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Review Article

Chemical Composition and Sensory Analysis of Olive Oil Produced In the North-West of Saudi Arabia

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Abstract *- Chemical composition and sensory analysis of olive oil samples extracted from different olive cultivars grown in the North-West of Saudi Arabia was conducted to evaluate the quality of olive oil. Organoleptic analysis of the olive oil samples shows Jordan variety with high fruity, low bitter, and light pungent flavor, tasting like sweet oil; Picual with strong fruitiness, light pungent flavor, and oil with typical organoleptic character. Coratina was with high level of fruitiness, high bitter, pungent and astringent flavor with very high oxidation stability. Olive oil production results proved the capability of the company to produce extra virgin olive oil with chemical composition and organoleptic characters matching the IOC standards from most of the varieties, and in particular, Jordan, Picual, and Coratina, as we observed high content of oleic acid and medium to low content of linoleic and Palmitic fatty acids; the linolenic fatty acid was below 1% on all varieties.*

Keywords *- Chemical Composition, %Oil Acidity, Peroxide Value, Rancidity, Sensory Analysis.*

1. Introduction

Olive oil is defined as oil obtained solely from the fruit of the olive tree (*Olea europaea* L.), and virgin olive oils are the oils obtained from the fruit of the olive tree solely by mechanical or other physical means under conditions, particularly thermal conditions that do not lead to alterations in the oil (IOC, Designations, and Definitions of olive oils). Olive oil extracted from healthy olive fruits and harvested at the appropriate maturity stage Fig 1A is characterized by excellent smell, strong flavor, and wonderful taste due to the presence of volatile materials, polyphenols, oleic acid, and linoleic acid. The bitter and spicy taste will force you to cough when sipping a tablespoon of this oil and touching the throat. The spicy taste of the oil is related to the polyphenols and the bitter taste of the glycosides found in green fruits and leaves. The color of the oil of good quality is light yellow to green Figure 1B –C, and the oil color is due to the chlorophyll and xanthophyll pigments. Olive oil is extracted at high temperatures, and the chemically extracted oil loses its taste, aroma, and flavor due to the loss of polyphenols. It will affect the degree of preservation.

Olive oil is a complex compound consisting of tri-fatty acid glyceride (IOC, Trade standard applying to olive oils and olive-pomace oils, 2015), which accounts for about 98.5% - 99% of the oil component and is called the saponfiable part; the other part is non-saponfiable and constitutes 1 – 1.5% of the oil component. It contains vitamins A, D, E, and K, polyphenols, colored compounds, and a small number of mineral elements such as iron, manganese, and calcium, in addition to aromatic substances, colloids, resins, and a small amount of water. In the components of triglyceride fatty acids: There are saturated fatty acids 8 - 23.5%, mono-unsaturated fatty acids 56 - 88.5%, di-unsaturated fatty acids 3.5% - 20% and tri-unsaturated fatty acids 0 - 1.5%.

When storing olive oil for a long period of time, it loses its taste and strong flavor due to oxidation and the occurrence of rancidity, which leads to bad taste and smell and becomes unfit for human consumption (Mailer *et al*., 2006; Vossen 2007. There are many changes in the composition of olive oil under certain conditions, and the most important of these changes are related to the quality of olive oil: acidity, oxidation, and rancidity. %Acidity is the percentage of free fatty acid in the oil estimated as oleic acid (g / 100 g oil). The percentage of acidity is an important measure for determining the quality of oil and its suitability for human consumption as per the international olive oil council standards [(IOC-1996); (EU – 2002)] into the following grades:

Extra virgin olive oil: %acidity equals or less than 0.8%.

Virgin olive oil: %acidity equals or less than 2%

Ordinary virgin olive oil: %acidity equals or less than 3.3%

Lampante virgin olive oil: %acidity is above 3.3%

The acidity of the oil is increased by the degradation of the triglyceride fatty acid by the lipase enzyme into the oil in the presence of high humidity of the oil or its surroundings with its heat leading to the production of free fatty acids along with di-glycerol or mono-glycerol or glycerol according to the following equation:

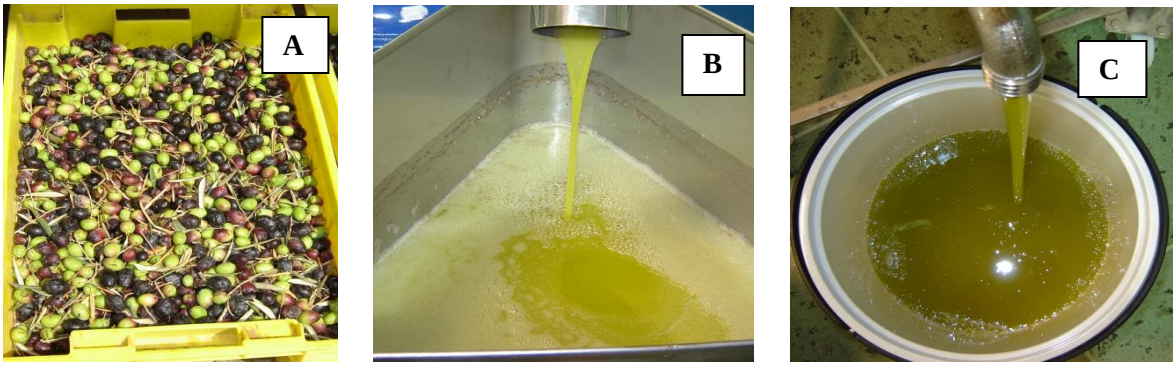

Fig. 1 A. Olive fruits of appropriate maturity, B. the color of the oil of good quality are light yellow to green, C.

$$\text{Oil + water} \xrightarrow{\text{Lipase enzyme with heat}} \text{fatty acids + glycerol}$$

The acidity of the oil is initiated when the oil is stored in containers accompanied by vegetative water or sediment for a long period of time, and acidity arises when neglecting the preservation and storage of oil. The origin of the acid can be from the beginning of storage for the following reasons:

- Injury of fruits by olive fruit fly.
- Infection of fruits with fungal pathogens such as *Gleosporium and Macrosporium*.
- Occurrence of rot fungus during storage due to delayed processing of the fruits for oil extraction after harvest, especially when there are mechanical bruises on the fruits.

Oxidation is the attachment of oxygen molecules with the unsaturated fatty acid molecule: The unsaturated bonds in the fatty acid molecule are active centers in terms of their ability to interact with the active oxygen, leading to the formation of hydroxyoxide and peroxide.

The olive oil is oxidized during the storage process by self-oxidation enzymes, which occur in the absence of air by the free radicles produced by the active oxygen. The antioxidants in the oil temporarily stop these reactions by absorbing those free radicles. When antioxidants are exhausted, free radicles begin to attack the fatty acids, and the oil becomes ***rancid*** and loses its validity rapidly, occurring in one to three years of storage, depending on the storage conditions of the oil and the class of the oil. Another type of oxidation occurs in the presence of light, called oxidative light, which occurs with the interaction of unsaturated bonds in the fatty acid with light-induced oxygen. This interaction is very fast compared to self-oxidation.

Oxidation is estimated in the oil by estimating the *peroxide* value, which represents the number of milliequivalent peroxide oxygen per kg of oil formed by the oxidation. This parameter measures the degree of oil oxidation and its degree of preservation: According to IOC standards, the use of oil is not allowed for human consumption if the peroxide value in the virgin oil exceeds 20.

The Rancimat test is a useful tool to establish the shelf life of the oil product. It measures the oxidative stability of the olive oil or fat resistance to oxidation (Metrohm Co Catalouge; Reza Farhoosh and Moosavi, 2007). It is carried out using an air current at a temperature of 110 or 130° C; the induction time of olive oil when it loses oxidative stability under this test is 6-11 hours. This test has been accepted into several international standards, for example, AOCS Cd 12b-92 and ISO 6886.

The fatty acid profile measures the proportions of individual fatty acids in the oil and is an important part of the oil chemistry (Codex Alimentarius, 2001). The proportions of the different fatty acids can influence the stability of the oil as well as determine the nutritional value of the oil. Some fatty acids are considered better than others as follows:

- *Oleic acid*: This mono-unsaturated fatty acid is most desired in good olive oil varieties due to its nutritional value.
- *linoleic acid*: This di-unsaturated fatty acid is less nutritional than oleic acid and is not desired in high percentages in good olive oil varieties as it causes instability to the oil due to the presence of a double bond which is chemically reactive.
- *Linolenic acid*: This tri-unsaturated fatty acid with a tri-double bond is more chemically reactive and is undesirable because it causes instability in the oil.
- *Palmitic and Stearic Acids*: These are other components of olive oil and are in the form of saturated fatty acids that are not desired for human nutrition.
- *Ratio of unsaturated/saturated fatty acids:* Olive oil with a low ratio of unsaturated /saturated fatty acid is not desirable as it will show a cloudy appearance of oil in winter when the temperature drop below 15° C.
- *Ratio of mono-unsaturated/poly-unsaturated fatty acids:*

Olive oil with a high ratio of mono-unsaturated to poly-unsaturated fatty acid is desirable as it means more nutritional value due to high oleic acid in the oil and more olive oil stability.

- *Ratio of Oleic Acid/Linoleic fatty acid:* Olive oil with a high ratio of oleic to linoleic fatty acid is desirable as it means more nutritional value due to high oleic acid in the and more stability to the oil as more linoleic cause instability to the olive oil.

New extracted olive oil from fruits harvested at the appropriate maturity stage of any variety contains high levels of antioxidants, including polyphenols, tocopherols, and chlorophyll (Montedero *et al*., 1991; Mailer *et al*., 2006; IOC). Antioxidants prevent oil oxidation and the occurrence of rancidity, which may be encouraged by other factors such as heat, moisture, air contact, and metal contact (iron, copper, and manganese).

Tocopherols control the oil's stability and the degree of preservation: 90% of them are in the form of *alpha-tocopherol*, known as vitamin E, and have a concentration of about 250 mg/kg oil. Olive oil may appear green due to *chlorophyll* which may reach a level higher than 10 mg/kg oil depending on the variety and maturity of the fruit, which gradually changes with increasing maturity until it disappears. Chlorophyll acts as an oxidizing agent in the presence of light but acts as an antioxidant when keeping oil in the dark alongside polyphenols. *Polyphenols* are strong antioxidants and important for olive oil's stability and flavor characteristics of bitterness and pungency in olive oil. There is a positive correlation between the polyphenols level and the oxidation stability of virgin olive oil, also between polyphenols and organoleptic characteristics. High polyphenols level in olive oil is crucial in preserving the oil's integrity and benefits and preventing oil rancidity. The amount of polyphenols in the extracted oil increases when using two-phase decanters because little water or none is added during the extraction compared to the three-phase decanters as the water is added to the mixture. The storage period of oil also affects its polyphenols content. Polyphenols act as self-antioxidants in stored oil. The level of polyphenol components in olive oil varies according to olive variety, fruits maturity stage and level of storage, extraction method, and oil storage period.

Sometimes the taste of old oil may seem good when exposed to air for the first time. Still, after a few weeks, the taste of the oil is old and oxidized, while modern oil remains good for several months despite exposure to air because it contains antioxidants.

One of the most important aspects of olive oil classification and value determination is sensory analysis (Mailer et al., 2006; Vossen, 2007; IOC, 2015): It is carried out by a group of eight tasters with good knowledge of sensory assessment of olive oil. They should be able to detect and identify the positive characteristics and defects of olive oil sensory components. As per IOC, the positive characteristics of virgin olive oil are:

- Fruity: oil taste and smell are similar to fresh matured olive fruits harvested at the proper stage of maturity.
- Spicy (peppery): the spicy taste of olive oil when it touches the throat, forcing you to cough.
- Green (grass or apple): oil taste like when you add green leaves with the olive fruits.
- Bitter: Characteristics of olive oil obtained from unripe olives. Perceived in the back of the tongue.
- Pungent: Biting tactile sensation characteristics of olive oil produced from unripe olives.
- Sweet oil: the fine taste of oil but not sugary and opposite to bitter, pungent, or peppery oil taste.
- Negative defects are caused by improper fruit storage and handling, pest infestation, processing, or storage problem, and they include:
- Rancid: Typical flavor of oils that have undergone heavy oxidative deterioration with an unpleasant smell.
- Fusty: Flavor of oils processed from olives stored for a long period of time in heaps or sacks.
- Moldy: Flavor of oil extracted from olives stored for lengthy storage under humid conditions.
- Muddy sediment: Flavor of oil left into prolonged contact with sediment.
- Putrid: Flavor of oil left into prolonged contact with sediment undergoing anaerobic fermentation.
- Metallic: Flavor of oil that has been in prolonged contact with metal surfaces.
- Heated: Flavor of olive oil exposed to high temperature during crushing or mixing of the olive paste.

This article is a review of research work published in January 2019, and it is a review of research work carried out by the author during the period 1997–2002 on the different olive cultivars grown at TADCO and the consultation visits of Mr.Sonnali on April 1998 and Professor Fontanazza on December 2002. This study aimed to evaluate the quality of TADCO olive oil extracted from different olive cultivars.

2. Materials and Methods

Fourteen settled (non-filtered) olive oil samples of 1997 products filled into glass bottles (500 ml) were sent for analysis on April 1998 to Chemi Service laboratory in Bari, Italy, through the consultant Mr. Attilio Sonnoli.

Further samples were collected to evaluate the quality of TADCO olive oil extracted from different olive cultivars; eight olive oil samples of old 2001 products were sent on October 10, 2002, along with olive fruits samples green and black; and another eight filtered olive oil samples of fresh

2002 product were sent to Italy on November 26, 2002, to the olive consultant Prof. Giuseppe Fontanazza. The oil samples were analyzed at the CNR/ISOFAM laboratory in Perugia, Italy (Fontanazza, 2002).

3. Results

Analysis of olive oil samples of 1997 products **(**Vossen, 2007; IOC 2015)

The results of the chemical and quality analysis on the olive oil samples of the 1997 product is presented in Table 1 and 2; we observed the following:

3.1. Percentage Olive Oil Extraction

Most of the olive cultivars produced medium to a high percentage of olive oil and ranging from 9.76 to 23.60; olive oil extraction from the cultivars Surani, Ayvalik, Coratina was above 20%, which reached 23.60, 21.84, 20.00% respectively followed by Jordan with 17.83% then Picual with12.84% then Frantioi with 10.63%.

3.2. %Acidity as oleic acid

The %acidity of the oil samples ranged from low with 0.12% to medium with 1.77%: eight olive oil samples were below 0.8%, representing the cultivars Jordan (4 samples), Picual (2 samples), Frantioi (one sample), Coratina (one sample); two samples with %acidity below 1% representing one sample for Picual and one sample for Surani. Four oil samples were with %acidity above 1%: Picual (one sample), Ayvalik (two samples), and Surani (one sample).

3.3. Peroxide Value

The peroxide value of the different oil samples ranged from a low value of 3.25 to a high value of 16.95 milliequivalent/kg olive Oil: Ayvalik olive oil samples were within a range of 3.25 – 5.35, followed by Picual with a range of 5.60 – 6.75 then Jordan with a range of 4.95 - 9.15 then Coratina one sample with 6.90, then Surani with a range 7.8 – 9.0 and Frantioi with a range of 9.5 – 16.95 milliequivalent/kg olive Oil.

3.4. Rancimat Test

The oxidative stability of the different oil samples ranged from low 2.20 to high 7.9 hours. As the harvest time was delayed, oxidative stability was compromised, as shown in the Jordan oil sample with a value of 3.74 for late harvest on November 19, and the same occurred on the Picual sample with a value of 2.20 for late harvest on December 9 and Frantioi for late harvest on October 19 with value 2.93. Also, in the case of late maturing varieties, the oxidative value was compromised, as in Ayvalik of October 22 harvests. Oxidative stability value was the highest on late maturing cultivar Coratina with a value of 7.9, followed by Picual with a value range of 5.52 - 5.93, then Jordan with a value range of 4.85 – 4.87 then Frantioi with a value 4.02 then Surani and Ayvalik with a value of 3 hours.

3.5. Polyphenols

The polyphenols level in the olive oil samples of the different oil cultivars ranged from a low level of 35 ppm to a high level of 430 ppm on the Coratina oil sample, followed by Frantioi with a range of 114 - 130 ppm, then Jordan with a range 55 – 100 ppm then Surani with a range 62 – 100 then Ayvalik 73 – 99 ppm then Picual 35 – 58. Polyphenols act as self-antioxidants in stored oil. The level of polyphenol components in olive oil varies according to olive variety, fruits maturity stage and level of storage, extraction method, and oil storage period.

3.6. Fatty Acid Profile

Analysis results shows the following:

3.6.1. Oleic Acid

Cultivars Jordan, Picual, and Coratina had a high percentage of oleic acid and ranged from 69.48 to 74.39%; oleic acid on Picual reached 74.39%, followed by Coratina at 73.90% then Jordan with 71.39%. Cultivars Ayvalik, Surani, and Frantioi were with a medium percentage of oleic acid and ranged from 62.48 – 67.28 and reached 67.28% on Ayvalik, followed by Surani at 65.58%, then Frantioi at 63.38%.

3.6.2. Linoleic Acid

The %linoleic acid on cultivars with high %oleic acid was with low linoleic acid as it ranged on picual 4.7 – 8.2% and Jordan it ranged 6.9 – 7.3% and on Coratina 9.9%, and this lead to more stability of olive oil. The %linoleic acid on cultivars with medium %oleic acid was higher, and it ranged on Ayvalik 11.3 – 13.2% and Frantioi 14.10 – 15.20%, and on Surani 11.3 – 17.2%, and this lead to less stability of olive oil.

3.6.3. Palmitic and Stearic Acids

The %total of saturated acid on most of the cultivars ranged from 17.1 - 19.9% except for Coratina, which contained 14.1%, far less than other cultivars.

3.7. Panel Test

Results of the panel test show the following:

3.7.1. High score and above 6.5

Two Picual oil samples from November 6 and 26 harvests, one Frantioi oil sample from October 18 harvest, and one Coratina oil sample from December 11 harvest.

3.7.2. Medium score range 4.5 – 6.5

Four Jordan oil samples # 1,2,3,4, one Picual oil sample from late harvest on December 9, Frantaioi oil samples from October 16 harvest, Ayvalik samples from Oct 22 harvest and two Surani oil samples from Oct 25 and November 17 harvest.

3.7.3. Low score 2.5 – 4.5

One Ayvalik oil sample from November 11 harvest.

3.8. Comments on the results of 1997 Product Samples

As per the panel test, there were no defects on the oil samples of the 1997 product, and the fruitiness of the oil samples was above 0, then all of the oil samples were fit for Extra Virgin or Virgin grade dependent on the results of the chemical analysis.

The results of the chemical analysis on the fourteen olive oil samples showed the grade of the oil samples conformed with extra virgin on Jordan, Picual, Frantioi, Coratina and in conformity with the virgin grade on Ayvalik and another four samples of picual and Frantioi as shown in Table 1 and 2.

It was observed three varieties with good chemical composition: Coratina, Jordan, and Picual as they showed a high %oleic acid which ranged from 69.48 – 74.39, and a low percentage of linoleic, linolenic acid, and a medium percentage of saturated fatty acid. High olive oil oxidation stability was also observed on Coratina, while it was medium stability on Jordan and Picual. Oxidation stability decreased on the late harvest of Jordan and Picual varieties.

3.9. Analysis of Olive Oil Samples of 2002 Product (Mailer et al., 2006; Vossen, 2007; Fontanazza et al., 2002; IOC 2015)

3.9.1. Percentage Olive Extraction

Most of the olive oil samples of the different cultivars were with a medium percentage of olive oil and ranged from 10.52 to 17.84; olive oil extraction from the cultivars Surani, Ayvalik, Coratina was relatively high as it reached 17.84, 16.83, 16.09% respectively followed by Verdale with 14.62% then Jordan 14.61% then Frantioi 13.86% then Picual 13.18% then Manzanilla 12.07% then Improved Nabali 10.52%.

3.9.2. Olive Oil Samples Analysis

The results of the chemical analysis on the olive oil samples of the 2002 product are presented in Table 3; we observed the following:

3.9.3. %Acidity as oleic acid

The %acidity of the oil samples ranged from low with 0.3% to medium with 1%: seven olive oil samples were below 0.8%, representing the cultivars Jordan, Frantioi, Surani, Manzanilla, Picual, Improved Nabali, and Coratina; two oil samples with acidity 1% representing Ayvalik and Verdale.

3.9.4. Peroxide Value (Meq O_2/kg oil)

Ayvalik olive oil sample was with peroxide value of 7.4 milliequivalent/kg olive, which was the lowest number, and the Surani oil sample was with peroxide value of 12.2, which was the highest, and the rest of the varieties were within the range of 7.4 – 12.2 milliequivalent/kg olive. These results indicate proper fruit and paste handling during oil extraction.

3.9.5. Polyphenols

The polyphenols level in the olive oil samples of the different olive cultivars ranged from a medium level of 85 ppm to a high level of 286 ppm. Manzanilla was with the highest polyphenol level, which reached 286 ppm, followed by Coratina with 266 ppm, which is less than in 1998 due to storage for one year, then Jordan with 170 ppm then, Frantioi with 168 ppm then, Verdale with 164 ppm then Ayvalik 92 ppm then Picual 89 ppm then Surani with 85 ppm. These levels were higher than in the 1998 analysis, as samples were sent immediately after extraction on November 2002.

3.9.6. Fatty Acid Profile

Analysis results show the following:

Oleic Acid

Cultivars Coratina, Manzanilla Jordan, and Picual had a relatively high percentage of oleic acid and ranged from 66 – 73.04; %oleic acid on Coratina reached 73.04%, followed by Manzanilla with 68.08% then Jordan with 67.73%, then Picual with 66%. Cultivars Improved Nabali, Frantioi, Surani, Verdale, and Ayvalik were with medium percentage oleic acid and ranged from 60.54 – 63.2%. It reached 60.54% on Improved Nabali, followed by Frantioi with 61.05%, Surani at 62.1%, Verdale at 62.86%, and Ayvalik at 63.20%.

Linoleic Acid

The %linoleic acid on cultivars with high %oleic acid was low, ranging from 8.36 – 11.1%; on Manzanilla, it reached 8.36%, followed by Jordan with 9.75%, then Coratina with 9.9% then 11.1% on Picual. The %linoleic acid on cultivars with medium %oleic acid was higher and ranged from 13.85 – 16.85%; on Verdale13.85% then, Surani at 14.33% then, Improved Nabali at 14.87% then Ayvalik with 15.03 then Frantioi 16.55%.

Palmitic and Stearic Acids

The %total of saturated fatty acids on most of the cultivars ranged from 17.1 - 19.9 except for Coratina, which contained 14.1%, far less than other cultivars.

Ratio of unsaturated/saturated fatty acids

Olive oil with a low ratio of unsaturated /saturated fatty acids are not desirable as it will show a cloudy appearance of oil in winter when the temperature drop below 15^{o} C. Coratina was with the highest ratio as it reached 5.53 followed by Frantioi with ratio 4.26 then Ayvalik with ratio 4.22 then Jordan with a ratio 4.04 then Picual 3.95 then Verdale & Manzanilla 3.82 then Surani 3.75 then Improved Nabali 3.57.

Ratio of mono-unsaturated/poly-unsaturated fatty acids

Olive oil with a high ratio of mono-unsaturated to poly-unsaturated fatty acid is desirable as it means more nutritional value due to high oleic acid in the oil and more

olive oil stability. Manzanilla, Coratina 01, and Jordan had high ratio values of 7.69, 6.98, 6.66, respectively, followed by picual with a ratio of 5.75 then, Verdale with 4.42 then, Surani with 4.23 then improved Nabali with 4.0then Frantioi 3.59.

Ratio of Oleic Acid/Linoleic fatty acid

Olive oil with a high ratio of oleic to linoleic fatty acid is desirable as it means more nutritional value due to high oleic acid in the oil and more stability to the oil as more linoleic cause instability to the olive due to presence of double bond. Manzanilla, Coratina 01, and Jordan had high ratio values of 8.14, 7.38, 6.95, respectively, followed by Picual with a ratio of 5.95 then, Verdale with 4.54 then, Surani with 4.33 then, Ayvalik with 4.20 then improved Nabali 4.07 then Frantioi 3.62.

3.10. Panel Test

The results of the organoleptic analysis on the olive oil samples of the 2002 product are represented in Table 4 as follows:

3.10.1. Frantioi oil sample

No defects were detected on the oil sample. The panel identified positive characteristics of this oil as fruity, with moderate bitter and pungent flavor, and scored 6.

3.10.2. Jordan oil sample

No defects were detected on the oil sample. The panel identified positive characteristics of this oil as highly fruity, with low bitter and light pungent flavor, taste like sweat oil, and it scored 5.

3.10.3. Picual oil sample

No defects were detected on the oil sample. The panel identified positive characteristics of this oil as it was with strong fruitiness, low bitter and light pungent flavor, oil with typical organoleptic character, and scored 5.

3.10.4. Manzanilla oil sample

No defects were detected on the oil sample, The panel identified positive characteristics of this oil as fruity with low bitter, moderate pungent flavor, and it scored 5.

3.10.5. Improved Nabali oil sample

No defects were detected on the oil sample, The panel identified positive characteristics of this oil as highly fruity, with low bitter and light pungent flavor, oil with typical organoleptic character, and it scored 4.5.

3.10.6. Ayvalik oil sample

No defects were detected on the oil sample. The panel identified low-level positive characteristics of this oil: with light fruity and light pungent flavor, no bitter taste, oil is sweet & medium fluid, and it scored 2.

3.10.7. Surani oil sample

Defect rancid 2 was detected on the oil sample. The panel identified no positive characters on this oil and scored 0.

3.10.8. Verdale oil sample

Defect rancid 2 was detected on the oil sample. The panel identified no positive characters on this oil and scored 0.

3.11. Comments on the results

As per the panel test on eight olive oil samples of 2002 product:

- There were no defects on the oil samples of Jordan, Frantioi, Manzanilla, Picual, Improved Nabali, and Ayvalik, and the fruitiness of the oil samples was above 0. These oil samples were fit for Extra Virgin or Virgin grade, dependent on the results of the chemical analysis.
- There were rancidity defects (score 2) detected on the oil samples of Surani and Verdale, and the total flavor was zero, then these samples due to rancidity defects were not fit for human consumption, and the class of these two samples is Lampante virgin olive oil as shown in Table 4
- As per the results of the chemical analysis on the eight olive oil samples, the grade of the oil samples conformed with extra virgin on Jordan, Frantioi, Manzanilla Picual, and Improved Nabali, and in conformity with the virgin grade on Ayvalik as shown in the Table. 5

4. Discussion

The sensory analysis results (Panel Test) (Mailer *et al*., 2006; Vossen, 2007; IOC 2015) on the fourteen olive oil samples of 1997 product (non-filtered) showed no defects in the oil samples Table 5, and the fruitiness of the oil samples was above 0. All of the oil samples were fit for extra virgin or virgin grade, dependent on the results of the chemical analysis. As per the results of the chemical analysis on the oil samples, the grade of the oil conformed with extra virgin on Jordan, Picual, Frantioi, and Coratina, and in conformity with the virgin grade on Ayvalik and another four samples of Picual, Frantioi.

The organoleptic analysis on the olive oil samples of the 2002 product showed the following:

4.1. Frantioi sample

No defects were detected on the oil sample; the panel identified positive characters on this oil as fruity, with moderate bitter and pungent flavor, and scored 6.

4.2. Jordan sample

No defects were detected on the oil sample; the panel identified positive characteristics of this oil as highly fruity,

with low bitter and light pungent flavor, tasting like sweat oil, and it scored 5.

4.3. Picual sample

No defects were detected on the oil sample; the panel identified positive characteristics of this oil as it was with strong fruitiness, low bitter and light pungent flavor, oil with typical organoleptic character, and it scored 5.

4.4. Manzanilla sample

No defects were detected on the oil sample, The panel identified positive characteristics of this oil as fruity with low bitter, moderate pungent flavor, and it scored 5.

4.5. Improved Nabali sample

No defects were detected on the oil sample, The panel identified positive characteristics of this oil as highly fruity, with low bitter and light pungent flavor, oil with a typical organoleptic character, and it scored 4.5.

The Sensory analysis test (Panel Test) (Mailer *et al*., 2006; Vossen, 2007; IOC 2015; Fontanazza *et al*., 2002) on the eight olive oil samples of 2002 product showed no defects on the oil samples of Jordan, Frantioi, Manzanilla, Picual, Improved Nabali, Ayvalik and the fruitiness of the oil samples was above 0. These oil samples were fit for Extra Virgin or Virgin grade, dependent on the results of the chemical analysis. As per the results of the chemical analysis on the eight olive oil samples, the grade of the oil samples conformed with extra virgin on Jordan, Frantioi, Manzanilla Picual, and Improved Nabali, and in conformity with the virgin grade on Ayvalik as shown in Table 6.

A rancidity defect (score 2) was detected on the oil samples of Surani and Verdale, and the total flavor was zero. Due to rancidity defects, these samples are not fit for human consumption, and the class of these two samples was Lampante virgin olive oil. This problem was checked and corrected in the processing and storage facilities at the company olive mill.

Results of the analysis of oil samples of 1997 and 2002 products (Vossen, 2007; IOC, 2015; Fontanazza *et al*., 2002) showed the good chemical composition of the varieties Coratina, Jordan, Picual as they have shown high %oleic acid which ranged 69.48 – 74.39 and low percentage of linoleic, linolenic acid besides the medium percentage of saturated fatty acid considering high summer temperature in the project. High olive oil oxidation stability was also observed on Coratina, while it was medium stability on Jordan and Picual. Oxidation stability decreased on late-harvest products of Jordan and Picual varieties.

On the 2002 product, we observed a high ratio of mono-unsaturated / poly-unsaturated fatty acid on Manzanilla, Coratina2001 product, and Jordan, which reached 7.69, 6.98, 6.66, respectively; also a high ratio of Oleic/Linoleic fatty acid on the same varieties which reached 8.14, 7.38, 6.95 respectively. Both results indicate the nutritional value of the oil due to high oleic acid content and more olive oil stability.

%Olive oil extraction on the mill showed higher %oil extraction (Pannelli et al., 1990; Fontanazza *et al*., 2002; Vossen, 2004) on the different varieties in the 1997 cropping season, which ranged from 9.76 – 23.6% in comparison to 2002 cropping season which ranged 10.52 – 17.84%. The drop in %oil extraction in 2002 was due to the adaption of a cold press at 28^{o}C. And early fruits harvest to get high olive oil quality. In general % of olive oil extraction under irrigated growing conditions in the desert is lower than %oil extraction under rain-fed growing conditions, but irrigated olive trees bear fruits annually, unlike rain-fed olive trees, which tend to have an alternate bearing. Olive varieties with high percentage olive oil extraction were Ayvalik, Surani, and Coratina, with a range of 15 – 20%, while Jordan, Picual, and Verdale were with medium %oil extraction, with a range of 12 – 15%; Improved Nabali and Frantioi were with low %oil extraction with a range of 10 – 12%.

5. Conclusion

The results demonstrated the possibility of producing extra virgin olive oil matching the IOC standards at TADCO. The area was free from the infestation of olive fruit flies, and rainfall was limited and predictable, so the farmers avoided harvesting olives during rainfall. As we observed in this work, the company produced high-quality olive oil from most varieties.

6. Recommendations

- Recommend applying an integrated management system for olive fruits and olive oil production based on understanding the various factors affecting the quality of olive fruits and olive oil through applying a food safety management system like ISO 22000.
- Regular monitoring of the quality of the olive oil products during storage through lab samples analysis.
- Create a Blend of olive oil from the different olive varieties; the blend is based on customer preference coupled with good chemical composition and organoleptic characters matching Jordan and Picual olive oil varieties.
- Use tight closed stainless steel storage silos and top them with nitrogen gas to avoid oil oxidation and help maintain quality and freshness.
- Use dark glass bottles for olive oil sales in the supermarket to avoid oil oxidation by light, and use food-grade laminated tins to pack olive oil for sales

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APPENDIX

Table 1. Analysis* results of fourteen olive oil samples of 1997 olive oil product on 28th of April 1998

Type of Analysis	Jordan	Jordan	Jordan	Jordan	Picual	Picual	Picual	Acceptable level **
Sample #	1	2	3	4	5	6	14	
Harvest Date	Sept 20, 1997	Oct 21, 1997	Nov 19, 1997	Nov 30, 1997	Nov 6, 1997	Nov 26, 1997	Dec 9, 1997	
% Oil Extraction	12.56	14..13	14.66	17.83	12.84	12.62	10.06	
Panel Taste Test	5.9	6.10	5.9	5.4	6.8	6.9	6.0	EVOO: Defect.- 0 fruity ≥ 0 VOO: Def. ≤ 3.5 fruity > 0 OVOO: Def. 3.5 - 6 LVOO: Def. > 6
%Acidity as Oleic Acid (g/100 g Oil)	0.32	0.37	0.32	0.58	0.16	0.12	1.13	≤ 0.8% EVOO ≤ 2% VOO ≤ 3.3% OVOO ≥ 3.3% LVOO
Peroxide Number (Meq O_2 / Kg Oil)	9.15	8.75	6.15	4.95	6.15	5.60	6.75	≤ 20
Rancimat Test (hours)	4.85	4.87	3.74	4.07	5.93	5.52	2.20	6 – 11 ***
Polyphenols (ppm)	96	103	55	100	56	35	58	
% Unsaturated Fatty Acid								
%Oleic Acid	70.68	70.29	71.39	71.09	73.09	74.39	69.48	55 – 83%
%Linoleic Acid	7.00	7.30	6.9	7.20	4.8	4.7	8.2	3.5 – 21%
%Linolenic Acid	0.9	0.8	0.8	0.7	0.8	0.8	0.8	≤ 1.0%
%Others	2.2	2.2	2.0	2.0	2.5	2.2	2.21	
%Total	80.78	81.3	81.09	80.99	81.19	82.09	80.69	
% Saturated Fatty Acids								
%Palmitic Acid	16.00	15.90	14.9	14.8	16.1	14.4	15.80	7.5 - 20%
%Stearic	2.5	2.8	3.3	3.5	2.3	2.9	2.90	0.5 – 5%
%Others	0.72	0.71	0.71	0.71	0.41	0.61	0.61	
%Total	19.22	18.7	18.91	19.01	18.81	17.91	19.31	

** Method of Analysis: By Gas Chromatography of methyl esters of fatty acids; Laboratory: Chemi Service Monopoli, Bary, Italy.*

*** In conformity with Olive Oil Standards 2003 (IOC & EU) and [IOC 1996 (EU – 2002)*
**** In Conformity with* ISO 6886, AOCS

Table 2. Analysis* results of fourteen olive oil samples of 1997 olive oil product on 28th of April 1998

Type of Analysis	Fran-tioi	Fran-tioi	Ayvalik	Ayvalik	Surani	Surani	Cora-tina	Acceptable level **
Sample #	8	9	10	11	7	12	13	
Harvest Date	Oct 16, 1997	Oct 18, 1997	Oct 22, 1997	Nov 11, 1997	Oct 25, 1997	Nov 17, 1997	Dec 11, 1997	
% Oil Extraction	9.76	10.63	21.84	20.71	13.44	23.60	20.00	
Panel Test	5..4	6.7	5.2	4.5	5.4	4.9	6.7	EVOO: Defect.- 0 fruity ≥ 0 VOO: Def. ≤ 3.5 fruity > 0 OVOO: Def. 3.5 - 6 LVOO: Def. > 6
%Acidity as Oleic Acid (g/ 100 g Oil)	0.84	0.42	1.77	1.28	0.81	1.06	0.3	≤ 0.8% EVOO ≤ 2% VOO ≤ 3.3% OVOO ≥ 3.3% LVOO
Peroxide Number (Meq O_2 / Kg Oil)	9.5	16.95	5.35	3.25	9.0	7.8	6.90	≤ 20
Rancimat Test (hours)	4.02	2.93	2.00	3.00	3.0	3.00	7.90	6 – 11 ***
Polyphenols (ppm)	114	130	99	73	100	62	430	
% Unsaturated Fatty Acid								
%Oleic Acid	63.38	62.48	64.57	67.28	62.58	65.58	73.90	55 – 83%
%Linoleic Acid	14.10	15.20	13.2	11.3	17.2	11.3	9.9	3.5 – 21%
%Linolenic Acid	1.10	1.10	0.70	0.6	1.00	0.7	0.7	≤ 1.0%
%Others	3.4	2.3	2.0	1.9	1.51	2.0	0.91	
%Total	80.88	81.08	80.47	81.08	82.29	79.48	85.28	
% Saturated Fatty Acids								
%Palmitic Acid	16.5	16.5	16.6	15.8	14.5	16.5	11.8	7.5 - 20%
%Stearic	2.0	1.9	2.2	2.4	2.6	3.4	2.2	0.5 – 5%
%Others	0.62	0.52	0.73	0.72	0.61	0.62	0.62	
%Total	19.12	18.92	19.53	18.92	17.71	20.52	14.72	

* Method of Analysis: By Gas Chromatography of methyl esters of fatty acids; Laboratory: *Chemi Service Monopoli, Bary, Italy.*

** *In conformity with Olive Oil Standards 2003 (IOC & EU) and [IOC 1996 (EU – 2002)]*

*** *In Conformity with* ISO 6886, AOCS

Table 3. Analysis results* of eight olive oil samples of 2002 product and one 2001 product analyzed on November 26, 2002

Type of Analysis	Jordan	Fran-tioi	Surani	Manz-nilla	Picual	Impr-Nabali	Ayvalik	Verdale	Cora-tina 2001 Prod.	Acceptable level **
Panel Test	5	6	Fruit. 0 Rancid 2	5	5	4.5	2	0	Not Tested	EVOO: Defect.- 0 fruity ≥ 0 VOO: Def. ≤ 3.5 fruity > 0 OVOO: Def. 3.5 - 6 LVOO: Def. > 6
%Oil Extraction	14.61	13.86	17.84	12.07	13.18	10.52	16.83	14.62	16.53	
%Acidity as Oleic Acid (g/100g oil)	0.3	0.5	0.7	0.5	0.4	0.4	1.0	1.0	0.4	≤ 0.8% EVOO ≤ 2% VOO ≤ 3.3% OVOO ≥ 3.3% LVOO
Peroxide Value (Meq O_2/kg)	9.6	9.2	12.2	8.2	9.2	8.0	7.4	10.3	8.4	≤ 20
Polyphenols (ppm)	170	168	85	286	89	132	92	164	266	
% Unsaturated Fatty Acid										
%Oleic Acid	67.73	61.05	62.1	68.08	66.0	60.54	63.2	62.86	73.04	55 – 83%
%Linoleic Acid	9.75	16.85	14.33	8.36	11.1	14.87	15.03	13.85	9.9	3.5 – 21%
%Linolenic Acid	0.71	0.80	0.77	0.76	0.73	0.74	0.74	0.78	0.71	< 1.0%
Palmetoleic Acid	1.56	2.00	1.33	1.56	1.61	1.66	1.39	1.39	0.61	
% Saturated Fatty Acid										
Palmitic Acid	16.33	16.55	17.18	17.12	16.85	18.81	16.38	17.26	12.5	7.5 - 20%
Stearic Acid	2.92	2.80	3.26	3.00	2.83	2.56	2.25	2.88	2.36	0.5 – 5%
Ratios										
UNS/SAT	4.04	4.26	3.75	3.82	3.95	3.57	4.22	3.82	5.53	
MONO/POLY	6.66	3.59	4.23	7.69	5.75	4.00	4.12	4.42	6.98	
C18:1/C18:2	6.95	3.62	4.33	8.14	5.95	4.07	4.20	4.54	7.38	

** Method of Analysis: By Gas Chromatography of methyl esters of fatty acids: CNR / ISAFOM, Perugia, Italy.*

*** In conformity with Olive Oil Standards 2003 (IOC & EU) and [IOC 1996 (EU – 2002)]*

Table 4. Organoleptic analysis results on olive oil samples of 2002 products of eight TADCO cultivars on November 26, 2002.

Cultivar	Defects	Flavor				
		Typical Sensations	Fruity	Bitter	Pungent	Total Flavor
Jordan			2.5	1.5	1	5
Frantioi			2	2	2	6
Surani	Rancid 2					0
Manzanillo			2	1	2	5
Picual		Oil with Typical Organoleptic Character	3	1	1	5
Improved Nabali		Oil with Typical Organoleptic Character	2.5	1	1	4.5
Ayvalik		Sweet & medium Fluid	1	0	1	2
Verdale	Rancid 2				0	0

Taste Scale: No sensation: 0 Week Sensation: 1 - 2
Moderate Sensation: 2 - 4 Strong Sensation: 4 – 5

Acceptable level for each grade:
EVOO: Defect,- 0 fruity > 0 VOO: Def. ≤ 3.5 fruity > 0
OVOO: Def. 3.5 - 6 LVOO: Def. > 6

Table 5. Summary results on the analysis of olive oil samples of different olive cultivars of 1997 product on April 1998.

Sample Number	Variety	Panel Test	%Acidity	Peroxide Number	Rancimat Test	Olive Oil Grade
1,2,3,4	Jordan	4.4 – 6.1	0.32 – 0.58	4.95 – 9.15	3.75 – 4.85	Extra Virgin
5,6	Picual	6.8 - 6.9	0.12 – 0.16	5.6 – 6.15	5.52 – 5.93	Extra Virgin
14	Picual	6.0	1.13	6.75	2.20	Virgin
9	Frantioi	6.7	0.42	16.95	2.93	Extra Virgin
8	Frantioi	5.4	0.84	9.5	4.02	Virgin
10.11	Ayvalik	4.5 – 5.2	1.28 – 1.77	3.25 – 5.35	2.00	Virgin
7.12	Surani	4.5 - 5.4	0.81 – 1.06	7.8 – 9.0	3	Virgin
13	Coratina	6.7	0.3	6.9	7.9	Extra Virgin

Table 6. Summary results on the analysis of olive oil samples of different olive cultivars of 2002 product on November 26, 2002.

Variety	Panel Test		%Acidity	Peroxide Value	Olive Oil Class & grade
	Defects	Positive Characters			
Jordan	0	5	0.3	9.6	Extra Virgin
Frantioi	0	6	0.5	9.2	Extra Virgin
Surani	2	0	0.7	12.2	Lampante
Manzanilla	0	5	0.5	8.2	Extra Virgin
Picual	0	5	0.4	9.2	Extra Virgin
Improved Nabali	0	4.5	0.4	8.0	Extra Virgin
Ayvalik	0	2	1.0	7.4	Virgin
Verdale	2	0	1.0	10.3	Lampante

Acceptable level for each grade:

EVOO: Defect.- 0 fruit. ≥ 0 **VOO: Def. ≤ 3.5 fruit. > 0**
OVOO: Def. 3.5 - 6 **LVOO: Def. > 6**