137
620	0.198	0.111	0.108	0.092	0.112
630	0.170	0.080	0.077	0.062	0.083
640	0.178	0.092	0.090	0.073	0.094
650	0.236	0.149	0.143	0.130	0.150
660	0.500	0.410	0.405	0.391	0.411
670	0.888	0.805	0.797	0.790	0.809
680	0.405	0.329	0.324	0.310	0.330
690	0.136	0.059	0.054	0.042	0.060
700	0.104	0.028	0.024	0.011	0.029
710	0.089	0.017	0.012	-0.001	0.017

Table 9 - Absorbance per wavelength for Olive Oil 3

Olive Oil 4					
Wavelength (nm)	Absorbance (Au)				
	Run 1	Run 2	Run 3	Run 4	Run 5
390	1.120	1.080	1.190	1.087	1.098
400	1.356	1.371	1.450	1.362	1.374
410	1.596	1.598	1.679	1.592	1.607
420	1.570	1.587	1.665	1.577	1.594
430	1.331	1.333	1.424	1.325	1.344
440	1.201	1.213	1.293	1.198	1.215
450	1.301	1.315	1.393	1.300	1.309
460	1.270	1.297	1.375	1.273	1.282
470	1.052	1.068	1.138	1.050	1.060
480	1.080	1.099	1.166	1.077	1.090
490	0.990	1.005	1.074	0.980	0.989
500	0.651	0.664	0.735	0.647	0.650
510	0.348	0.356	0.427	0.343	0.343
520	0.147	0.153	0.222	0.141	0.139
530	0.104	0.110	0.177	0.099	0.093
540	0.094	0.096	0.165	0.089	0.080
550	0.043	0.043	0.112	0.037	0.029
560	0.043	0.043	0.111	0.037	0.028
570	0.032	0.032	0.097	0.025	0.016
580	0.025	0.024	0.091	0.017	0.008
590	0.026	0.024	0.090	0.018	0.009
600	0.043	0.041	0.106	0.033	0.025
610	0.069	0.066	0.130	0.061	0.053
620	0.055	0.052	0.115	0.046	0.038
630	0.038	0.035	0.098	0.029	0.021
640	0.040	0.040	0.104	0.034	0.026
650	0.072	0.070	0.134	0.066	0.059
660	0.218	0.216	0.282	0.211	0.206
670	0.443	0.442	0.508	0.436	0.431
680	0.168	0.167	0.230	0.160	0.155
690	0.021	0.019	0.079	0.014	0.008
700	0.004	0.003	0.062	-0.003	-0.011
710	-0.002	-0.004	0.054	-0.010	-0.018

Table 10 - Absorbance per wavelength for Olive Oil 4

Olive Oil 5					
Wavelength (nm)	Absorbance (Au)				
	Run 1	Run 2	Run 3	Run 4	Run 5
390	0.958	0.925	0.986	1.008	1.014
400	1.203	1.151	1.223	1.222	1.226
410	1.363	1.319	1.407	1.404	1.393
420	1.324	1.261	1.349	1.345	1.346
430	1.086	1.039	1.116	1.111	1.108
440	0.959	0.919	0.985	0.983	0.979
450	1.044	1.000	1.072	1.070	1.068
460	1.009	0.971	1.032	1.033	1.032
470	0.823	0.790	0.850	0.847	0.846
480	0.854	0.827	0.883	0.881	0.881
490	0.773	0.743	0.801	0.799	0.797
500	0.486	0.466	0.508	0.507	0.505
510	0.234	0.224	0.257	0.256	0.255
520	0.080	0.074	0.101	0.099	0.096
530	0.051	0.045	0.072	0.072	0.069
540	0.040	0.032	0.060	0.059	0.056
550	0.004	-0.002	0.025	0.022	0.020
560	0.003	-0.004	0.024	0.021	0.019
570	-0.003	-0.014	0.016	0.012	0.010
580	-0.010	-0.019	0.009	0.006	0.006
590	-0.010	-0.019	0.008	0.007	0.004
600	0.004	-0.006	0.021	0.019	0.019
610	0.025	0.014	0.042	0.040	0.039
620	0.016	0.004	0.032	0.029	0.029
630	0.003	-0.007	0.020	0.017	0.017
640	0.007	-0.002	0.024	0.022	0.021
650	0.034	0.023	0.051	0.049	0.046
660	0.155	0.140	0.173	0.172	0.168
670	0.328	0.305	0.345	0.344	0.343
680	0.119	0.104	0.134	0.134	0.133
690	-0.001	-0.008	0.016	0.014	0.012
700	-0.013	-0.021	0.002	0.001	-0.001
710	-0.026	-0.033	-0.010	-0.011	-0.014

Table 11 - Absorbance per wavelength for Olive Oil 5