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REVIEW ARTICLE

MANAGEMENT OF OLIVE OIL PRODUCTION, STORAGE AND QUALITY UNDER SEMI-MEDITERRANEAN CLIMATIC CONDITIONS

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ABSTRACT

An integrated management system was developed and practiced at TADCO since 2002 cropping season for olive fruits and olive oil production from different olive varieties grown at the company project. The integrated management system was based on understanding the various factors affecting olive fruits and olive oil production including olive crop factors, stage of fruits maturity and its handling prior to extraction, perfection of olive oil extraction, settling the new produced oil to get rid of impurities, filtration, packing and storage. Storage of olive oil was improved by the replacement of steel drums with the Conical Drums (CRCA) and Aseptic Bags in autumn 2009. Monitoring the quality of olive oil at all stages of processing and storage through frequent oil sampling and laboratory analysis for %acidity, peroxide value and rancidity helped TADCO to maintain good olive oil quality. 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. Organoleptic analysis of the oil shown Jordan variety was high fruity, low bitter and light pungent flavor, taste like sweet oil; Picual with strong fruitiness, light pungent flavor, 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 blends were tested to improve the acceptance of the consumer to the oil of Coratina with the oil of other varieties to improve their chemical composition and the results of two blends were good.

Key words: Cold Press, Olive Oil, %Oil Acidity, Peroxide Value, Rancidity, Sensory Analysis.

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INTRODUCTION

Cultivation of olive crop is expanding in new areas around the globe outside the Mediterranean basin. The olive crop areas expanded rapidly in the north-west of Saudi Arabia in recent years after the introduction of super-high density planting. Getting high quality olive oil is of prime importance to the consumer locally and internationally. Although the cost of olive oil production under traditional planting is high in Saudi Arabia, it is still desired by the consumer due to high quality in terms of taste and flavor. The quality of olive oil produced is influenced by crop factors such as variety, health status of the trees, crop maintenance, irrigation and fertilization, pest and disease control, stage of fruits maturity (Montedoro and Servili, 1991; Cimato, 1990), method of harvest, fruits handling and storage prior to extraction. Quality is also affected by the conditions in which oil extraction was carried out in terms of the cleanliness of the fruits, the temperature of the fruit paste, the extraction method and its duration, the quantity of water added and the efficiency of separation of oil from water. In the fresh extract of olive oil, there are low percentages of water with suspended impurities such as pits of crushed seeds and pulp which precipitate in the bottom of the tank after several days of filling in the tanks. 20 – 30 days after extraction, filtering process should be carried out on the new olive oil to get rid of these impurities before storing oil to maintain its quality during the storage period. Any weakness in the contact ring from the fruits on the trees to the oil packed in the tins and bottles will affect the quality of the olive oil. This article is a review of research work carried out by the authors during the period 1997–2012 on the different olive cultivars grown at TADCO, and the consultation visits of Mr. Sonnali on April 1998, Professor Fontanazza on December 2002 and Eng'r Ali Abu Zurayk on January 2008.The purpose of this study was to develop practical methods for the production and storage of high olive oil quality before it reaches the end user.

Characteristics of Olive Oil and its Components: Olive oil is defined as oil obtained solely from 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

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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 is characterized with excellent smell, strong flavor and wonderful taste due to the presence of volatile materials, polyphenols, oleic acid and linoleic acid. When sipping a tablespoon of this oil and touching the throat, the bitter and spicy taste will force you to cough. The spicy taste of the oil is related to the polyphenols and bitter taste to the glycosides found in green fruits and leaves. The color of the oil of good quality is light yellow to green, and the color of the oil is due to the chlorophyll and xanthophyll pigments. Olive oil extracted at high temperature and the chemically extracted oil loses their taste, aroma and flavor due to the loss of the polyphenols, and 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 and it contains vitamins A, D, E, K, polyphenols, colored compounds and a small amount of mineral elements such as iron, manganese, 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 zero - 1.5%.

Chemical changes of olive oil during storage (Mailer and Beckingham, 2006; Vossen, 2007**):** 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 become unfit for human consumption. There are many changes in the composition of olive oil under certain conditions, and the most important of these changes, which are related to the quality of olive oil: acidity, oxidation and rancidity.

***1 - %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 oil: %acidity equals or less than 0.8%.
Virgin oil: %acidity equals or less than 2%
Ordinary virgin 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:

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

The acidity of the oil is initiated when the oil is stored in the 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, Macrosporium.*
- Occurrence of rot fungus during storage due to delay to process the fruits for oil extraction after harvest and especially when there are mechanical bruises on the fruits.

2- Oxidation: The attachment of oxygen molecule 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 anti-oxidants in the oil temporarily stop these reactions by absorbing those free radicles. When anti-oxidants are exhausted, free radicles begin to attack the fatty acids and the oil becomes rancid and loses its validity rapidly, occurring in a period of one to three years of storage, depending on the storage conditions of the oil and the class of the oil. There is another type of oxidation occurs in the presence of light and is called oxidative light which occurs with the interaction of unsaturated bonds in the fatty acid with light-induced oxygen and this interaction is very fast compared to the oxidation of the self-oxidation. Oxidation is estimated in the oil by estimating the *peroxide value*, *which represents the number of milliequivalentperoxide oxygen per kg of oil which is formed by the oxidation*. This parameter is a measure for 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 changes that occur in oil from the increase in acidity and oxidation lead to the deficiency of essential fatty acids of the oil glyceride such as oleic acid and linoleic acids, which leads to malfunction of human nutrition and health. Peroxides also break down vitamins in the oil, and the occurrence of toxicity and delay the growth of the human body and the inflation of Liver, kidney, dysfunction of the digestive and urinary systems.

Rancimat method (Metrohm Co Catalogue; Reza Farhoosh and Moosavi, 2007): It is a measure for the oxidative stability of oil or fat resistance to oxidation which is a useful tool to establish shelf life of the oil product. The Rancimat test for olive oil is carried out using an air current at 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 a number of national and international standards, for example AOCS Cd 12b-92 and ISO 6886.

***Organoleptic Analysis (Sensory Analysis*):** One of the most important aspects of olive oil classification and value determination is sensory analysis (Mailer and Beckingham, 2006; Vossen, 2007; IOC, 2015): It is carried out by a group of eight tasters with good knowledge on sensory assessment of olive oil. They should have ability to detect and identify the positive characters and defects of olive oil sensory components. As per IOC, positive characters of virgin olive oil are fruity, spicy (peppery), green (grass or apple), bitter, sweet qualities. Negative defects caused by improper fruit storage and handling, pest infestation, processing or storage problem

and it include: fusty, moldy, muddy sediment, putrid, metallic, rancid etc.

- Fatty Acid profile: It is a measure of the proportions of individual fatty acids in the oil and it is therefore 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 determining the nutritional value of the oil. Some fatty acids are considered better than others as follows:

***Oleic acid*:** This is mono-unsaturated fatty acid is most desired in good olive oil variety due to its nutritional value.

***Linoleic acid*:** This is di-unsaturated fatty acid is less nutritional than oleic acid and is not desired in high percentage in good olive oil variety as it cause instability to the oil due to the presence of double bond which is chemically reactive.

***Linolenic acid*:** This is tri-unsaturated fatty acid with three double bond is more chemically reactive is undesirable because it cause instability to the oil.

***Palmitic and Stearic Acids*:** These are other components of olive oil and they are in the form of saturated fatty acids which is not desired for human nutrition.

- *Ratio of unsaturated/saturated fatty acids:* Olive oil with low ratio of unsaturated /saturated fatty acid is not desirable as it will show cloudy appearance of oil in winter when the temperature drop below 15^{o} C.
- *Ratio of mono-unsaturated/poly-unsaturated fatty acids:* Olive oil with 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 high ratio of oleic to linoleic fatty acid is desirable as it means more nutritional value due high oleic acid in the oil, and more stability to the oil as more linoleic cause instability to the olive oil.

Olive Oil Natural Antioxidants (Montedoro and Servili, 1991; Mailer and Beckingham, 2006; IOC, Anti-oxidants in 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. Anti-oxidants prevent oil oxidation and the occurrence of rancidity, which may be encouraged by other factors such as heat, moisture, air contact, metal contact (iron, copper, manganese). The oil's stability and the degree of preservation are controlled by tocopherols: 90% of them are in the form of alpha- tocopherol,which is known as vitamin E and has a concentration of about 250 mg / kg oil. Olive oil may appear with green color 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 anti-oxidant when keeping oil in the dark alongside polyphenols. Polyphenols are strong antioxidants and are important for olive oil stability as well as the 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 characters. High polyphenols level in olive oil is very important in preserving the integrity and benefits of the oil and to prevent oil rancidity. The amount of polyphenols in the extracted oil is increased when using two-phase decanters because water is not added in the extraction in comparison of 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 on the 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, but after a few weeks, the taste of oil is old and oxidized, while the modern oil remains good for several months despite exposure to air because it contains anti-oxidants.

MATERIALS AND METHODS

Olive Oil Sampling: Olive oil samples representing each batch/variety and filled into dark glass bottles (180 ml) were collected frequently from the olive mill by Olive Quality Control Supervisor after oil extraction of each batch and after filtration in the olive mill and before packing into the drums. The samples were sent to TADCO laboratory, the received samples were recorded in the log book with lab number and their variety/batch number and kept for a short period of time on a clean desk away from direct sunlight and lab fumes before analysis. The samples were processed to determine their quality in terms of %acidity, peroxide value and rancidity according to the Saudi Standardization procedure in the year 2000 (SASO # 282), which was related to the analysis of olive oil samples. In the light of the results of the chemical analysis and taste test and it's suitability for the consumer, the olive oil was either filled in the drums for storage or filled in the bottles and tins for marketing purposes.

The olive oil quality class of each variety/batch was recorded in the log book. Another olive oil sample (reference sample) was maintained by the quality section for the purpose of following up their quality during storage and marketing. Further olive oil samples were frequently collected and sent to the lab during the year before filling into tins and bottles intended for marketing. To evaluate the quality of TADCO olive oil extracted from different cultivars, olive oil of 1997 product samples filled into glass bottles (500 ml) were sent for analysis on April 1998 to Chemi Service laboratory in Bary, Italy through the consultant Mr. Attilio Sonnoli. Another olive oil samples of the fresh 2002 product and stored 2001 product filled into glass bottles (500 ml) were sent for analysis to CNR/ISOFAM laboratory in Perugia, Italy through the consultant Giuseppe Fontanazza. To monitor the quality of stored olive oil products over the years, we conducted olive oil storage experiments during the period 2002 to 2005. Samples filled into dark glass bottles of 180 ml were collected by Olive Quality Control Supervisor in coordination with lab Chemist and sent to the lab on different occasions mentioned under each experiment.

Laboratory Analysis Procedures

The following is a description of TADCO laboratory procedures for the analysis of olive oil samples to determine their quality following Saudi Standardization protocols for olive oil analysis [(SASO # 282/2000)(GSO 1020)] (Methods of Test for Edible Olive Oil).

Determination of Acid Value and free Fatty Acids (SASO # 282/2000):

Reagents:

- Solvent mixture (95% ethanol, Diethyl-ether ratio I:I)
- Sodium Hydroxide 0.1 N aqueous solution accurately standardized.
- Phenolphthalein indicator solution 1% in ethanol 95%.

Apparatus: Conical Flask, 250 ml capacity: 3.

Procedure: Weigh accurately 8-10 g of the prepared oil or fat in a conical flask. Place 50 ml of the solvent mixture into another 250 ml conical flask, add 5 drops of phenolphthalein solution and neutralize with 0.1 N sodium hydroxide solution (till faint pink color). Pour the neutralized solvent mixture on the sample mix well and then titrate with 0.1 N standard sodium hydroxide solution until a pink color persists.

Calculation:

Acid Value = E x N x 56.1 / W
The acidity is calculated as free fatty acids according to the following equations:
Free fatty acids expressed as Oleic acid percent by weight = E x N x 28.2 / W
Free fatty acids, expressed as Lauric acid percent by weight= E x N x 20 / W
Free fatty acid, expressed as Palmitic acid, percent by weight= E x N x 25.6 / W

Where:

E = Volume in milliliters of sodium hydroxide solution required for neutralization
N= Normality of sodium hydroxide solution.
W= Weight in grams of the sample.

Determination of Peroxide Value (SASO # 282/2000):

Reagents:

- Solvent mixture, 2 volumes of glacial acetic acid plus 1 volume of chloroform
- 0.002N solution of sodium thiosulphate, freshly prepared by dilution from an accurately standardized 0.1 N solution.
- Potassium iodide, freshly powdered.
- Potassium iodide, 5% aqueous solution.
- Starch indicator, 1% solution, freshly prepared. Mix 1 g of soluble starch thoroughly with a small quantity of water, dilute the mixture to 100 ml, boil and cool to room temperature before use.
- Carbon dioxide.

Apparatus:

- Test tubes 150 x 25 mm. Before use, wash thoroughly with soap or synthetic detergent solution, rinse with hot water and allow standing in chromic acid mixture for a few hours. Then rinse thoroughly with distilled water and drying in an oven before use.
- Water Bath.
- Conical flask 300 ml capacity.

Procedure:

The test should preferably be carried out in artificial light free from ultra-violet radiation. Weigh a suitable quantity of the oil or melted fat into the test tube and while still liquid add 1 g of powdered potassium iodide and 20 ml of the solvent mixture. Gently bubble carbon dioxide through the mixture of oil and solvent. Heat the contents of the tube to boiling within 30 seconds, preferably in a steam bath, and allow them to boil vigorously for not more than 30 seconds. Transfer the contents of tube quickly to a 300 ml conical flask containing 20 ml of the potassium iodide aqueous solution and wash out the test tube twice with 25 to 30 ml of distilled water. Titrate the solution with the sodium thiosulphate solution using starch indicator. Do not add the starch until the end point is almost reached. Perform a blank test, to be sure that the titration is not more than 0.1 ml.

Calculation:

Peroxide value = 2 T / W

Where:
T = Volume in milliliters of 0.002N sodium thiosulphate required for titration.
W = Weight in grams, of the taken sample.

Qualitative Test for Rancidity (Kreis Test) (SASO # 282/2000):

Reagents:

- Hydrochloric acid, sp. gr. 1.19
- Phloroglucinol 0.1% solution in ether
- Test tubes, 150 x 25 mm. Before use, wash thoroughly with soap or synthetic detergent solution, rinse with hot water and allow to stand in chromic acid mixture for a few hours. Then rinse thoroughly (the last time with distilled water) and dry in an oven before use.

Procedure:

Put 10 ml of the prepared oil or melted fat in a test tube, add 10 ml of the phloroglucinol solution and 10 ml of the hydrochloric acid and shake for 20 seconds.

RESULTS

The production of pink color in the acid layer is an indication of incipient rancidity formation.

Olive Fruits Products of Different Cultivars Grown at TADCO

There were nine olive oil cultivars grown at TADCO: Jordan, Improved Nebali, Picual, Frantioi, Coratina, Verdale, Ayvalik, Surani and Manzanilla Figure 1 (a - g). The harvest season starts early in September and complete by the end of December. Jordan cultivar is early maturing in September followed by Frantioi late September and October, then Ayvalik and Surani after mid of October, then Picual in November, then improved Nebali mid of November to early December, then Verdale in December and Coratina matures in the middle of December. Harvest is carried out manually and by hand held devices. Over the period of the study, there was continuous increase on olive fruits productivity of the various cultivars from 876.6 M.T in 1999 to 2305 M.T in 2004**.**However, productivity after 2004 was affected significantly due to frost damage in the seasons 2007, 2008 and the combined damage of frost with rain in 2005 (Naser *et al.,* 2018) which enforced

TADCO to remove one orchard with week trees in 2009 and concentrated their efforts on healthy trees. The olive cultivars productivity of fruits during the period 2002 to 2004 when the trees were growing normally and not affected by frost or salts after heavy rain is presented Table 1. Fruits productivity of the olive cultivars ranged from 8.91 to 39.76 kg/tree. Verdale was the highest with 39.76 kg/tree followed by Manzanilla with 28.03 kg then Picual with 24.09 kg then Jordan with 20.78 kg then Coratina with 16.38 kg then Improved Nebali 14.75 kg which was still did not reach tree maturity age then Ayvalik 14.65 kg then Surani with 13.99 kg, then Frantioi with 8.91 kg/tree. Productivity of the olive cultivars per hectare ranged from 2.476 to 11.028 M.T/Ha., and the cultivars productivity/Ha followed the same pattern of productivity per tree. Few years after 2004 and by the cropping season of 2011, productivity of the olive orchards were improved significantly and productivity reached 2778 M.T. of olive fruits, see Table 2. Productivity of olive trees of all varieties reached the highest level in the history of TADCO olive project with an area of 278.84 Ha. and the total number of trees 79530, and these figures were significantly less than old figures in 2004 with an area of 380.8 Ha. and the total number of trees 107193. The average productivity of the varieties ranged 16.3 to 53.5 kg/tree. Coratina was the highest with 53.5 kg followed by Jordan with 49.6 kg then Surani with 46.6 kg then Verdale with 44.8 kg then Picual with 44.1 kg then improved Nebali with 27.9 kg then Gordal with 26 kg then Frantioi with 17.2 kg then Manzanilla with 16.8 kg/tree. This unpredicted productivity put the olive unit under high pressure for daily harvest, fruits storage and four months day and night olive mills operations at TADCO and at outside mill which in some cases affected olive oil quality. The average productivity of the varieties ranged 3.17 to 18.42 M.T/Ha: Surani was the highest with 18.42 M.T. followed by Coratina with 17.75 M.T. then Jordan with 16.35 M.T then Picual with 12.30 M.T. then Verdale with 8.41 M.T. then Improved Nebali with 7.88 M.T. then Frantioi with 5.74 M.T. then Gordal with 4.85 M.T.

OLIVE OIL PRODUCTION

Receive the olive fruits at the olive mill

To get high quality olive oil, olive consultant Mr. Sonnali recommended the company in 1997 and based on research in Italy to harvest the fruits when they reach the stage of physiological maturity (Montedoro and Servili, 1991; Pannelli *et al.,* 1990). For non-contemporary ripening fruits like Jordan and I. Nebali: one third of the fruits are completely colored and the other third are partially colored and the rest of the fruits are light green in color as shown in the left box in Figure 2A. For contemporary ripening fruits like Frantioi where the fruits skin is colored at a short period: the skin of the fruits is colored and the flesh is around 50% colored. This review did not cover the activities of super-high density mechanical harvest techniques regarding storage period after harvest; however other information in this review is applicable unless it was noted in the text. The following points should be taken into account once the fruits are harvested using manual methods or any other method which causes minimal mechanical damage:

i. Transportation of harvested fruits to the cold storage if the olive mill is not ready for processing the present harvest immediately, weigh the harvested fruits, record in the log book, then store them in the cold store for no more than two weeks at 5 – 7^{o} C. under a given batch number indicating in the log book the cultivar name, location and date of harvest. Avoid mixing cultivars, and only one fruits cultivar was stored under the same batch number.
ii. The fruits are free from fungal or insect injury or mechanical wounds or impurities, and in case of damage presence, the fruits should be stored in boxes separate from the sound fruits boxes because mixing them with healthy fruits boxes will affect the quality of oil produced.
iii. Do not mix the fruits falling on the ground with healthy fruits, but they are stored in separate boxes and processed with damaged fruits separately to maintain the quality of produced oil.
iv. Use clean plastic boxes with openings for ventilation during transportation from the field and during storage, and the fruits level in each box does not exceed 80-90% of the height of the box to avoid damaging the fruits.
v. Transport fruits from cold store to the olive mill of each variety/batch number. Receive fruit boxes and place them separately in a reception hall, clean and well-ventilated for several hours in preparation for olive oil extraction; take into consideration giving priority for processing the batches of healthy fruits before the batches of damaged ones.

Extraction of olive oil

Modern olive oil mill machines are shown in Figure 3 (a –f). A brief description of the technical operations (Fontanazza, 2002; Vossen, Paul) is described in the following text:

Olive Leaves Removal: Transfer the olive fruits of one variety/batch number to the receiver bay of the mill. The olive leaves are mixed with the fruits in the boxes at different rates when it is downloaded into the bay of the olive oil mill. These leaves are removed by an automatic machine that sucks the leaves and light weight impurities by a stream of air passing through the fruits and then discards them in a special tube to a container outside the olive mill in order to get rid of them. If any of these leaves are left with the fruits, this gives a green color and a bitter taste of olive oil, see Figure 4.

Washing the fruits: The fruits are washed with water to remove the dust and impurities of fungus and insects so as not to mix with the paste of fruits because it may sometimes cause a change in the flavor and smell of the oil product, see Figure 5.

Olive Fruits Crushing: The olive fruitsare passed on the crushing machine, so the fruits seeds and the flesh is broken into small parts, which leads to the breakage of oil cells and facilitate the exit of oil. Modern machines used to be either stone ormetal and the latter are used in TADCO mill. It is recommended that the process of crushing is done in a medium way to allow the completion of the process of oil separation, increasing the crushing to produce a smooth mixture shall make it difficult to extract oil from it. The rapid cycles of the crushing machine lead to a sharp rise in the temperature of the olive paste and cause the presence of mineral traces in the oil. Thus this process of mashing may cause oxidation affecting the organoleptic characters of the olive oil. Metal crushers are either hammer rotated in a perforated cylinder or in the form of serrated discs and the first type are common in Saudi Arabia, see Figure 6.

Table 1a. Fruits Productivity of olive cultivars during the period 2002 – 2004

Olive Cultivars	Year 2002 (M.T.)	Year 2003 (M.T.)	Year 2004 (M.T.)	Total (M.T.)	Mean (M.T.)	Number of Trees	Productivity Kg/Tree	Productivity Kg/Ha.
Jordan	98.612	45.158	160.485	304.255	101.38	4879	20.78	5773.3
Frantioi	138.196	258.632	66.612	463.44	154.48	17330	8.91	2476.4
Manzanilla	48.036	32.729	208.973	289.738	96.58	3446	28.03	8021.6
Surani	138.411	369.695	164.218	672.324	224.108	16008	13.99	3889.4
Picual	448.764	317.18	534.337	1300.28	433.43	17985	24.09	6694.9
Ayvalik	129.172	174.375	19.915	323.462	107.87	7363	14.65	4069
I. Nebali	353.819	175.229	884.062.	1415.11	471.70	31959	14.75	4918.6
Verdale	27.923	10.932	101.05	139.905	46.64	1173	39.76	11028.4
Coratina	76.22	138.509	155.403	370.132	123.38	7532	16.38	4782.2

Table 1b. Fruits Productivity of olive cultivars in the cropping season 2011

Cultivar Area(Ha.)	Jordan	Frantioi	Manzanilla	Surani	Picual	Impr. Nebali	Verdale	Coratina	Gordal*
	25.66	23.75	18.25	4.64	62.37	119.4	6.25	14.04	1.71
Number of Trees in2011	8456	8594	3446	1834	17381	33665	1173	4662	319
Productivity (M.T.)	419.68	147.83	57.83	85.45	767.35	940.59	52.59	249.22	8.30
Kg perTree	49.6	17.2	16.8	46.6	44.1	27.9	44.8	53.5	26.0
Productivity MT/Ha	16.355	5.741	3.169	18.417	12.303	7.878	8.414	17.751	4.851

*Gordal is a table variety.

a- Jordan Cultivar

b- Improved Nebali Cultivar

c- Picual Cultivar

d- Coratina Cultivar Fruits

e- Frantioi Cultivar Fruits

f- Verdale Cultivar Fruits

g- Manzanilla Cultivar Fruits

Figure 1 (a – g). Fruits images of TADCO olive oil cultivars

Olive Paste Mixing (Malaxation): The paste of the crushed fruits are mixed with the appropriate quantity of water to be kneaded through mechanical flipping and slowly leading to the release of oil droplets which combine with each other. The duration of mixing the olive paste, its heat and the material coated to the inner wall of the mixer are the main factors that must be taken into consideration when mixing the olive paste. If it exceeds a certain limit, it can affect the oxidation and organoleptic qualities of the oil. It is recommended to follow the mixing time of the paste 30-40 minutes and the paste temperature is around 28°C (cold extraction). The inner wall of the mixer is made of stainless steel, and this period is sufficient to collect small oil droplets into larger drops, see Figure 7. Olive oil extraction at high temperature (above 35° C) leads to the loss of polyphenols.

Figure 2. Olive fruits recommended for getting high quality olive oil (A), and (B) over matured olive fruits are not recommended.

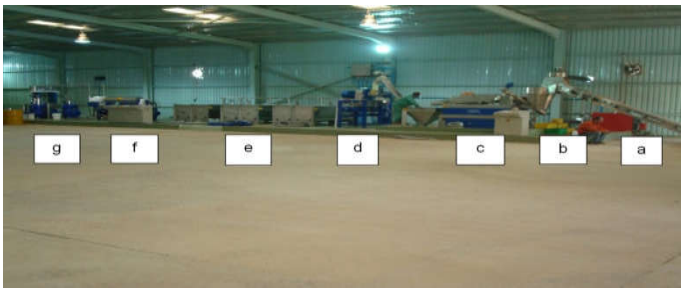

Figure 3. Modern olive oil mill: (a) Fruits collection escalator (b)Leaves and light Impurities separator blower (c) Olives washing machine (d) Olives crushing grinder (e) Mixing olive paste (Malaxation) machines (f) Centrifuge (Decanter) (g) Olive Oil Separators

Figure 4. Leaves and light Impurities separator blower and Washing sink

Figure 5. Olive fruits washing machine

Figure 6.Olive fruits crushing grinder

Figure 7. Olive paste mixing (malaxation) machines

Separation of olive paste from oil and water: This depends on the way oil is separated from the olive paste, centrifugation or surface tension. The modern contemporary decanter spins on a horizontal axis Figure 8 at a speed of 3000 - 3500 cycles per minute where it separates the olive paste into three main parts:

- Olive oil with a small amount of water collected in a special tank and moves to the oil separator A.
- Olive water with a small amount of oil collected in a special tank and moves to the oil separator B.
- The dry olive paste is sent through a spiral pipe to the outside of the mill for industrial use or for heating purposes.

Separation of olive oil from water: The olive oil is seperated by the first seperator (A), which works in a centrifuge manner,

and revolves at a speed of 6500 - 7000 cycle and leads to separate the oil from the water based on the difference of density as oil floats above water Figure 9A, and direct the oil without solid materials and water through a tube at the top of the septum into the receiving container, while the vegetative water is drawn from a tube at the bottom of the centrifuge. The oil is also sorted from the olive water by directing it into the second seperator (B), see Figure 9B, where the oil is transferred to the oil reservoir of the first centrifuge (A) to be redirected to the first batch then the oil is seperated and collected as previously mentioned.

Figure 8. Decanter (Centrifuge) to seperate olive paste from oil and water

Figure 9. Olive oil seperation from water (A), and water from oil (B)

Figure 10. Extracted olive is received in the stainless steel container

Collection of seperated olive oil: The extracted olive oil in centrifuge (A) is sent and received at a stainless steel container Figure 10 and sent to a collection barrelof around 80 – 100 liter capacity, and then pumped through polyethelene hose (food grade) into large stainless steel silos tanks for temporary storage.

Olive oil settling and temporary storage (Fontanazza *et al.*, 2002; Vossen, 2004)

The produced olive oil is received into one of the large tanks of olive oil silos (already cleaned), of the capacity range 9000 to 16400 liters, made of stainless steel and installed at a height of half meter from the ground floor Figure 11.

Figure 11. Olive oil is temporary stored into silo tanks

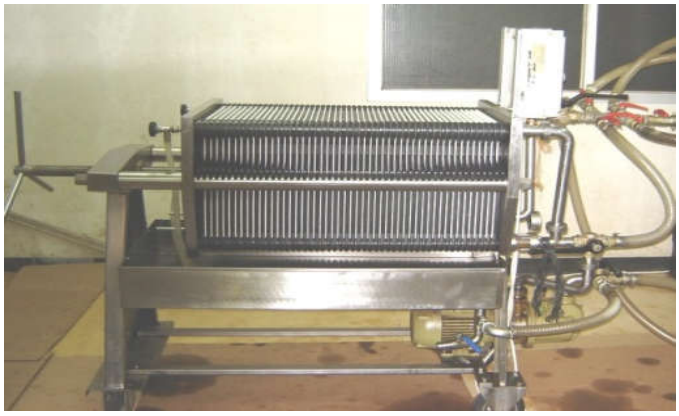

Figure 12.Olive oil filter

These silos are set up to facilitate the process of olive oil settling, storage and packaging after filtration. In the design of each tank is the presence of a faucet at the conical bottom which allows the get rid of vegetative water and impurities before the process of filtration, and in each silo there is another faucet located at the bottom edge of the silo to be used in the process of packing or unloading. Each silo tank could be connected with the collection barrel with a polyethylene hose to fill the oil into the silo tank. There is also another polyethylene hose which is used to connect the filter system with the silo tank. In the modern oil extraction, water and impurities of organic origin precipitate into the bottom of the silo tanks after several days of filling. These impurities contain fermentable sugars and a lot of proteins ready for degradation causing odors and acidity into the oil by the lipid-soluble enzymes in the water medium, leading to defects in the organoleptic qualities of the oil, such as the change of taste and flavor. The olive oil is left without stirring in each silo tank for a period of 20 – 30 days, to allow for the precipitation of impurities in the conical bottom of the silo tank, and these impurities were removed frequently and before the start of the filtration process because of its significant impact on the quality of the oil.

Table 2. Analysis results on eight turbid olive oil samples of 1997 product conducted at Safola laboratory, Jeddah on May 1998

Olive Oil Variety	Appearance	Filter Test	% Moisture
Jordan	Partial cloudy at ambient temperature Clear after filtration	Dirty	0.194
Improved Nebali	Clear at ambient temperature	Dirty	0.160
Picual	Densely cloudy at ambient temperature Clear after filtration	Very Dirty	0.183
Frantioi	Clear at ambient temperature	Partial Dirty	0.116
Coratina	cloudy at ambient temperature Clear after filtration	Dirty	0.132
Surani	cloudy at ambient temperature Clear after filtration	Dirty	0.164
Ayvalik	Hazy at ambient temperature Clear after filtration	Dirty	0.151
Manzanilla	Clear at ambient temperature	Dirty	0.170

Table 3.Analysis results on two new olive oil samples of 2003 product for one TADCO customer

Olive Oil Sample Type	% Acidity *Mg* KOH/g	Peroxide Value *Meq*/kg	Rancidity	Refractive Index
Filtered Oil	0.90	14.09	Free	1.4682
Non-Filtered Oil	0.93	19.07	Free	1.4646
Acceptable Level as perSaudi Standarization Number 283/2000	< 0.8	< 20	Free	1.4682 – 1.4657

Figure 13. Arrangement of olive oil drums of 2005 product left and 2004 right

The period of settlement could be shortened to ten days dependent on the need of the silos for storage of new olive oil production in the seasons of high production. Detailed information on olive oil productivity of the different olive cultivars (M.T.) at TADCO over the period 1999 to 2009 is shown in the research paper in 2018 (Naser *et al.,* 2018).

Olive oil filtration (Vossen, 2004)

Olive oil after settling was with cloudy appearance due to the presence of suspended particles such as colloid substances, resins, moisture, and small particles of fruit flesh, skin and seeds. The moisture is absorbed into the colloidal substance into the oil which causes hydrolysis of the oil triglyceride by the action of lipase enzyme into free fatty acids and glycerol which leads to the increase of olive oil acidity. The center of the filter consists of square-shaped sheets of cotton with absorbent dimensions 30 X30 cm (Figure 12). Analysis of eight olive oil samples of 1997 product sent to Safola company in Jeddah on May 1998 shown that filtration process was critically required to obtain a clear oil appearance acceptable to the consumer and to increase the degree of oil preservation Table 2.

The effect of the filtration process on the quality of the olive oil was observed on olive oil samples of 2003 product for one TADCO customer. Results had shown the acidity of the oil was slightly higher and the peroxide level was close to the expiry number (20 Meq O_2 / kg oil)in the non-filtered sample. The oil refractive index was also lower than the acceptable level of oil according to the Saudi Standards Association # 283/2000 (Edible Olive Oil, 2000) which is related to olive oil quality standards, see Table 3.

Olive Oil Storage until 2009

Olive oil stored in each silo tank is assigned with a new olive oil variety/batch number, and a sample of the oil is collected and sent to the laboratory from each tank stock before olive oil packing for the purpose of analyzing and determining its quality in terms of % acidity, peroxide value and rancidity. In the light of the results of the chemical analysis and taste test and it's suitability for the consumer, the olive oil is either filled into the drums for storage or filled into the bottles and tins for marketing purposes. Storage of the olive oil from 1997 until 2009season was carried out using steel drums with laminated inside face to protect the olive oil from direct touching with the

drum metal to prevent oil oxidation during the oil storage period, which may last for more than one year and was utilized for bulk sale and storage as it was less expensive than the silo for small and medium companies. The drums are filled with oil completely (215 L), so the oil is not reacted with the oxygen stored in the unfilled part of the drum. After filling the drums they were sealed tightly and then print the batch number on a label and stick it on the drum which represents the year of production, variety and operating number. Drums of each year had color different from the previous year to facilitate the handling of the product. The drums are placed on wooden pallets with an average of (4) drums on each pallet to facilitate the transport and storage of drums inside the warehouses, which were stored in the rooms of the storage warehouse at a temperature of 15-20^{0}C throughout the year. These warehouses ensure oil safety as it is dark, away from odors, humidity and sudden thermal changes, see Figure 13.

Olive Oil Storage into Conical Drums and Aseptic Bags After 2009 (OMCS Jordan)

Conical drums are specially made for heavy food concentrates 250 – 300 kg. The drums are used in connection with an inner aseptic bag suitable for the canning and forwarding of concentrated products like tomato paste, fruits paste etc. And can be utilized for the storage of olive oil, see Figure 14. It is with the following specifications and advantage (OMCS Jordan):

Conical drums are specially developed to satisfy requirements of Food/ Fruits industry. Manufactured from cold rolled closed annealed steel (CRCA), these drums acquire shape through expansion (Plastic Deformation of Metal). This neatly improves the strength of the drum and its mechanical characteristics. Conical drums are internally coated and externally painted and are available in 210 liters, suitable for filling full packed aseptic bag. Due to its structure and dimensions, a conical drum allows exceptional efficiency during transportation and storage. This is the main advantage of using such drums; as it will significantly save transportation costs of empty drums and also requires less space for storage in the warehouse. Overall external diameter of the drum makes it possible to store 4 drums in line that suits stuffing of 80 drums in a 20 feet shipping container. It is also possible to transport up to 1368 empty drums in a 40 feet Container. Once filled, drums can be stacked 3 to 4 high level with the pallets. Conical drums may be returned and reused.

- The bottom of the drum sits on the floor when full, so as the weight is more distributed around 2/3 of the drum base instead of only the rim. This gives the drum more stability during transportation.
- The body is made of 0.7mm thickness
- The cover is made specially to suit the bottom shape so as to stack drums on top of each other without using the wooden pallet.
- The cover is made of galvanized steel 0.6 mm thickness
- 80 drums could be fitted when full on wooden pallets inside one 20 feet container.
- Color is blue, and it could be any other color.
- 6 pallets could be stacked on top of each other.
- Drums could be stacked without using the wooden pallet.
- It is cheaper by 20% from the steel drums, and it saves 13% on packing materials and 13% on shipping cost as it can fit up to 22 tons of product inside 20 feet container.
- Less space in the store area as 100 drums on wooden pallet takes only 1.15 square meter of space instead of 50 square meter for the same quantity of steel drums.
- One person with fork lift can load and unload empty drums instead of 4-5 persons for handling steel drums.
- No need to have people unloading empty cylindrical drums every day, as conical drums could be stacked in the store area for the whole season; an area of 276 square meter could fit about 60000 empty drums.
- It could be used several times, all what is needed is to use a new aseptic bags. This will save a lot of money.

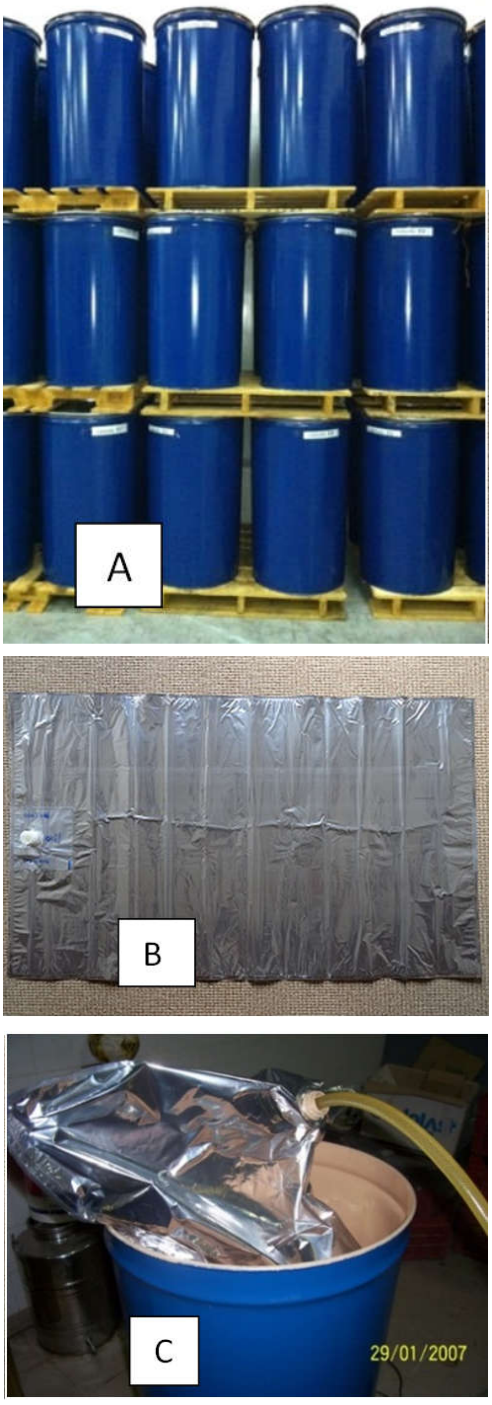

Figure 14. (A) Arrangement of Conical drums in the store, (B) Aseptic Bags, (C) Filling olive oil into aseptic bags

Aseptic Bags: Aseptic packaging ensures that olive oil remains sterile and free from bacteria or other harmful microorganisms. It also eliminates air oxidation prolonging the olive oil product shelf life and maintains the organoleptic properties of olive oil if the bag is filled completely with the oil to push the air out then tightly closed. The packaging itself can be sterilized after cleaning by steam, heat, radiation, or hydrogen peroxide.

EVALUATION OF TADCO OLIVE OIL QUALITY

Analysis of olive oil samples of 1997 products (Vossen, 2007): To evaluate the quality of TADCO olive oil extracted from different cultivars: fourteen settled (non-filtered) olive oil samples of 1997 product were sent for analysis on April 1998 to Chemi Service laboratory in Bari, Italy through the consultant Mr. Attilio Sonnoli. The results of the chemical and quality analysis on the olive oil samples of 1997 product is presented in Table 4a and 4b,we observed the following:

Percentage Olive Oil Extraction*:* Most of the olive cultivars produced medium to high percentage olive oil and ranged from 9.76 to 23.60; olive oil extraction from the cultivars Surani, Ayvalik, Coratina were 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%.

Panel Test: Results of the panel test shown the following:

- High score and above 6.5: Two Picual oil samples from November 6 and 26 harvest, one Frantioi oil sample from October 18 harvest and one Coratina oil sample from December 11 harvest.
- 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 sample from October 16 harvest, Ayvalik sample from Oct 22 harvest and two Surani oil samples from Oct 25 and November 17 harvest.
- Low score 2.5 – 4.5: one Ayvalik oil sample from November 11 harvest.

***%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), Surani (one sample).

***Peroxide Value*:** The peroxide value of the different oil samples ranged from low value 3.25 to high value 16.95 milliequivalent / kg olive Oil: Ayvalik olive oil samples were within a range 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.

***Rancimat Test*:** The oxidative stability of the different oil samples ranged from low2.20 to high 7.9 hours. As the harvest time was delayed, oxidative stability was compromised as shown in Jordan oil sample with value 3.74 for late harvest on November 19, and the same occurred on Picual sample with value 2.20 for late harvest on December 9 and on Frantioi for late harvest on October 19 with value 2.93. Also, in case of late maturing varieties, oxidative value was also compromised as in Ayvalik of October 22 harvest. Oxidative stability value was the highest on late maturing cultivar Coratina with value 7.9 followed by Picual with value range 5.52 - 5.93 then Jordan with value range 4.85 – 4.87 then Frantioi with a value 4.02 then Surani and Ayvalik with a value of 3 hour.

***Polyphenols*:** The polyphenols level in the olive oil samples of the different oil cultivars ranged from low level 35 ppm to high level 430 ppm on 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 on the olive oil varies according to: olive variety, fruits maturity stage andlevel of storage, extraction method and oil storage period.

Fatty Acid profile: Analysis results shown the following:

- *Oleic Acid:* Cultivars Jordan, Picual and Coratina were with high percentage of oleic acid and ranged from 69.48 – 74.39%; oleic acid on Picual reached 74.39% followed by Coratina with 73.90% then Jordan with 71.39%. Cultivars Ayvalik, Surani and Frantioi were with medium percentage oleic acid and ranged from 62.48 – 67.28 and it reached 67.28% on Ayvalik followed by Surani 65.58% then Frantioi 63.38%.
- *Linoleic Acid:* The %linoleic acid on cultivars with high %oleic acid were with low linoleic acid as it ranged on picual 4.7 – 8.2% and on 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 a range of 11.3 – 13.2% and on Frantioi 14.10 – 15.20% and on Surani 11.3 – 17.2%, and this lead to less stability of olive oil.
- *Palmitic and Stearic Acids*: The %total of saturated acid on most of the cultivars ranged 17.1 - 19.9% except Coratina which contained 14.1% which is far less than other cultivars.

Comments on the results of 1997 Product Samples

As per the panel test, there were no defects on the oil samples of 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. As per the results of the chemical analysis on the fourteen of olive oil samples showed the grade of the oil samples was extra virgin on Jordan, Picual, Frantioi, Coratina and virgin grade on Ayvalik and another four samples ofpicual and Frantioi as shown in Table 4a and 4b. It was observed three varieties with good chemical composition: Coratina, Jordan, Picual as they showed high %oleic acid which ranged 69.48 – 74.39 and low percentage of linoleic, linolenic acid, and medium percentage of saturated fatty acid. It was also observed high olive oil oxidation stability on Coratina, while it was medium stability on Jordan and Picual. Oxidation stability decreased on late harvest of Jordan and Picual varieties.

Analysis of Olive Oil Samples of 2002 Product: To evaluate the quality of TADCO olive oil extracted from different olive

Table 4a. Analysis* results of fourteen olive oil samples of different TADCO cultivars 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% EV ≤ 2% V ≤ 3.3% OV
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 Chromatographyof methyl esters of fatty acids; Laboratory: Chemi Service Monopoli, Bary, Italy.
** In conformity of Olive Oil Standards 2003 (IOC & EU) and [IOC 1996 (EU – 2002)
*** In Conformity of ISO 6886, AOCS

Table 4b. Laboratory analysis of olive oil samples of different TADCO cultivars on 28th of April 1998

Type of Analysis	Frantioi	Frantioi	Ayvalik	Ayvalik	Surani	Surani	Coratina	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% EV ≤ 2% V ≤ 3.3% OV
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 Chromatographyof methyl esters of fatty acids; Laboratory: Chemi Service Monopoli, Bary, Italy.
** In conformity of Olive Oil Standards 2003 (IOC & EU) and [IOC 1996 (EU – 2002)]
*** In Conformity of ISO 6886, AOCS

cultivars, eight samples of old 2001 product were sent on October 10, 2002 and another olive fruits samples green and black along with eight filtered olive oil samples of fresh 2002product were sent to Italy on November 26, 2002 to the olive consultant Prof. Giuseppe Fontanazza. The analysis of the oil samples was conducted at the CNR/ISOFAM laboratory in Perugia, Italy (Fontanazza, 2002). The results of the analysis were as follows:

Fruits Samples: The results of the analysis on the fruits samples are shown in Table 5. We observed the following:

- *% Olive oil extraction*: it was noted high olive oil content on the cultivars Ayvalik, Jordan, Frantaioi, Coratina, and Manzanilla which reached 20.99, 19.11, 17.59, 16.38, 16.05% respectively followed by Verdale with 15.60% then Picual 14.10% then Surani 11.48% then Improved Nebali with 10.79%.
- Fruits water content: The results of the analysis showed high water content on the fruits samples above the acceptable level 60% on all of the varieties except Ayvalik which reached 58.71%. High water content on the fruits of Surani and Improved Nebali reached 75.06, 72.55% respectively, and this reflected on low %oil content of the fruits of these varieties which reached 11.48. 10.79% respectively. So, as water content in the fruits decreased %oil content in the fruits was increased.
- %Oil Content / Dry matter: Results shown Ayvalik was with high oil content which reached 20.99% when the ratio of oil content/dry matter reached 50.83%, and the % oil dropped to 10.79%on Improved Nebali when this ratio dropped to 39.29%.

Panel Test: The results of the organoleptic analysis on the olive samples of 2002 product are represented in Table 6 as follows:

- Frantioi oil sample: no defects was detected on the oil sample, The panel identified positive characters on this oil as fruity, with moderate bitter and pungent flavor and it scored 6.
- Jordan oil sample: no defects was detected on the oil sample, The panel identified positive characters on this oil as high fruity, with low bitter and light pungent flavor, taste like sweat oil and it scored 5.
- Picual oil sample: no defects was detected on the oil sample, The panel identified positive characters on this oil as it was with strong fruitiness, low bitter and light pungent flavor, oil with typical organoleptic character, and it scored 5.
- Manzanilla oil sample: no defects was detected on the oil sample, The panel identified positive characters on this oil as fruity with low bitter, moderate pungent flavor, and it scored 5.
- Improved Nebali oil sample: no defects was detected on the oil sample, The panel identified positive characters on this oil as high fruity, with low bitter and light pungent flavor, oil with typical organoleptic character, and it scored 4.5.
- Ayvalik oil sample: no defects was detected on the oil sample, The panel identified low level positive characters on this oil as with light fruity and light pungent flavor, no bitter taste, oil is sweet and medium fluid, and it scored 2.
- Surani oil sample: defect rancid 2was detected on the oil sample. The panel identified nopositive characters on this oil and it scored 0.
- Verdale oil sample: defect rancid 2 was detected on the oil sample. The panel identified no positive characters on this oil and it scored 0.

% Olive oil extraction in the olive mill: Most of the olive oil samples of the different cultivars were with medium percentage olive oil and ranged from 10.52 to 17.84; olive oil extraction from the cultivars Surani, Ayvalik, Coratina was relatively highas 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 Nebali 10.52%.

Olive Oil Samples Analysis: The results of the chemical analysis on the olive oil samples of 2002 product is presented in Table 7, we observed the following:

***%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 Nebali and Coratina; two oil samples with acidity 1% representing Ayvalik and Verdale.

***Peroxide Value (Meq O_2/kg oil)*:** Ayvalik olive oil sample was with peroxide value 7.4 milliequivalent / kg olive which was the lowest number, and Surani oil sample was with peroxide value 12.2 which was the highest, and the rest of the varieties were within the range of 7.4 – 12.2 milli equivalent / kg olive.These results indicate proper handling of the fruits and the paste during oil extraction.

Polyphenols: The polyphenols level in the olive oil samples of the different olive cultivars ranged from medium level 85 ppm to high level 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 170 ppm then Frantioi 168 ppm then Verdale with 164 ppm then Ayvalik 92 ppm then Picual 89 ppm then Surani with 85 ppm. These levels are higher than in 1998 analysis as samples were sent immediately after extraction on November 2002.

Fatty Acid profile: Analysis results shown the following:

- *Oleic Acid*: Cultivars Coratina, Manzanilla Jordan, and Picualwere with 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 Nebali, Frantioi, Surani, Verdale and Ayvalikwere with medium percentage oleic acid and ranged from 60.54 – 63.2%, and it reached 60.54% on Improved Nebali followed by Frantioi with 61.05%, then Surani with 62.1% then Verdale with 62.86% then Ayvalik 63.20%.

- *Linoleic Acid:* The %linoleic acid on cultivars with high %oleic acid was low and it ranged from8.36 – 11.1%; and 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 it ranged 13.85 – 16.85%; and on Verdale13.85% then Surani 14.33% then Improved Nebali with 14.87% then Ayvalik15.03 then Frantioi 16.55%.

- *Palmitic and Stearic Acids:* The %total of saturated fatty acids on most of the cultivars ranged 17.1 - 19.9 except Coratina which contained 14.1% which is far less than other cultivars.

- *Ratio of unsaturated/saturated fatty acids:* Olive oil with low ratio of unsaturated /saturated fatty acid is not desirable as it will show 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 and Manzanilla 3.82 then Surani 3.75 then Improved Nebali 3.57.

- *Ratio of mono-unsaturated/poly-unsaturated fatty acids:* Olive oil with high ratio of mono-unsaturated to poly-unsaturated fatty acid is desirable as it means more nutritional value due high oleic acid in the oil, and more olive oil stability. Manzanilla, Coratina 01 and Jordan were with high ratio value 7.69, 6.98, 6.66 respectively followed by picual with ratio 5.75 then Verdale 4.42 then Surani 4.23 then improved Nebali with 4.0then Frantioi 3.59.

- *Ratio of Oleic Acid/Linoleicfatty acid:*Olive oil with high ratio of oleic to linoleic fatty acid is desirable as it means more nutritional value due 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 were with high ratio value 8.14, 7.38, 6.95 respectively followed by Picual with ratio 5.95 then Verdale 4.54 then Surani 4.33 then Ayvalik 4.20 then improved Nebali 4.07 then Frantioi 3.62.

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 Nebali, Ayvalik and the fruitiness of the oil samples was above 0, then these oil samples are fit for Extra Virgin or Virgin grade dependent on the results of the chemical analysis.
- There were rancidity defect (score 2) detected on the oil samples of Surani and Verdale and the total flavor is zero, then these samples due to rancidity defect are not fit for human consumption and the class of these two samples is Lampante oil as shown in Table 6
- As per the results of the chemical analysis on the eight olive oil samples, the grade of the oil samples was extra virgin on Jordan, Frantioi, Manzanilla Picual, Improved Nebali, and virgin grade on Ayvalik as shown in the Table.7.

EFFECT OF STORAGE PERIOD ON OLIVE OIL QUALITY

Effect of one year storage period on 2001 product: Comparative study was carried out on the results of the analysis of the 2001 product stored at TADCO for one year with the results of the analysis on the fresh 2002 product. The study included eight olive oil samples of: Jordan, Frantaioi, Manzanilla, Surani, Picual, Improved Nebali, Verdale and Ayvalik. The comparative results of the analysis are shown in Table 8. We observed the following:

- *%Acidity:* %Acidity of the 2002 product of all samples were below 0.8% and ranged 0.3- 0.7% except Ayvalik was 1%. In the other hand, %acidity of the samples of 2001 product were always slightly higher than the newly extracted olive oil product and the %acidity of the old product was high on Ayvalik sample with %acidity 3.1, and moderate on Verdale and Surani samples with %acidity 1.1. 1.3 respectively; the rest of the varieties samples were with %acidity below 0.8% and ranged 0.3 – 0.7, Figure 15.

Statistical analysis for the %acidity of 2001 and 2002 products using Statistix10 software had shown no significant difference between the two products and the results are presented in the following text:

Comparisons Old – New Olive Oil Products
%Acidity
Paired T Test
Null Hypothesis: difference = 0
Alternative Hyp: difference ≠ 0
Mean 0.5500
Std Error 0.2383
Lower 95% CI-0.0135
Mean - H0 0.5500
Upper 95% CI 1.1135
T 2.31
DF 7
P 0.0543
Cases Included 8 Missing Cases 0

Peroxide Value: It was observed that the peroxide valueof the samples stored for one year was always higher than the peroxide value of the newly extracted olive oil. Peroxide value of 2001 product was very high on Ayvalik sample as it reached 25.5 which was above the acceptable level followed by Verdale which reached 16, and the rest of the samples were within the range 9.8 – 12 Meq O2/Kg Oil, Figure 16. Peroxide value of the new product was relatively high and ranged between 7.4 – 12.2 Meq O_2/Kg oil.

Statistical analysis for the peroxide value of 2001 and 2002 products using Statistix10 software had shown no significant difference between the two products and is presented in the following text:

Comparisons of Old – New Olive Oil Products
Peroxide Value
Paired T Test
Null Hypothesis: difference = 0
Alternative Hyp: difference ≠ 0
Mean 4.5250
Std Error 2.0461
Lower 95% CI-0.3134
Mean - H0 4.5250
Upper 95% CI 9.3634
T 2.21
DF 7
P 0.0627
Cases Included 8 Missing Cases

Table 5. Laboratory analysis results on fresh olive fruits samples and %oil extracted from the fruits of different olive cultivars on October 10, 2002

Cultivar	Jordan	Frantioi	Manza-nilla	Surani	Picual	Ayvalik *	Impr. Nebali *	Verdale *	Coratina*
%Water	63.93	64.97	67.40	75.06	68.33	58.71	72.55	62.18	60.6
%Oil Content / Fresh Matter	19.11	17.59	16.05	11.48	14.10	20.99	10.79	15.60	16.38
%Oil Content / Dry Matter	52.98	50.31	49.15	46.02	44.45	50.83	39.29	41.25	41.59

* Fruits not matured yet.

Table 6. 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
Manza-nilla			2	1	2	5
Picual		Oilwith Typical Organoleptic Character	3	1	1	5
Improved Nebali		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.- 0fruity>0 VOO: Def. ≤ 3.5 fruity> 0
OVOO: Def. 3.5 - 6 LVOO: Def. > 6

Table 7. Analysis results* of eight olive oil samples of 2002 product and one 2001 product of TADCO cultivars on November 26, 2002

Type of Analysis	Jordan	Frantioi	Surani	Manz-nilla	Picual	Impr-Nebali	Ayvalik	Verdale	Coratina 2001 Product	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% EV ≤ 2% V ≤ 3.3% OV
Peroxide Value (Meq O2/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 of Olive Oil Standards 2003 (IOC & EU) and [IOC 1996 (EU – 2002)]

Table 8. Comparison of the olive oil analysis results of 2001 product stored for one year with the new product on December 2002

Variety	% Acidity (g/100g oil)		Peroxide Value (*Meq*/kg)		Polyphenols		Rancidity	
	2001 Product	2002 Product	2001 Product	2002 Product	2001 Product	2002 Product	2001 Product	2002 Product
Jordan	0.7	0.3	11.4	9.6	74	170	Rancid 3	Free
Frantioi	0.7	0.5	11.6	9.2	41	168	Musty-Humid	Free
Surani	1.3	0.7	11.4	12.2	47	85	Rancid 5	Rancid 2
Manazanilla	0.7	0.5	10.8	8.2	77	286	Rancid 1	Free
Picual	0.3	0.4	9.8	7.4	66	88	Free	Free
I. Nebali	0.7	0.4	12.0	8.0	91	132	Rancid 1	Free
Verdale	1.10	0.4	16.0	10.3	124	164	Rancid 4	Rancid 2
Ayvalik	3.1	1.0	25.5	7.4	53	92	Rancid 4	Free
Acceptable Level as per Standards 2003 (IOC & EU)	≤ 0.8		≤20				Free	

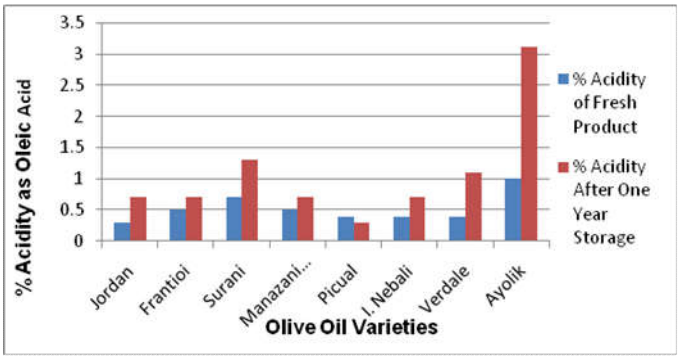

Figure 15. Comparison for the effect of storage for one year on the % acidity of olive oil of 2001 product in comparison of the new 2002 product

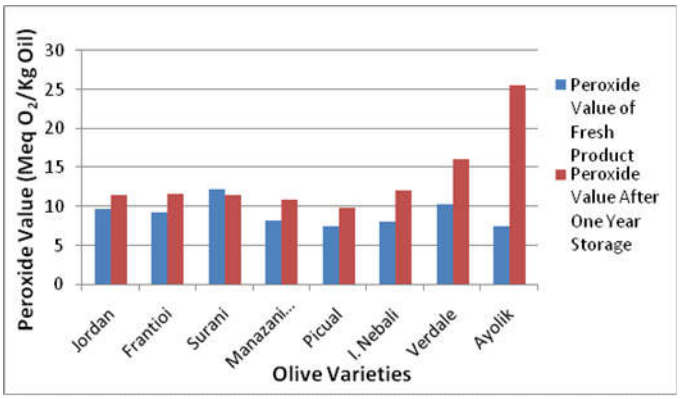

Figure 16. Comparison for the effect of storage for one year on the peroxide value of olive oil of 2001 product in comparison with the new 2002 product

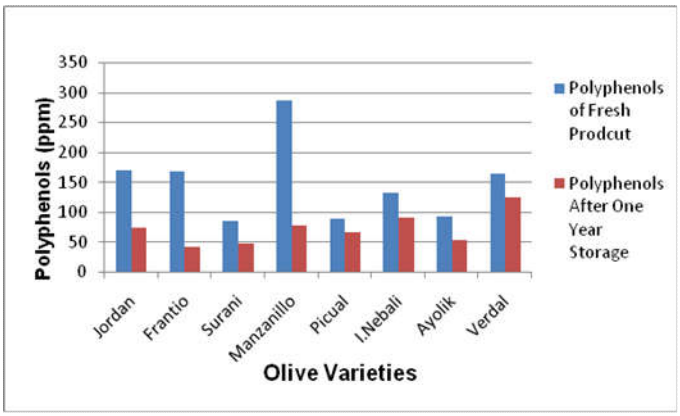

Figure17. Comparison for the effect of storage for one year on the level of polyphenols of olive oil of 2001 product in comparison of the new 2002 product

Polyphenols: It was observed that the polyphenols level of the samples stored for one year was always lower than the polyphenols of the newly extracted olive oil. Polyphenols of 2001 of Verdale sample was with relatively high level as it reached 124ppm, and the rest of the samples were within the range 41 - 91 ppm; Improved Nebali was with 91 ppm followed by Manzanilla with 77 ppm then Jordan 74 ppm then Picual with 66 ppm then Ayvalik with 53 ppm then Surani with 47 ppm then Frantioi with 41 ppm Figure 17. Coratina reached 266 ppm, and it was not included in the table due to late harvest for 2002 product. In 2002 product, Manzanilla was with 286 ppm followed by Jordan with 170 ppm then Frantioi with 168 ppm then Verdale with 164 ppm then ppm then Ayvalik with 92 ppm then Picual with 88 ppm then Surani with 85 ppm then Improved Nebali with 132 ppm then Ayvalik with 92 ppm then Picual with 89 ppm then Surani with 85 ppm.

Statistical analysis for the effect of storage period on the level of polyphenols of 2001 and 2002 products using Statistix10 software had shown significant difference between the two products and is presented in the following text:

Polyphenols Comparisons of Old – New Olive Oil Products
Paired T Test for New - Old

Null Hypothesis: difference = 0
Alternative Hyp: difference ≠ 0
Mean76.625
Std Error22.690
Lower 95% CI22.973
Mean - H076.625
Upper 95% CI130.28
T 3.38
DF 7
P0.0118
Cases Included 8 Missing Cases 0

Rancidity: The lab analysis of the oil samples in Italy detected variable degree of ranciditon all of the oil samples of 2001 product except Picual. So we decided to investigate the cause and the route of this problem through storage experiments between the period 2002 – 2005.

Effect of storage for two years period on 2003 product

This study included eight olive oil samples from the 2003 product represent eight olive cultivars grown at TADCO: Jordan, Frantaioi, Manzanilla, Surani, Picual, Ayvalik, Improved Nebali, and Coratina. The samples were collected into glass bottles from the cold store on two occasions: on September 2003 immediately after the process of extraction and filtration, and on December 2005 after more than two years storage. The chemical analysis was carried out in the company Laboratory on September 2003 and on December 2005. The results of the analysis are shown in Table 9 and Figure 18and 19.

Results indicated the following:

%Acidity: At the start of the experiment, the % acidity of the oil of 2003 product was below 0.8% and ranged from 0.17 to 0.76. After two years storage, %acidity remained less than 0.5%: on three varieties: Farantioi, Picual and Coratina. However, %acidity increased significantly on two varieties: Jordan and Ayvalik, and the rest of the varieties have %acidity increase range from slight to medium, but they were still below 0.8% as shown in Figure 18.

Statistical analysis for the %acidity of 2003 product samples using Statistix10 software had shown significant difference after two years storage and it is presented in the following text:
Storage for two Years, Sept 2003 to December 2005

%Acidity
Paired T Test
Null Hypothesis: difference = 0
Alternative Hyp: difference ≠ 0
Mean0.2888
Std Error0.0595

Table 9. Analysis results of eight olive oil samples of 2003 product conducted on September 2003 and on December 2005

Variety	% Acidity (g/100g oil)		Peroxide Value (*Meq*/kg)		Rancidity	
	Sept. 2003	Dec. 2005	Sept.2003	Dec. 2005	Sept. 2003	Dec. 2005
Jordan	0.48	1.00	8.56	16.21	Free	Free
Frantioi	0.24	0.38	4.39	8.22	Free	Free
Surani	0.50	0.76	9.91	12.19	Free	little
Manazanilla	0.17	0.60	9.59	12.68	Free	Free
Picual	0.16	0.22	13.79	18.69	Free	little
I. Nebali	0.43	0.68	9.09	11.53	Free	Free
Coratina	0.26	0.31	3.63	9.43	Free	Free
Ayvalik	0.76	1.12	7.03	12.85	Free	traces
Acceptable Level as per Standards 2003 (IOC & EU)	≤0.8	≤0.8	≤20	≤20	Free	Free

Table 10. Analysis results of eight olive oil samples of 2004 product conducted on September 2004 and on December 2005

Variety	% Acidity (g/100g oil)		Peroxide Value (*Meq*/kg)		Rancidity	
	Sept. 2004	Dec. 2005	Sept. 2004	Dec. 2005	Sept. 2004	Dec. 2005
Jordan	0.21	0.27	8.09	14.35	Free	Free
Frantioi	0.26	0.32	9.00	13.55	Free	Free
Surani	0.47	0.66	11.00	13.61	Free	Free
Manzanilla	0.39	0.51	4.60	8.94	Free	Free
Picual	0.09	0.18	4.36	10.61	Free	Free
Improved Nebali	0.21	0.33	3.27	12.13	Free	Free
Coratina	0.03	0.28	2.95	11.04	Free	Free
Ayvalik	0.51	0.72	6.24	10.87	Free	Free
Acceptable Level as per Standards 2003 (IOC & EU)	≤0.8	≤0.8	≤ 20	≤ 20	Free	Free

Lower 95% CI0.1480
Mean - H00.2888
Upper 95% CI0.4295
T 4.85
DF 7
P0.0019
Cases Included 8 Missing Cases 0

Peroxide Value: It was noted that the peroxide Value increased significantly on the varieties of Picual, Jordan, and increased moderately on the varieties Manzanilla, Surani, Coratina, Nebali, and slightly increased on Frantioi and Ayvalik varieties. All the varieties peroxide value remained below 20 as shown in Figure 19.

Statistical analysis for the peroxide value of 2003 product samples using Statistix10 software had shown significant difference after two years storage and it is presented in the following text:

Storage for two Years Sept 2003 to December 2005
Peroxide Value
Paired T Test
Null Hypothesis: difference = 0
Alternative Hyp: difference ≠ 0
Mean4.4850
Std Error0.6632
Lower 95% CI2.9167
Mean - H04.4850
Upper 95% CI6.0533
T 6.76
DF 7
P0.0003
Cases Included 8 Missing Cases 0

Rancidity: It was observed that the oil product was free from the rancidity at the start of the experiment in September 2003. After two years storage, traces of rancidity was observed on Ayvalik, and light rancidity was observed on Surani and Picual. The rest of the varieties Frantioi, Manzanilla, Jordan, Coratina and Improved Nebali were free from rancidity.

Effect of one year storage period on the 2004 product: This study included eight olive oil samples from the 2004 product represent olive cultivars: Jordan, Frantaioi, Manzanilla, Surani, Picual, Ayvalik, Improved Nebali and Coratina. The samples were collected into glass bottles from the cold store in two occasions: on September 2004 immediately after the extraction and filtration processes, and on December 2005 after more than one year storage. The chemical analysis was carried out in the company Laboratory on September 2004 and on December 2005. The results of the analysis are shown in Table 10 and Figure 20 and 21.

Results indicated the following:

% Acidity: At the start of the experiment, the acidity was below0.8% on all of the varieties which ranged from 0.09 to 0.51%; the acidity was less than 0.5% on all varieties except on Picual and it was with 0.51%, Figure 20. After more than one year storage, the acidity of the samples had increased moderately on the varieties Ayvalik and Surani, and slightly increased on the rest of the varieties; and the acidity on all varieties remained below 0.8%.

Statistical analysis for the %acidity of 2004 product samples using Statistix10 software had shown significant difference after one year storage period and it is presented in the following text:

2004 Product
Storage for one Year Sept 2004 to December 2005
%Acidity
Paired T Test for Dec - Sep
Null Hypothesis: difference = 0
Alternative Hyp: difference ≠ 0
Mean0.2588
Std Error0.0605
Lower 95% CI0.1157
Mean - H00.2588
Upper 95% CI0.4018
T 4.28
DF 7
P0.0037
Cases Included 8 Missing Cases 0

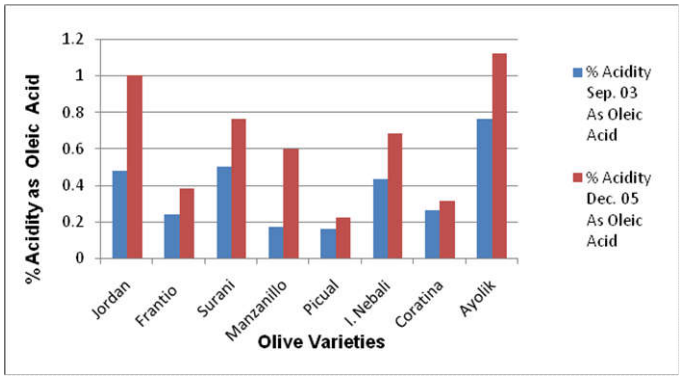

Figure 18. Effect of storage for two years storage on the % Acidity of olive oil of 2003 product

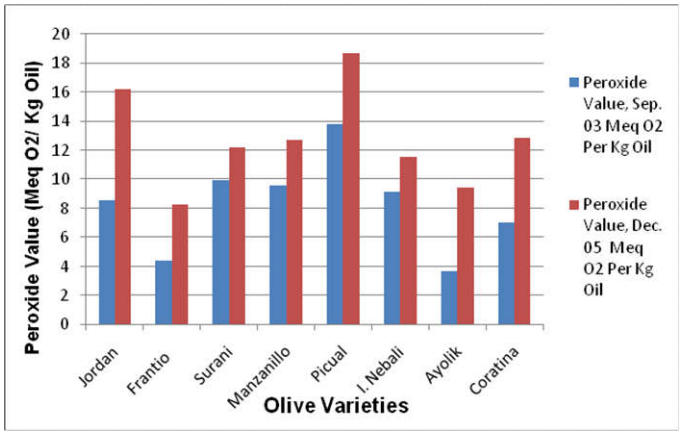

Figure 19. Effect of storage for two years on the peroxide value of olive oil of 2003 product

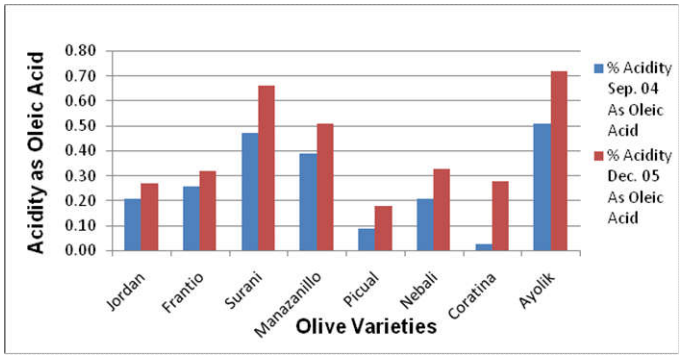

Figure 20. Effect of storage for one year on the % Acidity of olive oil of the 2004 product

Peroxide Value: It was noted at the start of the experiment that the peroxide value on the samples of the different varieties was relatively low on most of the varieties and ranged from 2.95 to 11.0 milliequivalent / kg olive oil. After one year of storage, there was a significant increase on the peroxide value on most of the varieties and it reached 14.95 *Meq*/kg on the Jordan variety, 13.61 on the Surani variety followed by the Frantioi 13.55 and then the other varieties as shown in Figure 21:

Statistical analysis for the Peroxide Value of 2004 product samples using Statistix10 software had shown significant difference after one year storage period and it is presented in the following text:
2004 Product
Storage for one Year Sept 2004 to December 2005
Peroxide Value
Paired T Test for Dec - Sep

Null Hypothesis: difference = 0
Alternative Hyp: difference ≠ 0
Mean4.5100
Std Error0.6800
Lower 95% CI2.9019
Mean - H04.5100
Upper 95% CI6.1181
T 6.63
DF 7
P0.0003

Rancidity: No traces of rancidity were observed onall the samples after one year storage period, and the oil is fit for human consumption.

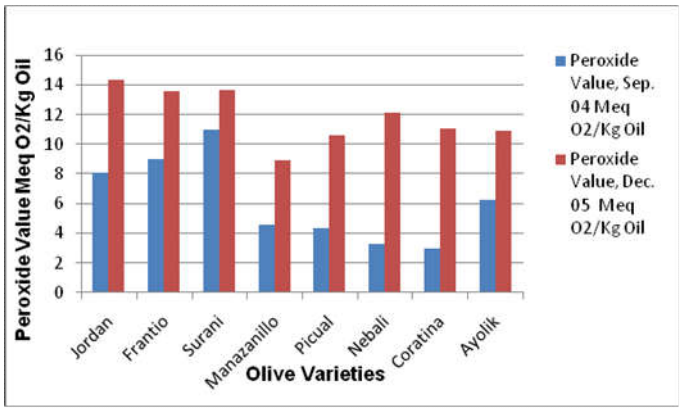

Figure 21. Effect of storage for one year on the on the peroxide value of olive oil of 2004 product

PACKING OLIVE OIL FOR SALES

Olive oil was filled into metal containers or glass bottles immediately after the filtration process for quantities directed for sale to the local market to be sold within one year of packing or filling from the drums during any period of the year. The choice was to pack into metal tins with a capacity of 0.175, 2, 4, 8 and 15 liters or glass bottles capacity 0.25, 0.5, 0.75 liters. The small bottles are placed inside the cartons in a supported manner to facilitate their transport and handling, and to prevent the exposure of glass containers to the light. Exposure of the transparent glass bottles to the light leads to the deterioration of the product, and therefore the glass bottles should be of the dark type in case of placing the packages in the supermarket exposed to the light. The Packages were filled completely, and then closed tightly, then printed the batch number on the tins and bottles.

Conditions of olive packing containers to maintain olive oil quality:

- Containers are free from moisture and odors.
- The packaging should be made of raw material that does not react with the oil, and darkened glass is preferred over the transparent glass.
- Avoid the exposure the contents of the package to light or air.
- Avoid the exposure of the oil to temperature higher than 25 degrees for long periods.

OLIVE OIL BLENDING

TADCO produce olive oil from different olive cultivars; the oil of some of these cultivars are preferred by the local consumer

as it is with nice smell, fruity with slight or no bitterness taste which give it the sweat taste like Jordan variety, while the oil of Coratina is not preferred by the local consumer due to strong bitter and pungent taste as it contains high level of polyphenols in comparison to the oil of other TADCO cultivars which is preferred by the local consumer like Jordan, Surani and picual in the same order. Improved Nebali varietyis with low content of oleic acid and high level of linoleic acid and it need to be blended with Coratina and or other TADCO olive oil varieties to satisfy SASO and IOC standards.

Table 11. Sensory test on four olive oil blends on February 7, 2008

Olive Oil Variety	Olive Oil Blends Proportions			
	Blend A Sample # 863	Blend B Sample # 864	Blend C Sample # 865	Blend D Sample # 866
Jordan	--	1 Part	--	41 Parts
Frantioi	--	--	1 Part	17 Parts
Manzanilla	--	--	1 Part	6 Parts
Surani	1 Part	--	1 Part	4 Parts
Picual	1 Part	1 Part	--	100 Parts
Ayvalik	--	--	--	--
I. Nebali	--	1 Part	--	170 Parts
Coratina	2 Parts	2 Parts	--	27 Parts
	Sensory evaluation on the four olive oil blends			
Blend Name	Flavor			
	Fruity	Bitter	Pungent	Total Score
A	5	2	2	9
B	3	2.5	2	7.5
C	3	0.5	2	5.5
D	3	1.5	2	6.5

Table 12. Chemical analysis on olive oil samples on four olive oil blends February 7, 2008

Olive Oil Blend	Blend A	Blend B	Blend C	Blend D	Z
Panel Test	9	7.5	5.5	6.5	EVOO: Defect.- 0 fruity ≥ 0 VOO: Def. ≤ 3.5 fruity> 0 OVOO: Def. 3.5 - 6 LVOO: Def. > 6
%Acidity as Oleic Acid (Mg KOH/g Oil)	0.64	0.53	0.75	0.62	≤ 0.8% EV ≤ 2% V ≤ 3.3% OV
Peroxide Number (Meq O2 / Kg Oil)	9.31	7.13	10.59	9.11	≤ 20
Rancidity	Free	Free	Free	Free	Free

The chemical composition of the oil blend shall have higher level of oleic acid and better taste which leads to increased oxidation stability and increased shelf life of the product thanks to the polyphenols. TADCO frequently attempted to make a blend of olive oil which is with consistent taste and acceptable by the consumers. On February 2008, a panel of TADCO tasters from Olive business unit, Sales section and Lab staff were coached by the Olive consultant Eng'r Ali Abu Zurayk to conduct sensory test on four olive oil blends, the results are shown in Table 11 and 12.

Results of the sensory test and chemical tests had shown that blend A and B were the best followed by blend C and D. Survey of olive oil stock at TADCO on April 2009 had shown that the majority of olive oil stock was from Improved Nebali with 44.4% followed by Picual with 28.4% then Jordan 10.2% then the other varieties. This situation created quality control problem due to the presence of so many batches of olive oil need to be monitored regularly, and marketing problem as some varieties was difficult to be packed alone due to low quantity or due to sensory attributes. So it should be blended with other varieties to become acceptable by the consumer. The suggested blending was based on the storage of each variety separate and as per the sales request was sold alone like Jordan, Picual, Frantioi. Blending was carried out before backing as per the accepted blend by the Sales and the end user preference.

DISCUSSION

An integrated management system was developed and practiced at TADCO since 2002 cropping season for the olive fruits and olive oil production from different olive varieties grown at the company. These varieties were originated from the Mediterranean basin countries such as Spain, Italy, Turkey, Syria and Jordan. This system was achieved by the acquirement of technical solutions through olive consultants visit, skilled olive technicians from famous olive growing countries, research and lab experimentation and monitoring the quality of the oil products. The integrated management system was based on the understanding the various factors affecting olive fruits and olive oil production and quality briefed in the following text, and the implementation of technical solutions: (Montedero *et al.,* 1991; Pannelli *et al.,* 1990; Fontanazza *et al.,* 2002; Vossen, 2004; Mikchelakis, 1992):

- Olive crop factors: This includes the selected olive variety like Jordan, Picual, Surani etc., olive tree health, olive tree maintenance through pruning, irrigation& fertigation management, pest and disease control etc.
- Production of olive fruits: It includes the stage of fruits maturity, method of fruits harvest, fruits health status, fruits bruises, fruits handling ,transportation ofthe fruits directly to the olive mill or to the cold storage and store the fruits at 5 - 7^0 C. for no more than two weeks prior to the oil extraction.
- Extraction of olive oil: the factors involved are olive mill readiness and cleanness, fruits cleaning from leaves and dirt, right speed of the grinder, cold press at 28 – 30^0 C through the control of the paste mixing machine temperature, control the quantity of water added to the olive paste, moderate malaxation speed, and the duration of malaxation 30 – 40 minutes, perfection of olive oil separation through the decanter and through the centrifuge machines.
- Temporary storage: Store extracted olive oil into the clean silo tanks and allow settling the olive oil of each variety into a separate stainless steel tank for a period of 20 -30 days. Check the quality of each batch in the lab before storage into the tanks and store it separately if the quality was not extra virgin grade. Frequently remove the precipitated dirt material and vegetable water from the conical bottom of the storage tank.
- Filtration: The olive oil is filtered in preparation for packing to the market or for long duration storage (one year or more). Check the storage tanks of the filtration room were clean, send oil sample to the laboratory before backing and record the quantity of the produced olive oil and the grade on the log records of the computer.
- Packing and Storage: Fill the olive oil into the drums or into the commercial packing containers intended for sale, and make sure of complete filling the drum to push the air outside the containers. The typed or printed batch number should appear on the containers. One reference sample of olive oil was kept with quality control supervisor office for future checking. The stored drums and containers were stored at the store room sat 15 – 20^o C. away from light, strange fumes, high heat or freezing temperatures.

Table 13. Summary results onthe 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 14. Summary results on the analysis of olive oil samples of different olive cultivars of 2001 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 Nebali	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

Table 15. Olive oil samples analysis of different varietiesduring the period 2004– 2010

Variety/Product	Date of Test	Acidity	Peroxide Value	Rancidity
Jordan 03	1/11/2004	0.31	7.10	Free
Frantioi 03	18/12/2005	0.38	8.22	Free
Coratina 03	18/12/2005	0.31	12.85	Free
Vredale 05	20/1/2008	0.52	7.65	Free
Frantioi 05	20/1/2008	0.35	2.74	Free
Ayvalik 05	20/01/2008	0.69	2.58	Free
Jordan 06	20/01/2008	0.45	5.40	Free
Surani 06	20/01/2008	0.61	5.67	Free
Picual 07	4/2/2010	0.12	9.68	Free

Storage of the olive oil from 1997 until 2009 season was carried out using clean steel drums with laminated inside face to protect the olive oil from direct touching with the drum metal to prevent oil oxidation during the storage period, which may last for more than one year and is less cost than the silos for small and medium companies. The drums were filled with oil completely (215 L), so the oil is not reacted with the oxygen stored in the unfilled part of the drum. Conical drums replaced steel drums after 2009 (OMICS Jordan): These drums are available in 210 liters and used in connection with inner aseptic bags, and they were suitable for olive oil storage. Due to its structure (CRCA) and dimensions, a conical drum allows exceptional efficiency during transportation and storage. This is the main advantage of using such drums as it will significantly save transportation costs of empty drums and also requires less space for storage in the warehouse. It is cheaper by 20% from the steel drums, and it saves 13% on packing materials and 13% on shipping cost. It could be used several times, all what is needed is to use a new aseptic bag, and this reduced the cost of oil production and storage. The sensory analysis results (Mailer *et al.,* 2006; Vossen, 2007; IOC 2015) on the fourteen olive oil samples of 1997 product (non-filtered) shown no defects on the oil samples Table 16, 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. As per the results of the chemical analysis on the oil samples, the grade of the oil was in conformity with extra virgin on Jordan, Picual, Frantioi, Coratina, and in conformity with virgin grade on Ayvalik and another four samples of Picual, Frantioi.

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

- Frantioi sample: no defects was detected on the oil sample, The panel identified positive characters on this oil as fruity, with moderate bitter and pungent flavor and it scored 6.
- Jordan sample: no defects was detected on the oil sample, The panel identified positive characters on this oil as high fruity, with low bitter and light pungent flavor, taste like sweat oil and it scored 5.
- Picual sample: no defects was detected on the oil sample, The panel identified positive characters on this oil as it was with strong fruitiness, low bitter and light pungent flavor, oil with typical organoleptic character, and it scored 5.
- Manzanilla sample: no defects was detected on the oil sample, The panel identified positive characters on this oil as fruity with low bitter, moderate pungent flavor, and it scored 5.
- Improved Nebali sample: no defects was detected on the oil sample, The panel identified positive characters on this oil as high fruity, with low bitter and light pungent flavor, oil with typical organoleptic character, and it scored 4.5

The Sensory analysis test (Mailer *et al.,* 2006; Vossen, 2007; IOC 2015; Fontanazza *et al.,* 2002) on the eight olive oil samples of 2002 product shown no defects on the oil samples

of Jordan, Frantioi, Manzanilla, Picual, Improved Nebali, Ayvalik and the fruitiness of the oil samples was above 0, then 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 was in conformity with extra virgin on Jordan, Frantioi, Manzanilla Picual, Improved Nebali, and in conformity with virgin grade on Ayvalik as shown in Table 17. There were rancidity defect (score 2) detected on the oil samples of Surani and Verdale and the total flavor is zero, then these samples due to rancidity defect are not fit for human consumption and the class of these two samples is Lampante oil. Results of the analysis on oil samples of 1997 and 2002 products (Vossen, 2007; IOC, 2015; Fontanazza *et al.,* 2002) shown good chemical composition of the varieties Coratina, Jordan, Picual as they shown high %oleic acid which ranged 69.48 – 74.39 and low percentage of linoleic, linolenic acid besides medium percentage of saturated fatty acid considering high summer temperature in the project. It was also observed high olive oil oxidation stability 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 High ratio of mono-unsaturated/poly-unsaturated fatty acid on Manzanilla, Coratina 01 and Jordan which reached 7.69, 6.98, 6.66 respectively; also high ratio of Oleic Acid/Lenoleic fatty acid on the same varieties which reached 8.14, 7.38, 6.95 respectively. Both results indicate more nutritional value of the oil due high oleic acid content in the oil, and more olive oil stability. Due to the production of olive crop under desert growing conditions, trees receive weekly irrigation to protect the trees from heat stress and reduce premature fruits drop. However trees irrigation should be managed with reduced quantities before harvest. % Moisture test on the fruits of the different olive varieties shown high water content on the fruits above the acceptable level 60% on all of the varieties except Ayvalik which reached 58.71%. High water content on the fruits of Surani and improved Nebali reached 75.06, 72.55% respectively, and this led to low %oil content on their fruits which reached 11.48, 10.79% respectively. On the other hand, low water content on the olive fruits led to high oil content which reached 20.99, 19.11%.on Ayvalik and Jordan respectively. Expression of the results as ratio of oil content/dry matter was investigated and it reached 50.83%.on Ayvalik with the result of 20.99% oil content; and when the ratio of the oil content/dry matter dropped to 39.29%, the %oil content dropped to10.79% on the fruits of Improved Nebali. These results demonstrate that when this ratio reached near 50%, the fruits have reached maximum oil content and the grower should start harvesting the fruits (Mailer *et al.,* 2006; Vossen, 2007; Fontanazza *et al.,* 2002).

% Olive oil extraction on the mill shown higher %oil extraction (Mailer *et al.,* 2006; Vossen, 2007; Fontanazza *et al.,* 2002). on the different varieties in 1997 cropping season which ranged 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 cold press at 28^{o}C. And early fruits harvest to get high olive oil quality. In general %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 alternate bearing. Olive varieties with high percentage olive oil extraction were Ayvalik, Surani and Coratina with range of 15 – 20%, while Jordan, Picual Verdale were with medium %oil extraction with a range of 12 – 15%; Improved Nebali and Frantioi were with low %oil extraction with a range of 10 – 12%. For unexpected reason, rancidity was detected on the stored 2001 product except Picual. The oil samples was analyzed in Italy on October 2002, they detected variable degree of rancidity on all of the oil samples except Picual, and this indicated a problem in the processing and storage of olive oil which was investigated and corrected at the olive mill and storage facilities. The research and the lab conducted olive oil storage experiments during the period 2002 – 2005 to find the cause and the route of rancidity on olive oil at the company.

The comparative study between the fresh 2002 product and the stored 2001 product showed the following:

- Significant increase of %acidity on three varieties of Ayvalik, Surani and verdale, and slight increase on the rest of five varieties: Jordan, Frantioi, Manzanilla, Picual, Improved Nebali which remained with % acidity below 0.8%.
- Significant Increase in the peroxide value of Ayvalik which exceeded the acceptable level 20, and moderate increase on Verdale peroxide value; the rest of the six cultivars were with slight increase.
- Significant decrease in the oil content of polyphenols on most of the varieties samples, which affected the degree of oil preservation of these varieties after more than a year of oil storage.
- As per the sensory test, all the samples were with rancidity defect. So the class of the rancid oil samples was lampantino virgin olive oil and it is not fit for human consumption (Vossen, 2007; IOC 2015; Codex Alimentarius, 2001).

The storage of olive oil samples of 2003 product for two years led to slight Increase of %acidityon three varieties of Frantioi, Picual, Coratina, and%acidity increased by a range of medium to high level on the rest of the varieties samples. It also led to high increase on the peroxide value on most of the varieties except Frantioi and Ayvalik as they were with medium increase. Storage for two years led to the development of rancidity traces on Ayvalik, and slight rancidity on the varieties samples of Surani and Picual. The rest of the varieties Frantioi, Manzanilla, Jordan, Coratina and Improved Nebali remained free of rancidity. The class of the olive oil samples of Jordan and Ayvalik were in conformity with virgin grade varieties samples were in conformity with extra virgin grade (Vossen, 2007; IOC 2015; Codex Alimentarius, 2001), and the rest of the varieties samples were in conformity with extra virgin grade. The storage of olive oil samples of 2004 product for one year led to slight increase in %acidity on the varieties of Jordan, Frantaioi, Picual, Improved Nebali and Coratina, while the %acidity in the rest of the varieties increased moderately. It also led to significant increase on the peroxide value on most of the varieties samples except Manzanilla and Picual, but rancidity test shown all samples were free of rancidity and the olive oil still fit for human consumption. By the end of the experiment, all of the varieties samples were in conformity with extra virgin grade (Vossen, 2007; Codex Alimentarius, 2001),). TADCO produce olive oil from different olive cultivars; the oil of some of these varieties were preferred by the local consumer as it was with nice smell,

fruity with slight or no bitterness taste which give it the sweat taste like Jordan variety, while the oil of Coratina is not preferred by the local consumers due to strong bitter and pungent taste in comparison to the oil of other varieties which is preferred by local consumers like Jordan, Surani and Picual in the same order. Improved Nebali variety is with low content of oleic acid and high level of linoleic acid and it need to be blended with Coratina and or other TADCO olive oil varieties to satisfy SASO and IOC standards varieties (Vossen, 2007; Codex Alimentarius, 2001).). The chemical composition of the oil blend should have higher level of oleic acid and better taste which lead to increased oxidation stability and increased shelf life of the product thanks to the polyphenols on Coratina. Olive oil blends were tested at TADCO to get a blend oil mix with consistent taste and accepted by the consumers, also the aim of the blending was to improve the chemical composition of some varieties. The results of the sensory test and chemical tests had shown that two blends were the best followed by blend of the other two blends. Blending oil was based on the storage of each variety separate and as per the sales request is sold alone like Jordan, Picual, Frantioi or the blending was carried out before backing as per the accepted blend by the Sales and the end user preference. Evidence to support the success of integrated management of olive oil production, storage and quality is presented in the following samples analysis Table 18. Results shown that after a storage period of more than two years, the quality of olive oil of different varieties packed into sealed steel drums were in conformity to extra virgin grade, and there were no negative effect on the quality of stored olive oil.

Conclusion

No doubt extreme weather conditions affects the chemistry of the olive oil produced such as oleic, linoleic and saturated fatty acids which affect olive oil quality and stability. The results demonstrated the possibility of producing extra virgin olive oil matching the IOC standards as the area was free from the infestation of olive fruit fly, and rainfall was limited and predictable, so the farmers avoided harvesting olives during rainfall. As we observed in the review, the company produced high quality olive oil from most of the varieties. The big challenge to the company was to maintain high olive oil quality after pressing for the next season. Rancidity of oil was a serious issue on 2001 product and it was solved by sound planning for oil processing and storage based on understanding that oil is a food material need clean and hygiene facilities at all processing stages: oil extraction, temporary storage into clean large silo tanks to settle the oil for few weeks and remove the water and impurities, then filtration in a clean store then storage, fill the oil into aseptic bags inside clean drums until it was full before closing and sealing the drums to get rid of air out of the bag then store in dark stores at 15 – 20^{o}C. Sampling olive oil through the season for the packed tins and bottles helped to monitor the olive oil quality during the storage period and marketing and apply correction measures if it was needed.

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