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Characterizing the Phenolic Compounds contents and Antioxidant Activity of Extra Virgin Olive Oils collected from different regions of West Bank- Palestine

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Declaration

I certify that this thesis submitted for the degree of master is the result of my own research, except where otherwise acknowledges, and that this thesis (or any part of the same) has not been submitted for the higher degree to any other university or institute.

Signed……

Wael Hani Ali Dwaik

Date: / /2016

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Abstract

This work is aiming to evaluate antioxidant activity, total phenolics content, total flavonoids content and other quality parameters (acid value, peroxide value, K_{232}, K_{272}, iodine value) of olive oil from different geographical regions of West Bank, to demonstrate if there were a correlation between each assay and the other assays for different farmers in the same geographical region and to demonstrate a possible correlation between studied quality parameters and selected agronomic parameters (olive fly infection, days of storage, green to black %, fruits drop % and olive yield %).

No enough research information had been written about total phenolic content, total flavonoid content and antioxidant activity of Palestinian olive oil and ther were no enough research informations about correlations between studied quality parameters.

Antioxidants contents were assayed using FRAP, CUPRAC, DPPH, and ABTS colorimetric methods. TPC and TFC of the extracts were evaluated using Folin-Ciocalteau, and aluminum chloride colorimetric methods, respectively.

Variations of the studied parameters (TPC, TFC, FRAP, CUPRAC, ABTS, DPPH, Acidity%, peroxide value, K_{232}, K_{270}, Iodine value, specific gravity and refractive index) for olive oil samples between governerates, regions and farmers were analysed statistically, and results showed that: In 2013, there were significant differences between governorates whereas: Hebron have refractive higher than Jenin, Nablus has iodine value higher than Hebron, and Nablus has DPPH higher than Hebron. Also there were significant differences between regions whereas: Si'ir has refractive higher than Burkin. Salfit has DPPH higher than both Surif and Si'ir. Surif has ABTS higher than Asira Al-Shamaliya. Dheisha has TFC higher than Asira Al-Shamaliya, and Surif has TFC higher than Asira Al-Shamaliya also, and also there were significant differences between farmers in all scales in Jenin governorate except the refractive scale. There were significant differences between Farmers in all scales in Nablus governorate. There were significant differences between farmers in all scales in Tulkarm governorate except in the Peroxide value, DPPH and ABTS scales. Finally, there were significant differences between farmers in all scales in both Bethlehem and Hebron governorates.

In 2014, there were significant differences between governorates whereas: Nablus has DPPH higher than Hebron. Both Jenin and Hebron have ABTS higher than Nablus. Jenin has FRAP higher than each one of Nablus, Tulkarm, Bethlehem and Hebron. Hebron has TFC higher than Nablus. Also there were significant differences between regions whereas: Surif has K_{270} higher than each one of Burkin, Salfit, Asira Al-Qibliya, Dheisha, and Al-Shuyukh. Both Salfit and Asira Al-Qibliya have iodine values higher than both Dheisha and Surif. Each one of Dheisha and Surif and Al-Shuyukh have ABTS higher than Asira Al-Qibliya. Burkin has FRAP higher than each one of Bayt Jala, Surif and Al-Shuyukh. Anabta has TFC higher than Salfit.Surif has TFC higher than each one of Salfit, Asira Al-Qibliya, and Bayt Jala, also there were significant differences between Farmers in all scales in Jenin governorate except in K_{270}, %Acidity, FRAP and TPC scales. There were significant differences between Farmers in all scales in Nablus governorate. There were significant differences between farmers in all scales in Tulkarm governorate except in refractive, specific gravity, CUPRIC and TFC scales. There were significant differences between farmers in all scales in Bethlehem governorate except in specific gravity and FRAP scales. Finally, there were significant differences between farmers in all scales in Hebron governorate.

There was no significant difference in the studied quality parameters of olive oil between governerates, and to some extent between regions too, while there was a significant difference between farmers.

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List of Abbreviations

Abbreviation	Description
AA	Antioxidants
BHA	Buthylhydroxyanisol
BHT	Butylhydroxytoluene
Nc	Neocuproine
FRAP	Ferric Ion Reducing Antioxidant Power Assay
DPPH	2,2-Diphenyl-1-picrylhydrazyl
CUPRAC	CUPRAC ion reducing antioxidant capacity
RI	Refractive index
PV	Peroxide value
THBP	Tetrahydroxybenzophenone
TBHQ	tert-Butylhydroquinone
TAA	Total antioxidant activity
RSA	Radical scavenging activity
TPTZ	Tripyridyltriazine
ROS	Radical Oxygen Species
O	Oleic acid
P	Palmitic acid
L	Linoleic acid
Ln	Linolinic acid
S	Stearic acid
$L^{\cdot}$	Fatty acid radical
$LOO^{\cdot}$	Fatty acid peroxyl radical
LOOH	Lipid hydroperoxides
OFI	Olive fly infection
DOS	Days of storage
GtoBper	Green to black %

Abbreviation	Description
Dropper	Drop %
Yieldper	Olive yield%
GAE	Gallic acid equivalent
EVOO	Extra virgin olive oil
VOO	Virgin olive oil
AOAC	Association of Official Analytical Chemists
IOOC	International Olive Oil Council
IOC	International Olive Council
TPC	Total Phenolics content
TFC	Total Flavonoids content
PE	Polyethylene bottles
D.W	Distilled water
TPTZ	Tripyridyltriazine
ABTS	2,2-azino-di- (3-ethyl-benzothialozine-sulphonic acid
DPPH	2,2-diphenyl-1- (2,4,6-trinitrophenyl)hydrazyl)

CHAPTER ONE

INTRODUCTION

1. Introduction:

1.1. Background and Rationale

Olive tree (*Olea europaea* L) is an important tree internationally that produces high nutritional and health quality edible oil. The global production of olive oil in 2015 was around 3,225,500 tons (IOC, 2016), from which around 14,000 tons are produced in Palestine. As olive oil production fluctuates from year to year, the mean annual production of olive oil globally during the recent five years (2011-2014) was 2,940,300 tons (IOC, 2016) and the average annual contribution in Palestine was 15,500 tons (IOOC, 2008). The European Union (EU) is the leading producer of olive oil and within the EU, the Mediterranean members are the biggest producers and consumers of olive oil. (IOC, 2016).

Olive tree is one of the most important trees in Palestine, it is also symbolic of Palestinians roots and attachment to the land, with the soil and climate producing some of the world's highest quality olive oil. From more than 750 million olive trees cultivated worldwide, 95% of which planted in the Mediterranean region. (IOOC, 2007).

Olives share in about 45% of the Palestinian agricultural score and with fruits from which virgin and extra virgin olive oil is produced. 45% of Palestinian agricultural land (about 100000 hectare) is planted with olive trees (Salimia et al, 2010). The expected amount of olive oil extracted by the aid of 270 oil press plants found in West Bank and Gaza are 32-35 thous- and metric tons yearly. Approximately 93% of the olive harvest in Palestine is used for their oil which comprises 18% of total agricultural economy. One liter of the Palestinian olive oil costs the farmer about 2.3 $ and is sold between 6-7 $. Places in West Bank-Palestine were oil samples for this research were collected are shown in (Figure1.1).

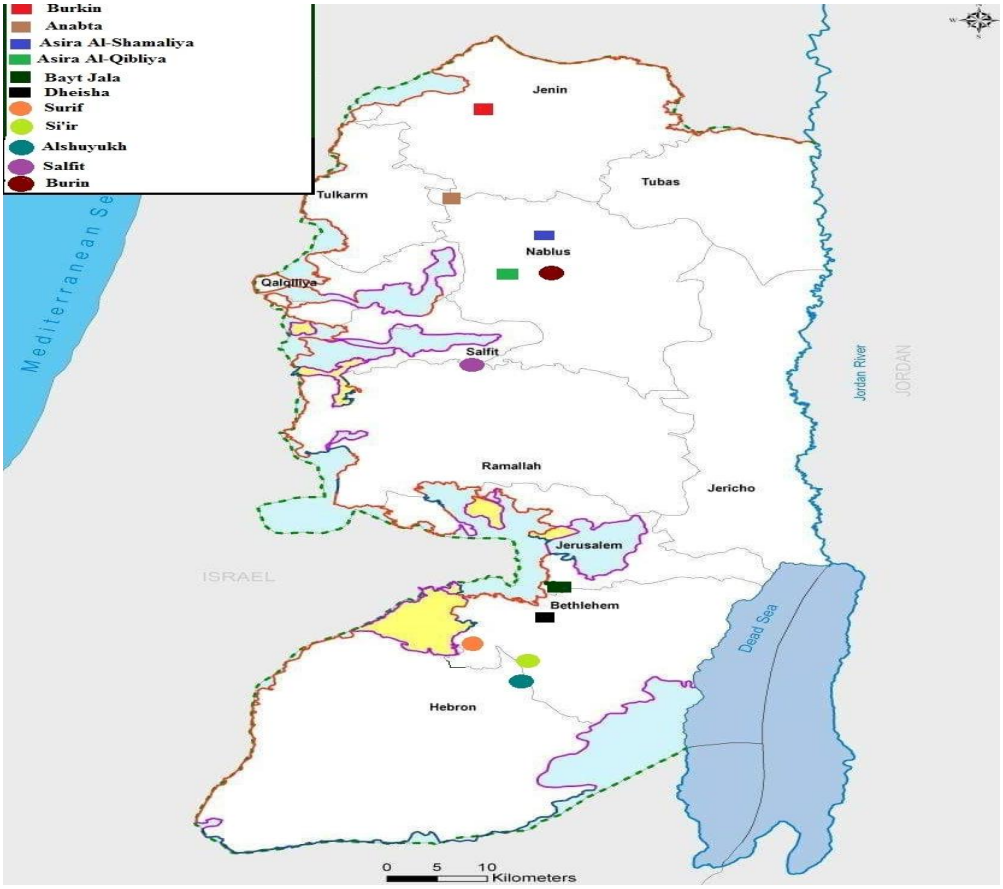


Figure1.1: places where samples were collected in the West Bank of Palestine.

Quality of olive oil is defined as the combination of its attributes that have significance in determining the degree of its acceptability by the consumer, and may be also defined from commercial, nutritional or organoleptic perspectives. The nutritional value of extra virgin olive oil (EVOO) originates from its high levels of oleic acid content and minor components, such as phenolic compounds that donate the oil its aroma. Therefore, these quality parameters promote the consumption demands and price of olive oil in comparison with other edible oils ranking it superior among vegetable oils (Vacca et al, 2006).

There is a need to develop reliable analytical methods to ensure compliance of olive oil quality with labeling, and to determine the genuineness of the product by the detection of eventual defects during adulterations, processing and storage conditions. Therefore, the International Olive Oil Council (IOOC) and European Communities Legislation (EC) define the identity characteristics of olive oil by specifying analytical methods and standard limit values of the quality parameters such as Peroxide Value (PV), Acidity%, Ultra Violet (UV) absorbance

values (K_{232} and K_{270}) and organoleptic characteristics (odor, taste and color) for olive oils in order to improve product quality, expand international trade, and raise its consumption (Abbadi et al, 2014).

Numerous factors such as olive variety, environmental, climatic, soil and cultivation conditions, age of the tree, olive ripeness, olive health, etc. are involved in the composition differences in virgin olive oil during its formation in the fruit (Dobarganes & Velasco, 2002).Various factors from intrinsic to agronomic, affect phenolic compounds. Olive cultivars, together with geographical origin, are responsible for the typicality of olives, table olives, and olive oils. Attention has to be paid to agricultural practices and cultivation systems (Malheiro et al, 2015).

1.2. Phenolic compounds

1.2.1. Definition

Phenolic compounds are the most abundant secondary metabolites of plants.They are complex class of chemicals including a hydroxyl group on a benzene ring. The plant phenols are aromatic secondary metabolites that contain a fundamental range of substances having an aromatic ring bearing one or more hydroxyl compounds. Plant phenols are defined based on metabolic origin and these substances derived from the shikimate pathway and phenylpropanoid metabolism (Ryan et al, 2002).

Many terms are used in existing literature to refer to these compounds such as phenols, phenolic contents, polyphenols, biophenols and others, depending on the matrix investigated. However, two of them were adopted as the most preferred ones when dealing with *Olea europaeae L.* matrices, i.e. olive phenols and/or olive phenolic compounds (Uccella, 2000).

A virgin olive oil contains at least 30 phenolic compounds. Phenolic total amount and composition of olive oil varies from 100 to 1000 mg/kg. Polyphenols are in fact a complex mixture of compounds with different chemical structures obtained from the oil by extraction with methanol-water. Phenolic compounds are related to the stability of the oil but also to its biological properties. Most phenolic compounds are found in nature in a conjugated form. (Houshia & Qutit, 2014).

1.2.2. Functions in olive oil

a. Nutritional quality: The presence of phenols with high antioxidant activities increases the

nutritional value of olive oils. (El Riachy et al, 2011).

b. Health benefits of olive oil phenols: The beneficial effects of olive oil phenols have been the focus of several investigations. In addition to their widely documented antioxidant activities, they seem to exert also others such as antithrombotic and antihypertensive effects. Moreover, they were associated with protective effects against certain types of cancer, neurodegenerative and cardiovascular diseases, in addition to the anti-aging protection. (Vissers et al, 2004).

c. Sensory quality: Phenols, together with volatiles, are the main responsible factors for sensory attributes of olive oils, providing a delicate and unique flavour highly appreciated by the consumers. (Servili et al, 2009).

d. Oxidative stability: Phenols are fundamental also for the shelf-life and oxidative stability of virgin olive oils. They resist a lipid oxidation already at initial stage by mechanisms such as radical scavenging, hydrogen atom transfer and/or metal-chelating abilities. (Jerman, 2014).

1.2.3. Factors affecting their levels

Polyphenol levels in olives depend on climate, variety, agricultural practices and ripeness at harvest. Polyphenol levels in the fruit are affected by irrigation during the growing season: thrifty watering increases the phenol level. Since polyphenol levels naturally decrease as the olive fruit ripens, harvest time affects their level in the oil: early harvests result in oils with higher polyphenol values (Houshia&Qutit, 2014).

Polyphenol levels decrease during milling and storage. Many polyphenols are water soluble and are lost with the vegetation water during processing. In addition, polyphenol levels will slowly decrease during storage, as they dampen oxidation in the oil given these unavoidable losses, an initial high polyphenol level is essential for ensuring longer shelf life and greater health properties (Manach, 2004) (Figure1.2) shows the factors that affect olives and olive products phenolic composition and levels (Malheiro et al, 2015).

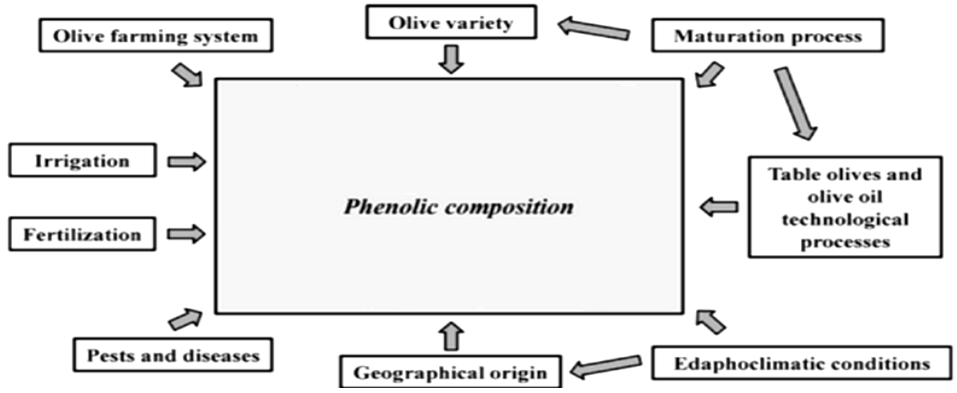


Figure1.2: factors that affect olives and olive products phenolic composition (Malheiro et al, 2015).

1.2.4. Phenolic compounds groups

Polyphenols may be classified into different groups as a function of the number of phenol rings that they contain and on the basis of structural elements that bind these rings to one another. The main classes include phenolic acids, flavonoids, stilbenes and lignans. (Figure 1.3) illustrates the different classes of polar phenolic compounds present in olive oil with molecular structures of representative examples (Rodríguez et al, 2015).

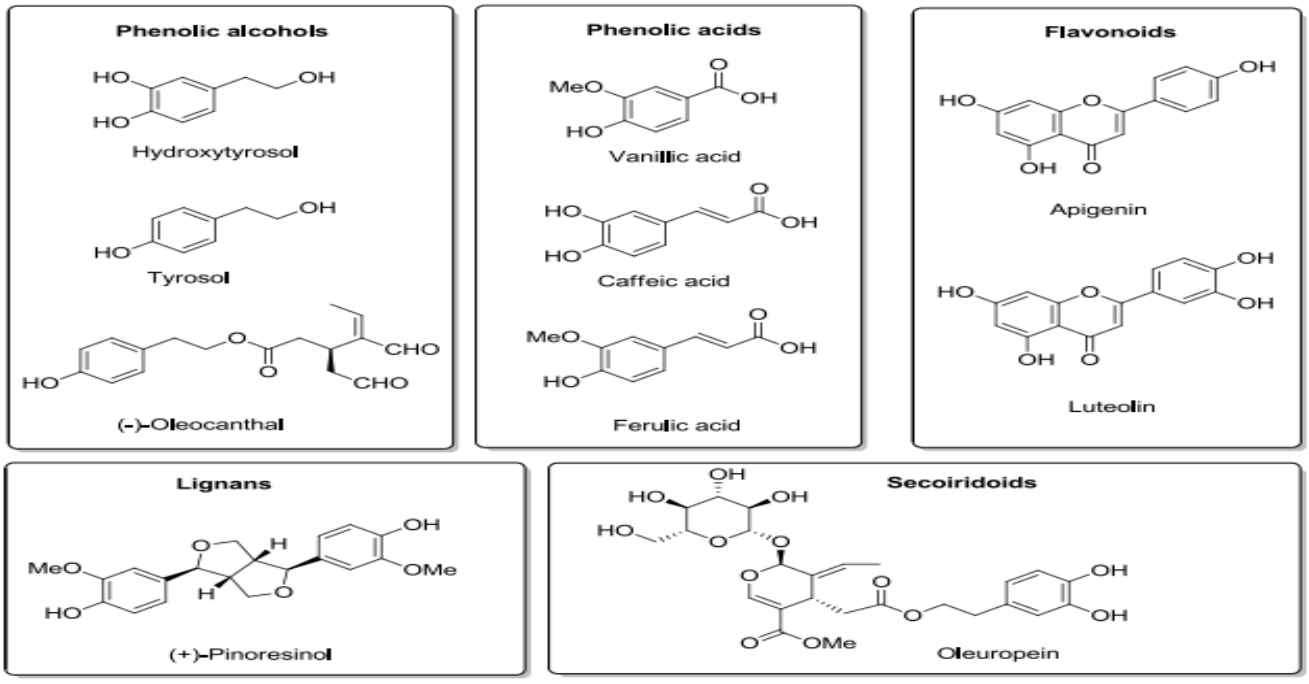


Figure.1.3: The different classes of polar phenolic compounds present in olive oil with molecular structures of representative examples (Rodríguez et al, 2015).

1.3. Oxidation

Oxidation is a chemical reaction that transfers electrons from a substance to an oxidizing agent. Oxidation reactions can produce free radicals, which start chain reactions that damage cells (Hamid et al, 2010). A free radical can be defined as any molecular species capable of independent existence that contains an unpaired electron in an atomic orbital. The presence of an unpaired electron results in certain common properties that are shared by most radicals. Many radicals are unstable and highly reactive (Lobo et al, 2010).

Reactions occur continually inside the body, giving rise to the formation of free radicals (peroxidants). As a rule, free radicals do not cause severe damage due to the protection provided by antioxidants, which help to keep a balance up to a point. If the balance is spoiled, however, "oxidative stress" occurs, leading to deterioration of normal cell functions and even cell death (IOC, 2015). Oxidative stress is characterized as an imbalance between the production of reactive species and antioxidant defense activity, and its enhanced state has been associated with many of the chronic diseases such as cancer, diabetes, neurodegenerative and cardiovascular diseases (White et al, 2014).

1.4. Antioxidants

1.4.1. Definition

Antioxidants may be defined as substances which can, when present at low concentrations compared to that of oxidizable substrates, significantly delay or inhibit oxidization of those substrates (Antolovich et al, 2002).

1.4.2. Antioxidants in Olive Oil

Vitamin E (alpha-tocopherol), carotenoids and phenolic compounds (simple phenols such as hydroxytyrosol and complex phenols such as oleuropein) are all antioxidants whose activity has been demonstrated invitro and recently invivo, revealing further advantages in the prevention of certain diseases and also of ageing. Virgin olive oil is particularly rich in these substances and it has a strong antioxidant effect, protecting against damage from free radicals (scavenger activity) and against the formation of cancer (IOC, 2015).

1.4.3. Classification of antioxidants

Antioxidants are grouped into two namely; Primary or natural antioxidants and Secondary or synthetic antioxidants.

Primary antioxidants (antioxidants proper) ascorbic acid and its derivatives, tocopherols, the esters of gallic acid, erythorbic acid and its sodium salt, BHA, BHT and other substances THBP and TBHQ. − Secondary antioxidants (substances with antioxidant action but that have other functions as well). Sulphur dioxide and sulphites as well as lecithin are secondary antioxidants (Butnariu & Grozea, 2013).

1.4.4. Mechanism of action of antioxidants

Free radicals attack all major classes of biomolecules, mainly the polyunsaturated fatty acids (PUFA) of cell membranes. The oxidative damage of PUFA, known as lipid peroxidation is particularly destructive, because it proceeds as a self-perpetuating chain reaction (Lobo et al, 2010). Oxidation of the PUFA generates a fatty acid radical ($L^{\cdot}$) (eqn (1)), which rapidly adds oxygen to form a fatty acid peroxyl radical ($LOO^{\cdot}$, eqn (2)). The peroxyl radicals are the carriers of the chain reactions. The peroxyl radicals can further oxidize PUFA molecules and initiate new chain reactions, producing lipid hydroperoxides (LOOH) eqn (3) that can break down to yet more radical species (Esterbauer et al, 1990).

$LH + R^{\cdot} \rightarrow L^{\cdot} + RH$…….. (1)

$L^{\cdot} + O_2 \rightarrow LOO^{\cdot}$ …….. (2)

$LOO^{\cdot} + LH \rightarrow LOOH + L^{\cdot}$ ……. (3)

1.4.5. Methods of evaluation and principles

There are different methods to evaluate the antioxidant capacity of foodstuffs including olive oil among which are: DPPH, FRAP, CUPRAC and ABTS.

1.4.5.1. DPPH:

This is known as a Standard 2,2-Diphenyl-1-picrylhydrazyl (DPPH) assay. This assay is based on the theory that a hydrogen donor is an antioxidant. It measures compounds that are radical

scavengers. DPPH assay is based on the measurement of the scavenging ability of antioxidants towards the stable DPPH radical (MacDonald-Wicks et al, 2006). (Figure 1.4) below, shows the mechanism by which DPPH• accepts hydrogen from an antioxidant. DPPH• is one of the few stable and commercially available organic nitrogen radicals (MacDonald-Wicks et al, 2006). The antioxidant effect is proportional to the disappearance of DPPH• in test samples. Monitoring DPPH• with a UV spectrometer has become the most commonly used method because of its simplicity and accuracy. DPPH• shows a strong absorption maximum at 517 nm (purple). The color turns from purple to yellow followed by the formation of DPPH upon absorption of hydrogen from an antioxidant. This reaction is stoichiometric with respect to the number of hydrogen atoms absorbed. Therefore, the antioxidant effect can be easily evaluated by following the decrease of UV absorption at 517 nm. (Moon et al, 2009).

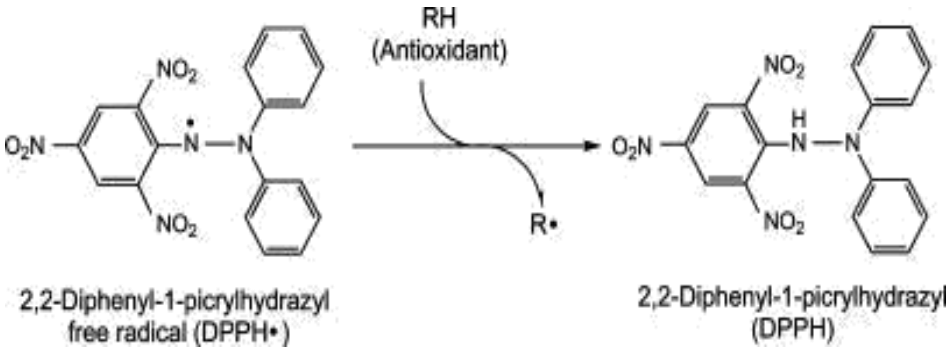


Figure.1.4: Mechanism of DPPH• free radical (Moon et al, 2009).

1.4.5.2. FRAP assay:

Ferric Ion Reducing Antioxidant Power Assay (FRAP) is simple, fast, inexpensive, and robust method, and does not require specialized equipment. In the FRAP method, the yellow Fe^{3+}TPTZ complex (2,4,6-tri (2-pyridyl)-1,3,5-triazine) is reduced to the blue Fe^{2+}TPTZ complex by electron-donating substances (such as phenolic compounds) under acidic conditions (Benzie et al, 1996) see (Figure 1.5). Any electron donating substances with a half reaction of lower redox potential than Fe^{3+}/Fe^{2+} TPTZ will drive the reaction and the formation of the blue complex forward. The reaction detects compounds with redox potentials of <0.7 V (the redox potential of Fe^{3+}-TPTZ) (Prior et al, 2005).

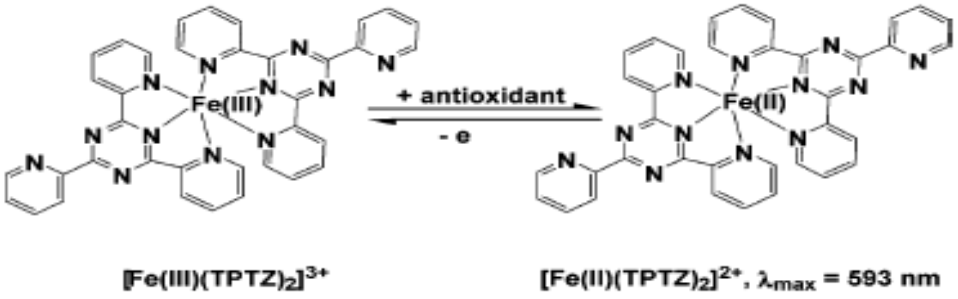


Figure 1.5: Reduction of yellow Fe^{3+} TPTZ complex (2,4,6-tri (2-pyridyl)-1,3,5-triazine) with antioxidants to the blue Fe^{2+} TPTZ complex by FRAP reagent (Prior et al, 2005).

1.4.5.3. CUPRAC assay

The putative CUPRAC method was developed by (Apak et al, 2006). These assays are based on the reduction of Cu^{+2} to Cu^{+} by the combined action of all antioxidants or reducing in aqueous-ethanolic medium (pH 7.0) in the presence of neocuproine (2,9-dimethyl-1,10-phenanthroline), by polyphenols, yielding a Cu^{+} complexes with maximum absorption peak at 450 nm (Figure 1.6) (Lee et al, 2011). This method can be used for the determination of the antioxidant capacity of food constituent by the Cu^{+2}-neocuproine (Cu^{+2}-Nc) reagent as the chromogenic oxidizing agent. The reduction of Cu^{+2} in the presence of neocuproine by a reducing agent yields a Cu^{+} complex with maximum absorption peak at 450 nm (Tutem et al, 1991).

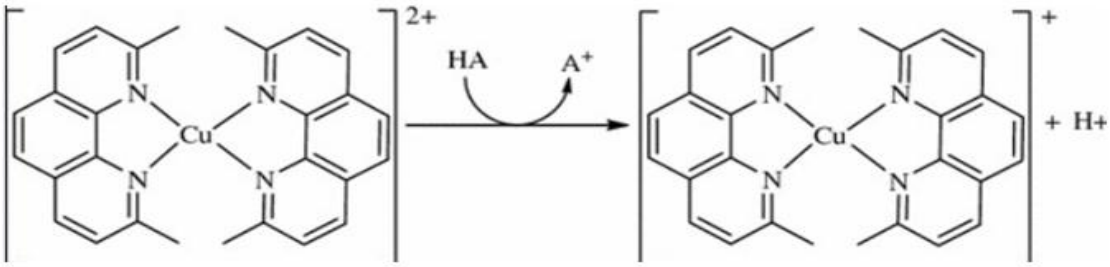


Figure1.6: CUPRAC reaction by an antioxidant molecule (HA: an antioxidant molecule, A+: an oxidized antioxidant molecule). Protons liberated in the reaction are neutralized by the ammonium acetate buffer (Tutem et al, 1991).

1.4.5.4. ABTS method

The ABTS cation radical (ABTS•+) (Marc et al, 2004) which absorbs at 743 nm (giving a bluish-green colour) is formed by the loss of an electron by the nitrogen atom of ABTS (2,2'-azino-bis (3-ethylbenzthiazoline-6-sulphonic acid)). In the presence of Trolox (or of another hydrogen donating antioxidant), the nitrogen atom quenches the hydrogen atom, yielding the solution decolorization. ABTS can oxidized by potassium persulphate (Pellegrini et al.2003) (Thaipong et al, 2006) see (Figure 1.7), giving rise to the ABTS cation radical (ABTS•+) whose absorbance diminution at 743 nm was monitored in the presence of Trolox, chosen as standard antioxidant (Pisoschi & Negulescu, 2012).

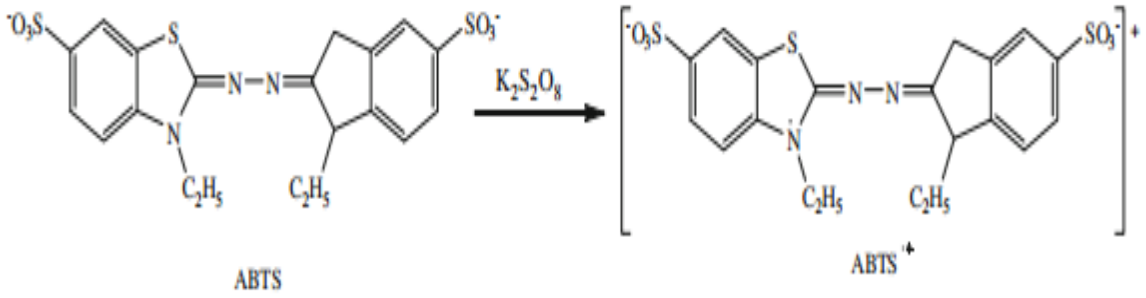


Figure 1.7: Oxidation of ABTS with $K_2S_2O_8$ and generation of $ABTS^+$ (Miller et al, 1993).

CHAPTER TWO

Literature review

2.1. Literature review

Dağdelen (2016) The objective of this study was to identify the antioxidant and antimicrobial activities of the phenolic extracts and mineral contents of virgin olive oils (*Olea europaea* L. cv. Edincik Su) obtained from three different locations, Edincik, Gomec, and Izmir in Turkey. Antioxidant activity was analysed spectrometrically. Total phenolic of Edincik Su olive cultivar was found between 159.99 and 189.64 mg gallic acid equivalent/kg.

El Sohaimy et al (2016) The aim of the present study was to investigate the chemical and physical characteristics of the olive oil in different ripening stages of Manzanilla and Kalamata varieties to determine the optimum harvesting time of the olive fruits. Refractive index values of Manzanilla and Kalamata oils were below the Standard limit. Reddish stage (S4) of ripening showed the best physicochemical characteristics. The total flavonoids level in early maturation stages higher than late maturation stages. Finally, we can conclude that the reddish ripening stage (S4) is the best stage for harvesting of the olive fruits to get the high quality of oil. The total flavonoid content in samples was measured colorimetrically by assay developed by Zhishen *et al*. (1999), while refractive index of the examined olive oil was measured as described by Edmiston (2001). The results showed that total flavonoids content of extracted oil from Manzanilla variety was ranged from 61.62±1.74 to 139.43±1.63 μg catechol/g, while the flavonoids content of Kalamata oil was varied from 56.33±1.93 to 134.60±0.94 μg catechol/g, and the refractive index values of Manzanilla oil were between 1.4674-1.4677 and 1.4678-1.4683 for Kalamata oil.

Ballus et al (2015) reported that olive oil samples from Gemlik and Halhalı varieties grown in Hatay and Mardin provinces in Turkey investigated during four maturation stages were analyzed for their chemical properties such as free acidity, peroxide value, total carotenoid, total chlorophyll, total phenolic contents, antioxidant activity, fatty acid and sterol compositions. Chemical properties, fatty acids and sterol profiles of olive oil samples generally showed statistically significant differences depending on the varieties, maturation and growing areas ($p < 0.05$). The total phenolic compounds of olive oil samples ranged from 20.62 in Gemlik to 525.22 mg GAE/kg oil in Halhalı from Hatay. In general, the phenolic

contents and antioxidant activities of olive oil samples were positively associated. Oleic acid content was the highest 71.53 % in H1 samples in Hatay.

Baiano A., et al (2014) In order to investigate the effects of a prolonged storage, olives from cv. Coratina were crushed using a three phase system to produce extra virgin olive oil analysed for sensory and chemical-physical indices, phenolic profile, tocopherol content, and antioxidant activity during an 8-years storage, they found that the oil lost its characteristics of extra-virgin after 6 years of storage, time at which the median of the defects was higher than 0 and free acidity% exceeded the limit fixed for this category by the European Regulation whereas the stability against oxidation persisted for a longer period due to the high concentration of oleuropein derivatives. A strong positive linear correlation was observed between the phenolic content and antioxidant activity measured according to the ABTS+. to indicate a noticeable radical scavenging ability of phenolic compounds.

Abbadi Jehad, et al (2014) studied the effect of storage conditions and packaging on the quality of olive oil reaffirming that at both storage temperatures, the best container in maintaining the extra virgin olive oil (EVOO) quality was glass and the worst was pottery. Grading of stored olive oil under investigation using sensory evaluation was not sufficient. Also it was clear that the absorption coefficient K_{270} was the most sensitive determinant chemical test that determines the quality of stored olive oil and could be used as a rapid indicator test.

Houshia Orwa, et al (2014) the purpose of the study was to measure the total concentration of polyphenol in some samples of Palestinian olive oil. The total polyphenol content of the methanol extracts was evaluated colorimetrically using the Folin- Ciocalteau reagent. A diluted extract or phenolic standard was mixed with Folin- Ciocalteau reagent and acqueous Na_2CO_3 and the total polyphenols were determined colorimetrically at 725 nm. Gallic acid standard solutions were used to calibrate the method. The concentration of polyphenols in olive oil ranges from 150 to 300 mg/kg.

Eid M. & EL-Sayed M. (2013) characterized virgin olive oil from four olive oil cultivars (Koroniki, Arbequina and new cultivars No.1 and No.138) cultivated in El-Khatatba zone in Egypt during two successive seasons 2010/2011 and 2011/2012. The quality indices (Free acidity, Peroxide value, K_{232}, K_{270} and fatty acids, minor components beside oxidative stability and sterol composition of the obtained olive oils (VOO) were analyzed to obtain a more complete characterization of these varietal oils. Results revealed that, all the analyzed VOOs were classified into ‘‘Extra virgin’’ category according to the regulated physicochemical parameters. % FFA (as Oleic acid) range between 0.28 and 0.80, Peroxide value (meq O_2/kg oil) range between 4.20 and 10.11, K_{232} range between 0.89 and 1.99, K_{270} range between 0.06 and 0.17 and total polyphenols (mg caffiec acid/kg) range between 60.40 and 174.20.

Dabbou S., et al (2011) studied the antioxidant capacity of phenolic extracts of four Tunisian olive oils from Chaïbi, Oueslati and two mixture olive cultivars in relation to their lipid composition and α-tocopherol content. Total phenol content ranged between 396 and 652 mg kg^{-1}. Furthermore, the highest antioxidant capacity in virgin olive oil measured by total antioxidant activity by ABTS test (TAA-ABTS) was observed in Mix2 (0.9 mmol TE kg^{-1}) which showed the correlation between the antioxidant capacity of virgin olive oils studied with polar components and lipid profile, important components to their shelf life.

Amarna et al (2011) Aimed to investigate the quality of olive oil produced in the northern West Bank. Forty samples were collected from two villages: Assera Al Shamalia (located in the western foothills) and Bet Dagan (eastern foothills). The samples were analyzed for iodine number, peroxide value, refractive index and free acidity using official AOAC analytical methods for fats and oils. Average iodine number of the studied olive oil samples was 91.8 g/100g with refractive index of 1.4696, free acid value of 1.22% and peroxide value of 19.1 meq O_2/kg.

Minioti, K. S., & Georgiou, C. A. (2010) This study aimed to map the total antioxidant capacity (TAC) of 50 Greek olive oil samples from the 2005-2006 season according to production region and cultivar and to compare the 2, 2'-azino-bis (3-ethylbenzo-thiazoline-6-sulfonic acid (ABTS), 2, 2-diphenyl-1-picrylhydrazyl radical (DPPH) and Folin-Ciocalteu tests for use with olive oil. Antioxidant capacities determined in the hydrophilic fraction range between 5.42 - 22.5 mM gallic acid Kg^{-1} olive oil for the ABTS method and 1.29 - 9.95 mM Kg^{-1} for the DPPH method while in total, olive oil TAC ranges between 77 – 177 mM Kg^{-1} as assessed by the DPPH method. The results of total phenol content range between 3.8 and 29.4 mM Kg^{-1} olive oil. Total phenol content correlates with total antioxidant capacity assessed in the hydrophilic fraction through the DPPH (r 0.89) and the ABTS (r 0.69) assays. The hydrophilic fraction DPPH values correlate significantly with the ABTS values (r 0.81). However, the DPPH values for total olive oil correlate poorly with the ABTS assay, the Folin-Ciocalteu method and the DPPH assay in hydrophilic fraction. Although total phenolic content shows good correlation with ABTS and DPPH values and could serve as a useful indicator for olive oil antioxidant capacity.

2.2. Problems statement

Inspite of the great importance of olive oil in Palestine, no enough data about the total phenolic compounds contents and total flavonoid content and antioxidant activity and concerning phenolic compounds characterization is available. Therefore real research should be taken. No enough research information had been written about total phenolic content, total flavonoid content and antioxidant activity of Palestinian olive oil.

Values of total phenolic content, total flavonoid content, antioxidant activity, acidity%, iodine value, peroxide value, specific gravity, refractive index, K_{232} and K_{270} are very important to compare the oils from olive trees from different regions in Palestine and to compare the difference between farmers.

2.3. Hypotheses and research questions

Hypothesis of this study declares the existence of variations in TPC, TFC and antioxidant activity in terms of geographical origin in olive oil in West Bank-Palestine. Additionally, we expect that there will be differences in the amount of TPC, TFC, and AA as a function of farmer in the same area in West Bank in Palestine.

1. Is there a relationship between total Phenolic Contents and antioxidant activity and also between total flavonoids content and antioxidant activity of Palestinian olive oil?
2. Is there any change in total antioxidant activity, total phenolic contents and total flavonoids content in olive oil as a function of geographical region (north, middle and south regions of West Bank-Palestine)?
3. Is there any change in total antioxidant activity, total phenolic contents and total flavonoids contentin olive oil between farmers in the same region?
4. Is there a relationship between one assay for olive oil like TPC and other assays and etc.?

2.4. Objectives and aims

a. To evaluate antioxidant activity, total phenolic contents and total flavonoids content acidity%, peroxide value, K_{232}, K_{270}, iodine value, specific gravity and refractive index of olive oil from different geographical regions of West Bank (north, middle and south).
b. To demonstrate a possible relationship between phenolic contents and antioxidant activity and also between total flavonoids content and antioxidant activity.
c. To demonstrate a possible difference between each assay and the other assays for different farmers in the same geographical region.
d. To demonstrate a possible relationship between each assay and the other assays.

CHAPTER THREE

MATERIALS AND METHODS

3.1. Experimental Design

3.1.1. Samples collection and preservation

The oil samples were collected in 2013 and 2014 freshly from the farmers during milling their olive fruits. Different farmers (1-6) were chosen randomly from different geographical areas in the West Bank: Jenin (Burkin), Tulkarm (Anabta), Nablus (Salfeet, North Asera, Burin and South Asera), Bethlehem (Bayt Jala and Dheisha) and Hebron (Sourif, Si'ir and Alshuokh).The samples were taken in late October 2013 and late October 2014 in similar conditions. Olive oil samples (300 ml, in replicates) were taken in PE bottles without head space from the milled oil of the farmer at each collecting time. Collected oil samples were preserved in a cold container and directly shipped (in the same day) to a refrigerator in the laboratory (-20 °C).

3.1.2. Primary quality tests

The samples were tested for their initial oil quality (acidity%, peroxide value, K_{232}, K_{270}, iodine value, specific gravity and refractive index).

3.1.3. Testing Antioxidants

The oil samples were extracted for total phenolic content (TPC), total flavonoids contents (TFC). The oil samples were analyzed for TPC, TFC, and antioxidant activities (FRAP, CUPRAC, ABTS and DPPH). Olive oil samples were extracted in replicates and analyzed in replicates. Results were interpreted for the collected from each farmer as mean value and was compared to the other farmers in different geographical areas for statistical significant differencies for each quality parameter**.**

3.2. Solution preparation

3.2.1. Total Phenolic Contents:

Diluted Folin reagent was prepared by diluting 10 ml Folin in 100 ml distilled water), or 25 ml of Folin were diluted up to 250 ml using D.W.

7.5% $NaHCO_3$ was prepared by placing 7.5 g of $NaHCO_3$ in a 100 volumetric flask and dissolving into distilled water.

3.2.2. Total flavonoid content:

For the preparation of 50 ml of 10%(w/v) $AlCl_3.6H_2O$, 9 g of $AlCl_3.6H_2O$ (Mwt= (241.43 g/mol) were put in a 50 ml volumetric flask and distilled water was put up to the mark.

For the preparation of 50 ml of 5%(w/v) $NaNO_2$, 2.5 g of $NaNO_2$ (Mwt= (68.995 g/mol) were put in a 50 ml volumetric flask and distilled water was put up to the mark.

For the preparation of 250 ml of 1M NaOH, 10 g of NaOH (Mwt= (40 g/mol) were put in a 250 ml volumetric flask and distilled water was put up to the mark.

3.2.3. FRAP method:

For the preparation of 100 ml of 20 mM $FeCl_3.6H_2O$, 0.54 g of $FeCl_3.6H_2O$ (Mwt= (270.296 g/mol) were dissolved in a 100 ml volumetric flask and diluted to the mark with distilled water.

For the preparation of 1L of 40 mM HCl solution, 3.77 ml of HCl stock solution (10.6 M) were put in a 1L volumetric flask and distilled water was added up to the mark.

For the preparation of 100 ml of 10 mM tripyridyltriazine (TPTZ), 0.312 g of TPTZ (Mwt= (312.33g/mol) were put in a 100 ml volumetric flask and diluted to the mark with 40 mM HCl solution.

For the preparation of 100 ml of 0.3M acetate buffer (pH 3.6) (according to British Pharmacopeia), 16.8 g of acetic acid and 0.8 g of NaOH were dissolved in a 1L volumetric flask and diluted to the mark with distilled water.

FRAP reagent is composed of 10 mM (TPTZ), 40 mM HCl and 20 mM $FeCl_3.6H_2O$ in the ratio (10:1:1) by volume respectively, for example; 100 ml of 10 mM tripyridyltriazine TPTZ, 10 ml of (40 mM HCl) and 10 ml of (20 mM $FeCl_3.6H_2O$).

3.2.4. CUPRAC method (Cupper Reducing Antioxidant Capacity):

For the preparation of 250 ml of $CuCl_2$ (1×10^{-2} mol/L), 0.336 g of (anhydrous $CuCl_2$) (Mwt= (134.45 g/mol) were dissolved in a 250 volumetric flask and diluted up to the mark with distilled water.

For the preparation of 250 ml of neocuproine alcoholic solution (7.5×10^{-3}mol/L), 0.39 g of neocuproine (Mwt= (208.26 g/mol) were dissolved in a 250 volumetric flask and then diluted up to the mark with ethnol (96%).

For the preparation of 250 ml of NH_4Ac (1mol/L, pH7.0) buffer solution, 19.27 g of NH_4Ac (Mwt= (77.08 g/mol) were dissolved in a 250 volumetric flask and diluted up to the mark with distilled water.

3.2.5. Free radical scavenging activity using DPPH:

For the preparation of 250 ml of 0.0634 mM of DPPH solution, 0.0064 g of DPPH (Mwt= (394.2 g/mol) were dissolved in a 250 volumetric flask and diluted up to the mark with methanol (95%).

3.2.6. Free radical scavenging activity using ABTS:

For the preparation of 250 ml of 7 mM ABTS (Mwt= (548.68 g/mol), 0.96 g of ABTS were dissolved in a 250 ml volumetric flask and diluted up to the mark with distilled water.

For the preparation of 250 ml of 2.45 mM of potassium persulphate ($K_2S_2O_8$) (Mwt= (270.322 g/mol), 0.165 g of $K_2S_2O_8$ were dissolved in a 250 ml volumetric flask and diluted up to the mark with distilled water.

3.2.7. Peroxide value Test:

For the preparation of saturated potassium iodide solution, more than 144 g of potassium iodide were dissolved in 100 mL of water using the magnetic stirrer, creating a saturated solution. Anything more than 144 grams will not dissolve since the solubility of potassium iodide at room temperature is 144 g KI/100 ml D.W.

3.2.8. Iodine value test:

For the preparation of 0.1 N of $Na_2S_2O_3.5H_2O$ solution, 24.8 g of $Na_2S_2O_3.5H_2O$ (Mwt= (248.08 g/mol) were put in 1L volumetric flask and distilled water was put up to the mark.

For the preparation of KI solution (15% w/v), 15 g were put in a 100 ml volumetric flask and distilled water was put up to the mark.

For the preparation of starch indicator (1% w/v), 1 g of starch was put in a 100 ml volumetric flask and distilled water was put up to the mark.

3.2.9. K_{232} and K_{270} test:

For the preparation of oil sample at 30°C, 1% solution of oil was prepared in cyclohexane (0.25 g oil in 25 ml cyclohexane).

3.3. Extraction of oil samples for TPC, TFC, FRAP, CUPRAC, DPPH and ABTS tests:

An aliquot of 20g of olive oil samples were dissolved in 20 ml of n-hexane and transferred to a separatory funnel, then three portions of 10 ml of methanol-water mixture (80:20 v/v) were added, and the methanolic extracts were collected and washed with 20 ml of n-hexane to remove the remained residual oil. The methanolic extracts were then placed in the fridge until analysis. The oil samples were extracted in replicates and analyzed for (TPC, TFC, FRAP, CUPRAC, DPPH and ABTS tests) in replicates.

3.4. Tests:

3.4.1. Determination of total phenolic contents (TPC)

Materials used were: Folin–Ciocalteu reagent, Distilled water, Sodium bicarbonate, gallic acid, UV-Vis spectrophotometer.

TPC was determined spectrophotometrically using Folin–Ciocalteu reagent (Singleton & Rossi, 1965). To 100µL of the sample extract, 1.8 ml of Folin–Ciocalteu reagent was added (note: Before adding the Folin-reagent they were prepared 10 folds; means 10 ml in 100 D.W), then left for 5 min., 1.2 ml of 7.5 % $NaHCO_3$ (7.5 gm in 100 ml D.W) solution was added. The mixture was allowed to stand for 60 min and absorption was measured at 765 nm against

a reagent blank (D.W) in UV–Vis spectrophotometer. Aqueous solutions of known gallic acid concentrations in the range of (100 – 500 ppm) were used for calibration. Results were expressed as mg gallic acid equivalents (GAE)/g sample.

3.4.2. Determination of Total flavonoid content (TFC)

Materials used were: Distilled water, Sodium Nitrite, Aluminum Chloride (Hexa hydrated), Sodium hydroxide, Catechin, UV-Vis Spectrophotometer.

TFC was analyzed using the Aluminium chloride method (Zhishen et al, 1999). An aliquot (1 ml) of Olive oil extract was put in 10 ml of volumetric flask containing 4 ml of distilled water, 0.3 ml portion of 5% $NaNO_2$ and 0.3 ml portion of 10% $AlCl_3.6H_2O$. The mixture was allowed to stand for 6 min. at room temperature. Two millilitres of 1 N NaOH was added and the solution was diluted to 10 ml with distilled water. The absorbance of the solution versus a blank (all reagents except olive oil sample extract) at 510 nm was measured immediately. Aqueous solutions of known catechin concentrations in the range of 30– 200 ppm were used for calibration.

3.4.3. Determination of antioxidant activity (AA) by FRAP method:

Materials used were: TPTZ, HCl (stock solution), Iron (III)Chloride, Vortex, Water Bath, UV-Vis Spectrophotometer.

Ferric reducing antioxidant power (FRAP) was performed according to the procedure described by (Benzie and Strain, 1996). The FRAP reagent included 300 mM acetate buffer (pH 3.6), 10 mM TPTZ in 40 mM HCl and 20 mM $FeCl_3$ in the ratio 10:1:1 (v/v/v). Three ml of the FRAP reagent was mixed with 100µl of the sample extract in a test tube and vortexed in the incubator at 37°C for 30 min in a water bath. Reduction of ferric-tripyridyltriazine to the ferrous complex formed an intense blue color that was measured at 593 nm at the end of 4 min by the UV-Vis Spectrophotometer.

3.4.4. CUPRAC reducing antioxidant power

Materials used were: Cupper (II) Chloride, Neocuproine, Ethanol (96%), Ammonium Acetate, Distilled Water, Torolox, UV-Vis Spectrophotometer.

The CUPRAC ion reducing antioxidant capacity of olive oil extract was determined according to the method of (Apak et al, 2008). 0.1 ml of sample extract was mixed with 1 ml each of $CuCl_2$ solution (1.0×10^{-2} mol/ L), neocuproine alcoholic solution (7.5×10^{-3}mol/L), and NH_4Ac (1mol/L, pH7.0) buffer solution and 1 ml of water to make the final volume 4.1 ml. After 30 min, the absorbance was recorded at 450 nm against the reagent blank (all reagents except olive oil sample extract). Standard curve was prepared using different concentration of Trolox (20-180 ppm).

The results were expressed as µmol Trolox/g.

3.4.5. Free radical scavenging activity using DPPH

Materials used were: DPPH**,** Methnol (95%), Torolox, UV-Vis Spectrophotometer.

A 3.9 ml aliquot of a 0.0634 mM of DPPH solution, in methanol (95%) was added to 0.1 ml of each extract (the extract mentioned before) and shaken vigorously. Change in the absorbance of the sample extract was measured at 515 nm for 30 min. till the absorbance reached a steady state. Methanol (95%) was used as a blank.

(Different concentrations of Torolox for the calibration curve from 20-120 ppm were used), and the results were expressed as mg Torolox/ Kg oil.

3.4.6. Free radical scavenging activity using ABTS

Materials used were: ABTS**,** potassium persulphate ($K_2S_2O_8$), Torolox, UV-Vis Spectrophotometer.

A modified procedure using ABTS as described by (Re et al, 1999) was used.

The $ABTS^+$ stock solution (7 mM) was prepared through reaction of 7 mM ABTS and 2.45 mM of potassium persulphate ($K_2S_2O_8$) as the oxidant agent. The working solution of $ABTS^+$ was obtained by diluting the stock solution in ethanol to give an absorption of 0.70 ± 0.02 at λ = 734 nm. Sample extract (50 µL) was added to 90 µL of $ABTS^+$ solution and absorbance readings at 734 nm were taken at 30^oC exactly 10 min after initial mixing. For the calibration curve, concentrations from 5-40 ppm were used and the results were expressed as mg Torolox/Kg oil.

3.4.7. Acidity Percentage Test

Materials used were: Ethanol (96%), NaOH, Phenolphthalein solution, Hot plate.

By using the AOAC method number 940.28 to determine acid value in fats and oils, 7gm of oil sample was put into a dry and clean 250 ml Erlenmeyer flask, then 50 ml of 96% ethanol was neutralized with 0.1 N aqueous NaOH solution in presence of 2 ml phenolphthalein solution to produce faint permanent pink, then the neutralized ethanol was added to the oil in the flask, then the mixture was shaken vigorously and boiled on a hot plate for two minutes then titrated with 0.1 N aqueous NaOH solution until permanent faint pink colour appeared and persisted one minute.

3.4.8. Peroxide value Test

Materials used were: Glacial acetic acid, Chloroform**,** Potassium iodide**,** Distilled Water, Sodium thiosulfate, Starch.

By using the AOAC method number 965.33, about 5g of oil were weighed into 250 ml glass-stoppered conical flask, then 30 ml of glacial acetic acid-Chloroform solution (3:1 by volume) were added with swirling to dissolve oil completely, then 1 ml of saturated potassium iodide solution was added (Potassium iodide has a solubility of 144 g/ 100 ml of water at room temperature. Therefore, at room temperature more than 144 g of potassium iodide were dissolved in 100 ml of water, creating a saturated solution. Anything more than 144 grams will not dissolve), then the flask was quickly stoppard and let to stand with occasional shaking for 1 minute in the dark, thereafter, 30 ml of freshly boiled and cooled water were added and flask contents were titrated with 0.01 N sodium thiosulfate solution with vigorous shaking until yellow colour had almost gone, about 0.5 ml of starch solution was added and titration was continued with vigorous shaking to release all iodine from chloroform layer, until the blue color just disappeared. Blank determination is conducted in the same way without the sample (Blank is composed of all additions except oil sample).

3.4.9. Iodine value test

Materials used were: Chloroform, Hanus solution**,** Potassium iodide**,** Distilled Water**,** Sodium thiosulfate (Penta Hydrated)**,** Starch.

By using the modified method based on the Hanus AOAC method, about 0.2 g of oil sample was weighed in a glass-stoppered 500 ml Erlenmeyer flask, then 10 ml of chloroform were added gently until the oil was dissolved, by a pipette 25 ml of Hanus solution were added, the flask then stoppered and allowed to stand for 30 minutes; during that the flask was shaked gently at 5-6 minutes intervals. After that 15 ml of KI solution (15% w/v) was added with shaking, then 100 ml of D.W was added and the whole mixture was titrated by 0.1 N of $Na_2S_2O_3.5H_2O$ solution with constant shaking until yellow solution turned almost colourless, then few drops of starch indicator (1% w/v) were added and titration was continued until blue colour entirely disappeared.

Blank was conducted in the same way without sample.

3.4.10. K_{232}, K_{270}

Materials used were: Cyclohexane, UV-Vis Spectrophotometer.

By using the IOOC COI/T20/Doc. number 19/Rev.1 2001, 1% solution of oil sample at 27°C (temperature of the lab) was prepared in cyclohexane (0.25 g oil in 25 ml solvent), then the absorption was taken at 232 and 270 nm, respectively, with a UV spectrophotometer, using a path length (a cuvette width) of 1 cm.

3.4.11. Index of refraction of oil By Abbrefractometer

Materials used were: Abbrefractometer**.**

By using the AOAC method number 921.08, the prism surface of the abbrefractometer was filled with oil sample, then the adjustment was rotated until the field of vision was divided into dark and light, then the border line was narrowed and the result was taken.

3.4.12. Specific gravity of oil using Pycnometer method

Materials used were: Pycnometer, Analytical Balance, Distilled Water**.**

By using the AOAC method number 920.212, a clean dry pycnometer was filled with sample (at 20°C) then was Placed in a water bath for 30 min at 25°C then the oil level was adjusted and the pycnometer was stoppered and removed from the bath and dried. The weight of

pycnometer with sample was taken and the specific gravity was calculated by subtraction the weight of pycnometer from its empty weight and divided by weight of water at 25°C.

3.5. Questionnaire

A questionnaire was given to the farmers includes six questions about if their olive fruits were affected by olive fly, days of storage between harvesting and oil extraction, green olive to black olive ratio percentage, oil percentage (percentage weight of extracted oil to weight of olive fruit before extraction), drop percentage (percentage of olive fruit found under the tree before harvesting to the total olive fruit weight) and olive yield percentage (percentage of olive fruit weight in comparison with maximum olive fruit weight ever seen).

3.6. Statistical Analysis

Pearson correlations were calculated to test the relation between individual quality indicators (TPC, TFC, FRAP, CUPRAC, ABTS, DPPH, Acidity%, Peroxide value, K_{232}, K_{270}, Iodine value, Specific gravity and Refractive index) with each one of the other quality indices. The NOMISS option was used in order to obtain results consistent with subsequent multiple regression studies.

CHAPTER FOUR

Results and Discussions

4.1. Assays Results in governorates

Olive oil samples from sixty farmers were collected in 2013 and 2014 freshly during milling their olive fruits from different geographical areas in the West Bank: Jenin (Burkin), Tulkarm (Anabta), Nablus (Salfeet, North Asera, Burin and South Asera), Bethlehem (Bayt Jala and Dheisha) and Hebron (Sourif, Si'ir and Alshuokh).The samples were taken in late October 2013 and late October 2014 in similar conditions.

The samples were analyzed for their total Phenolic Contents, total flavonoids content, their antioxidant activity (FRAP, CUPRAC, ABTS and DPPH), acidity%, peroxide value, iodine value, specific gravity, K_{232}, K_{270} and refractive index.

4.1.1. Total Phenolic Contents according to governorate and year

In 2013, the highest TPC value (722) was in Hebron and the lowest TPC value (462) was in Nablus. On the other hand, in 2014, the highest TPC value (606) was in Jenin and the lowest TPC value (361) was in Bethlehem (Table 4.1).

The total phenolic contents (mg gallic acid/Kg of oil) of olive oil samples were 628±284 and 361±161 respectively in 2013 and 2014 in Bethlehem, 722±324 and 601±211 respectively in Hebron, 589±118 and 606±66 respectively in Jenin, 462±401 and 406±19 respectively in Nablus and 696±114 and 469±154 respectively in Tulkarm (Table 4.1).

According to (Figure 4.1) we observed a decrease in total Phenolic Contents in the olive oil during 2014 for all governorates except in Jenin there was a slightly increase in 2014 in comparison with 2013.

Some factors affect TPC of olive oil like cultivar, climate and other environmental factors, harvesting time, extraction process, conditions of packing, distribution, and storage (Servili et al, 2004).

In spite of all the data shown above there was no significant difference between TPC values in governerates since the Standard deviations were high.

Houshia Orwa, et al (2014) reported that the total concentration of polyphenol in some samples of Palestinian olive oil from Jerusalem, Tulkarem and Jenin ranges from 150 to 300 mg/kg while our TPC results were higher.

Table 4.1: Average TPC Values (mg gallic acid/Kg of oil) from different geographical regions in West Bank-Palestine according to governorate and year; results are expressed as average ± SD.

City	Year	
	2013	2014
Bethlehem	628±284	361±161
Hebron	722±324	601±211
Jenin	589±118	606±66
Nablus	462±401	406±19
Tulkarm	696±114	469±154

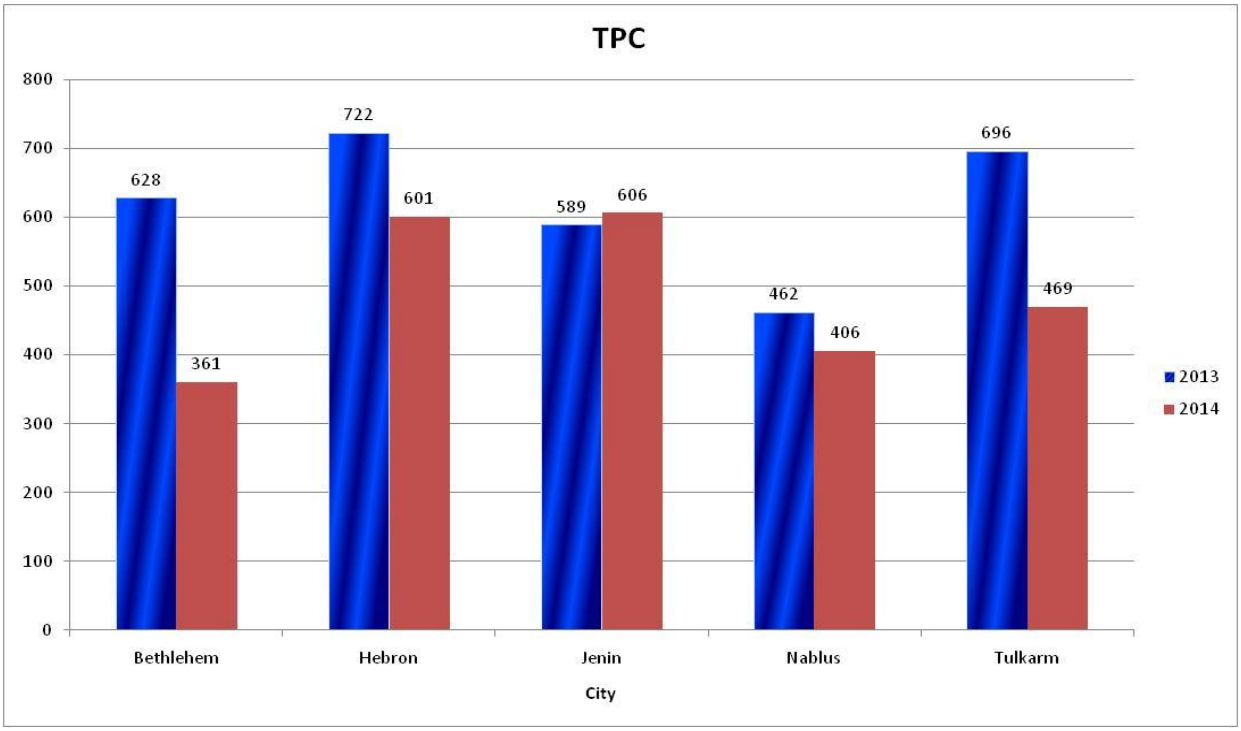


Figure 4.1: Mean values of TPC (mg gallic acid/Kg of oil) in the different governorates during 2013 and 2014.

4.1.2. Total Flavonoid Content according to governorate and year

In 2013, the highest TFC value (106.2) was in Tulkarm and the lowest TFC value (46.3) was in Nablus. From the other hand, In 2014, the highest TFC value (115.8) was in Tulkarm and the lowest TFC value (66.9) was in Nablus (Table 4.2).

The total flavonoid content (mg catechin/Kg of oil) of olive oil samples were 95.5±41 and 69.7±13 respectively in 2013 and 2014 in Bethlehem, 101.5±51 and 101.1±34 respectively in Hebron, 96.3±59 and 85.5±21 respectively in Jenin, 46.3±43 and 66.9±39 respectively in Nablus and 106.2±30 and 115.8±7 respectively in Tulkarm (Table 4.2).

The flavonoid composition of olive oil can be influenced by different factors such as the growing climate, harvest maturity, olive cultivar, agronomic practices including irrigation or application of fertilizers, ripening hormones and the techniques employed to process and extract the oil (Rwothomio, 2011) so it is difficult to determine the specific reason for the difference in TFC values between governerates since geographical origin alone is not sufficient (Kalogeropoulos & Tsimidou, 2014).

Table 4.2: Average TFC values (mg catechin/Kg of oil) from different geographical regions in Palestine according to governorate and year; results are expressed as average ± SD.

City	Year	
	2013	**2014**
Bethlehem	95.5±41	69.7±13
Hebron	101.5±51	101.1±34
Jenin	96.3±59	85.5±21
Nablus	46.3±43	66.9±39
Tulkarm	106.2±30	115.8±7

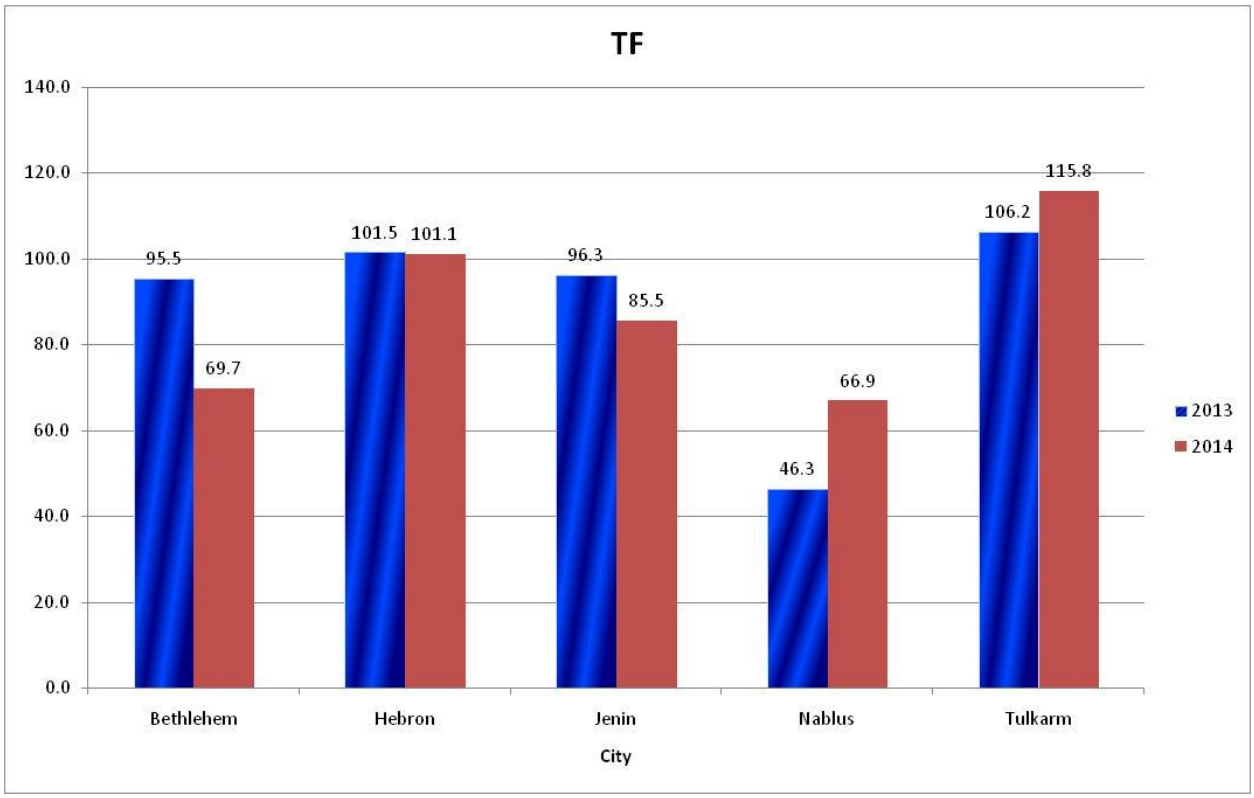


Figure 4.2 Mean values of TFC (mg catechin/Kg of oil) in the different governorates during 2013 and 2014.

4.1.3. Antioxidant activity (FRAP) according to governorate and year

Ferric Ion Reducing Antioxidant Power Assay (FRAP) is simple, fast, inexpensive, and robust method, and does not required specialized equipment. In the FRAP method the yellow Fe^{3+} TPTZ complex (2,4,6-tri (2-pyridyl)-1,3,5-triazine) is reduced to the blue Fe^{2+} TPTZ complex by electron-donating substances (such as phenolic compounds) under acidic conditions (Benzie et al, 1996).

In 2013, the highest FRAP value (17.50) was in Jenin and the lowest FRAP value (8.83) was in Nablus. From the other hand, In 2014, the highest FRAP value (14.83) was in Jenin and the lowest FRAP value (5.79) was in Hebron (Table 4.3).

The antioxidant activity FRAP values (mmole Fe^{+2}/Kg of oil) of olive oil samples were 9.14±4.90 and 6.33±2.18 respectively in 2013 and 2014 in Bethlehem, 9.81±6.80 and 5.79±2.98 respectively in Hebron, 17.50±6.10 and 14.83±1.21 respectively in Jenin, 8.83±8.00

and 7.88±3.14 respectively in Nablus and 11.83±1.14 and 6.67±3.11 respectively in Tulkarm (Table 4.3).

According to (Figure 4.3) we observed a decrease in antioxidant activity FRAP values in the olive oil during 2014 for all governorates.

Dabbou Samia, et al (2011) showed that there were correlation between the antioxidant capacity of virgin olive oils studied with polar components important to their shelf life.

According to Ballus et al (2015) and Yancheva et al (2016) it was observed that the higher the total phenolic compounds in oil, the higher the antioxidant capacities, regardless of the method antioxidant activity assay employed, so since FRAP is one of the antioxidant activity assays which is performed under acidic (pH 3.6) conditions and it has a high and significant positive correlation with the TPC, so the difference in FRAP values can not be explained according to governerates since geographical origin alone is not sufficient to explain the TPC content and our results are in agreement with.

Table 4.3: Average FRAP values (mmole Fe^{+2}/Kg of oil) from different geographical regions in Palestine according to governorate and year; results are expressed as average ± SD.

City	Year	
	2013	**2014**
Bethlehem	9.14±4.90	6.33±2.18
Hebron	9.81±6.80	5.79±2.98
Jenin	17.50±6.10	14.83±1.21
Nablus	8.83±8.00	7.88±3.14
Tulkarm	11.83±1.14	6.67±3.11

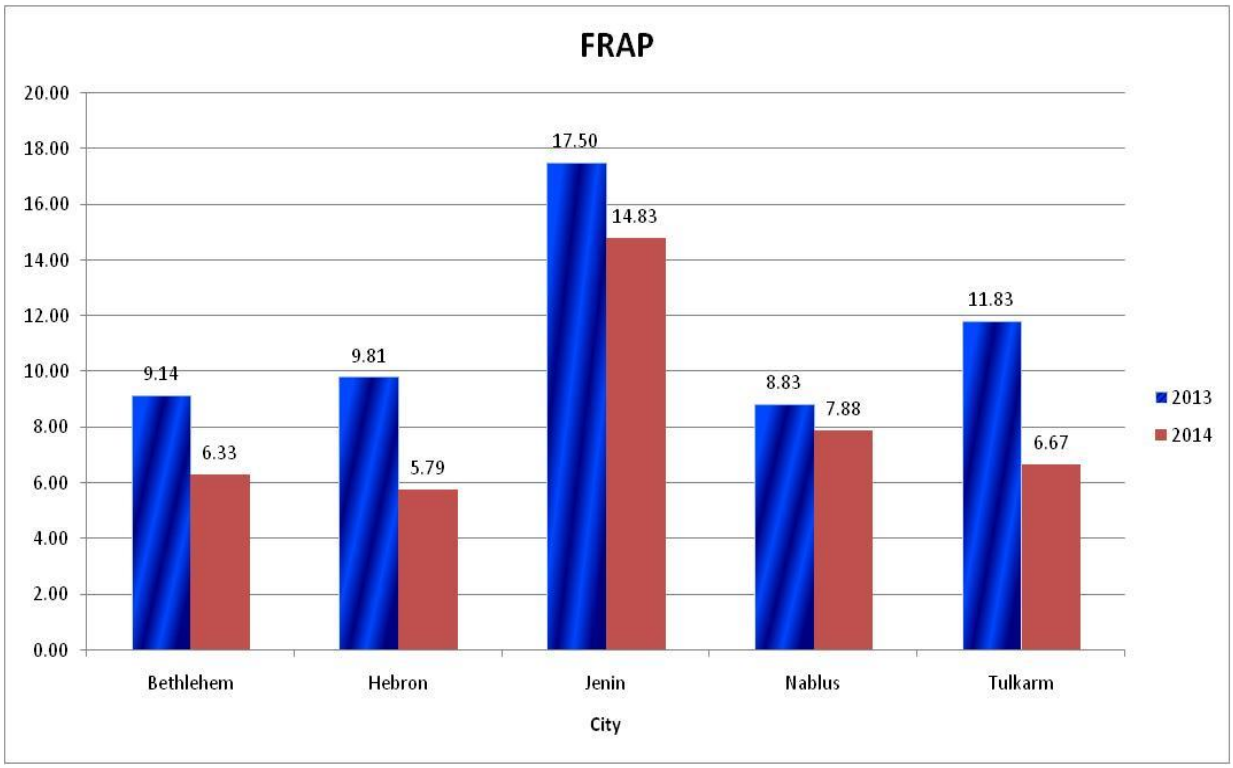


Figure 4.3: Mean values of FRAP assay (mmole Fe^{+2}/Kg of oil) in different governorates during 2013 and 2014.

4.1.4. CUPRAC Values according to governorate and year

This assay is based on the reduction of Cu^{+2} to Cu^{+} by the combined action of all antioxidants or reducing agents in aqueous-ethanolic medium (pH 7.0) in the presence of neocuproine (2,9-dimethyl-1,10-phenanthroline), by polyphenols, yielding a Cu^{+} complexes with maximum absorption peak at 450 nm (Lee et al, 2011). This method can be used for the determination of the antioxidant capacity of food constituent by the Cu^{+2}-neocuproine (Cu^{+2}-Nc) reagent as the chromogenic oxidizing agent. The reduction of Cu^{+2} in the presence of neocuproine by a reducing agent yields a Cu^{+} complex with maximum absorption peak at 450 nm (Tutem et al, 1991)**.**

In 2013, the highest CUPRAC value (20.08) was in Jenin and the lowest CUPRAC value (10.64) was in Nablus. On the other hand, In 2014, the highest CUPRAC value (16.66) was in Tulkarm and the lowest CUPRAC value (10.82) was in Nablus (Table 4.4).

The antioxidant activity CUPRAC values (mg Torolox/g oil) of olive oil samples were 16.63±5.89 and 12.63±5.18 respectively in 2013 and 2014 in Bethlehem, 17.6±6.78 and 14.45±3.47 respectively in Hebron, 20.08±9.89 and 14.13±2.08 respectively in Jenin, 10.64±6.99 and 10.82±4.84 respectively in Nablus and 19.71±3.06 and 16.66±4.75 respectively in Tulkarm (Table 4.4).

According to (Figure 4.4) we observed a decrease in antioxidant activity CUPRAC values in the olive oil during 2014 for all governorates except in Nablus there was a slightly increase in 2014.

According to Ballus et al (2015) and Yancheva et al (2016) it was observed that the higher the total phenolic compounds in oil, the higher the antioxidant capacities, regardless of the method antioxidant activity assay employed. Dabbou Samia, et al (2011) showed that there were correlation between the antioxidant capacity of virgin olive oils studied with polar components important to their shelf life. According to Ballus et al (2015) and Yancheva et al (2016) CUPRAC assay is performed under neutral (pH 7) conditions and it has a high and significant positive correlation with the TPC, so the difference in CUPRAC values can not be explained according to different governerates since geographical origin alone is not sufficient to explain TPC content and our results are in agreement.

Table 4.4: Average CUPRAC Values (mg Torolox/g oil) from different geographical regions in Palestine according to governorate and year; results are expressed as average±SD.

City	Year	
	2013	**2014**
Bethlehem	16.63±5.89	12.63±5.18
Hebron	17.6±6.78	14.45±3.47
Jenin	20.08±9.89	14.13±2.08
Nablus	10.64±6.99	10.82±4.84
Tulkarm	19.71±3.06	16.66±4.75

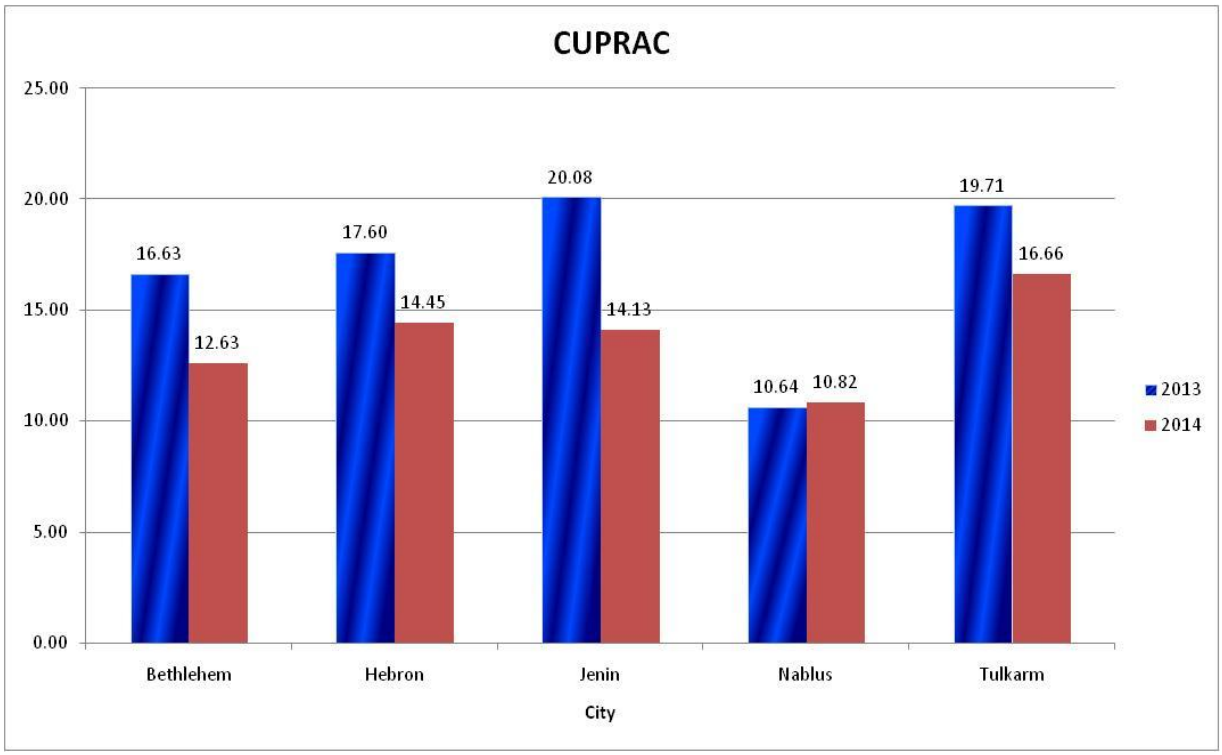


Figure 4.4: Mean values of CUPRAC assay (mg Torolox/g oil) in the different governorates during 2013 and 2014.

4.1.5. ABTS values according to governorate and year

ABTS (2,2'-azino-bis (3-ethylbenzthiazoline-6-sulphonic acid)) can be oxidized by potassium persulphate (Pellegrini et al, 2003; Thaipong et al, 2006), giving rise to the ABTS cation radical (ABTS•+) whose absorbance diminution at 743 nm was monitored in the presence of Trolox, chosen as standard antioxidant (Pisoschi & Negulescu, 2012).

In 2013, the highest ABTS value (715.71) was in Hebron and the lowest ABTS value (406.67) was in Tulkarm. On the other hand, In 2014, the highest ABTS value (761.67) was in Jenin and the lowest ABTS value (313.33) was in Nablus (Table 4.5).

The antioxidant activity ABTS values (mg Torolox/Kg oil) of olive oil samples were 682.86±381.12 and 540.56±251.14 respectively in 2013 and 2014 in Bethlehem, 715.71±392.11 and 690.30±188.91 respectively in Hebron, 607.50±449.20 and 761.67±162.10 respectively in Jenin, 573.67±381.31 and 313.33±110.98 respectively in Nablus and 406.67±21.9 and 316.67±181.21 respectively in Tulkarm (Table 4.5).

According to (Figure 4.5) we observed a decrease in antioxidant activity ABTS values in the olive oil during 2014 for all governorates except in Jenin there was an increase in 2014.

Dabbou Samia, et al (2011) showed that there were correlation between the antioxidant capacity of virgin olive oils studied with polar components important to their shelf life and reported that the highest antioxidant capacity in virgin olive oil measured by total antioxidant activity by ABTS test (TAA-ABTS) was observed in Mix2 (0.9 mmol TE kg^{-1}).

ABTS assay has a high and significant positive correlation with the TPC, so the difference in ABTS values can not be explained according to different governerates since geographical origin alone is not sufficient to explain the TPC content and our results are in agreement with (Ballus et al, 2015; Yancheva et al, 2016) and the results will be discussed later when comparing farmers data within the same region according to their questionnaire.

Table 4.5: Average ABTS Values (mg Torolox/Kg oil) from different geographical regions in Palestine according to governorate and year; results are expressed as average ± SD.

City	Year	
	2013	**2014**
Bethlehem	682.86±381.12	540.56±251.14
Hebron	715.71±392.11	690.30±188.91
Jenin	607.50±449.20	761.67±162.10
Nablus	573.67±381.31	313.33±110.98
Tulkarm	406.67±21.9	316.67±181.21

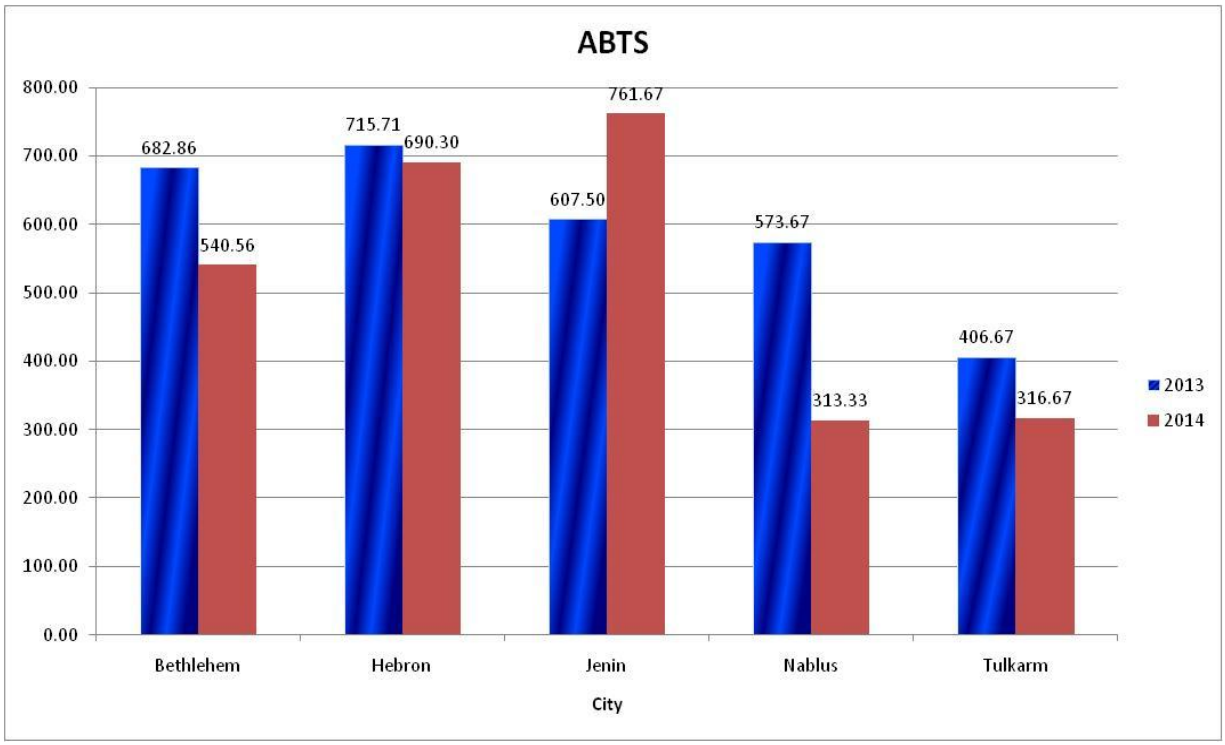


Figure 4.5: Mean values of ABTS assay (mg Torolox/Kg oil) in the different governorates during 2013 and 2014.

4.1.6. DPPH values according to governorate and year

DPPH (2,2-Diphenyl-1-picrylhydrazyl) assay is based on the measurement of the scavenging ability of antioxidants towards the stable DPPH radical (MacDonald-Wicks et al, 2006). Therefore, the antioxidant effect can be easily evaluated by following the decrease of UV absorption at 517 nm. (Moon et al, 2009).

In 2013, the highest DPPH value (645.07) was in Nablus and the lowest DPPH value (319.43) was in Hebron. On the other hand, in 2014, the highest DPPH value (686.70) was in Nablus and the lowest DPPH value (424.52) was in Hebron (Table 4.6).

The antioxidant activity DPPH values (mg Torolox/Kg oil) of olive oil samples were 503.48±272.53 and 458.72±69.97 respectively in 2013 and 2014 in Bethlehem, 319.43±99.34 and 424.52±122.32 respectively in Hebron, 438.67±422.21 and 561.83±291.31 respectively in Jenin, 645.07±189.49 and 686.70±204.97 respectively in Nablus and 351.33±11.31 and 445.67±250.95 respectively in Tulkarm (Table 4.6).

According to (Figure 4.6) we observed an increase in the antioxidant activity DPPH values in the olive oil during 2014 for all governorates except in Bethlehem there was a decrease in 2014.

DPPH assay is an efficient electron donor, regardless of the reaction medium conditions and the compounds to be reduced.

There is a correlation between the total phenolic contents and $DPPH^{\bullet}$ for EVOO polar extracts.

Dabbou Samia, et al (2011) showed that there was a correlation between the antioxidant capacity of virgin olive oils studied with polar components important to their shelf life.

The difference in DPPH values can not be explained according to the differenence in governerates since geographical origin alone is not sufficient to explain the TPC values (Ballus et al, 2015; Yancheva et al, 2016; Sánchez S. et al, 2007) and the results will be discussed later when comparing farmers data within the same region according to their questionnaire.

Table 4.6: Average DPPH values (mg Torolox/Kg oil) from different geographical regions in Palestine according to governorate and year; results are expressed as average ± SD.

City	Year	
	2013	**2014**
Bethlehem	503.48±272.53	458.72±69.97
Hebron	319.43±99.34	424.52±122.32
Jenin	438.67±422.21	561.83±291.31
Nablus	645.07±189.49	686.70±204.97
Tulkarm	351.33±11.31	445.67±250.95

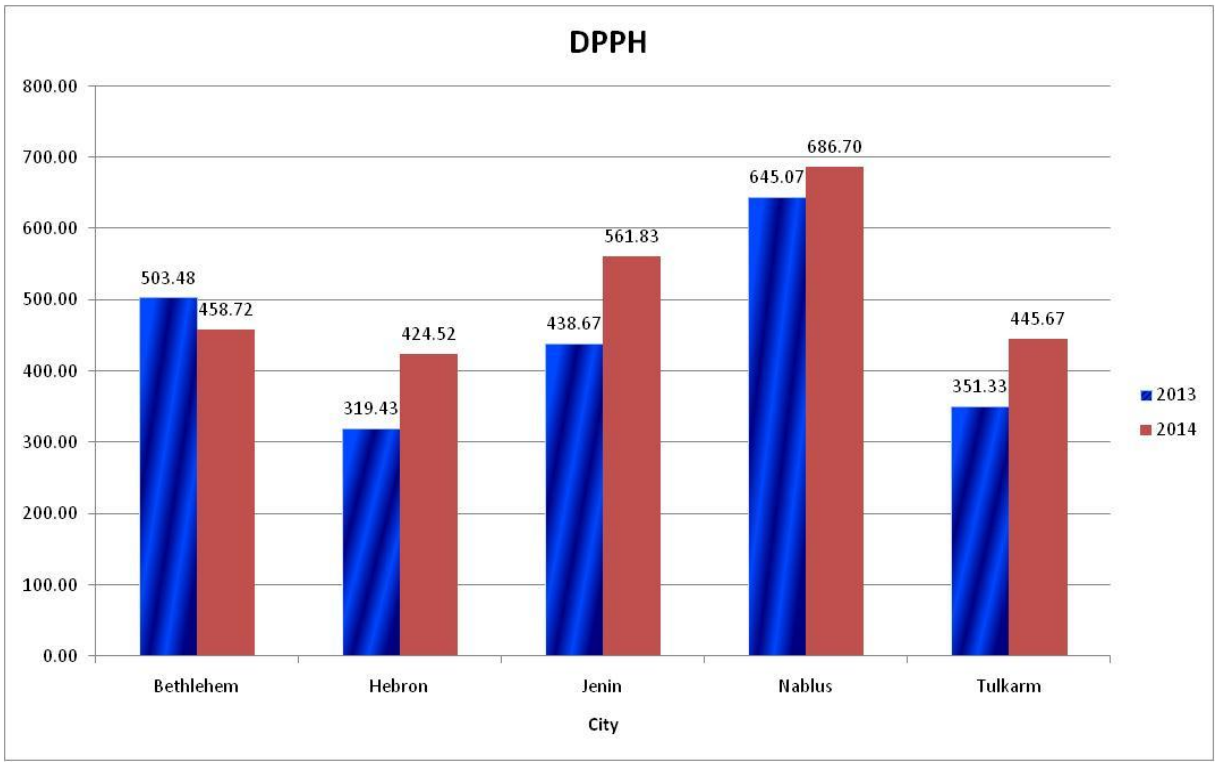


Figure 4.6: Mean values of DPPH assay (mg Torolox/Kg oil) in the different governorates during 2013 and 2014.

4.1.7. Iodine Values according to governorate and year

The iodine number equals the number of grams of iodine required to saturate the fatty acids present in 100 g of the oil or fat (Gupta & Kanwar.1994).

In 2013, the highest Iodine value (95.63) was in Tulkarm and the lowest Iodine value (66.52) was in Hebron. On the other hand, In 2014, the highest Iodine value (92.45) was in Jenin and the lowest Iodine value (75.68) was in Bethlehem (Table 4.7).

The Iodine values (g Iodine/100 g oil) of olive oil samples were 74.06±15.65 and 75.68±13.77 respectively in 2013 and 2014 in Bethlehem, 66.52±4.38 and 76.81±13.89 respectively in Hebron, 84.68±15.17 and 92.45±11.92 respectively in Jenin, 85.99±13.2 and 87.7±10.9 respectively in Nablus and 95.63±9.76 and 76.91±5.66 respectively in Tulkarm (Table 4.7).

There are several factors that affect iodine value such as olive fly infection, ripening level and location of olive tree as reported in the paper of (Amarna et al, 2011).

Gharbi et al, (2015) found that the rate of polyunsaturated fatty acid synthesis are affected by the ripeness of the pressed olives.

Table 4.7: Average Iodine values (g Iodine/100 g oil) from different geographical regions in Palestine according to governorate and year; results are expressed as average ± SD (25°C).

City	Year	
	2013	**2014**
Bethlehem	74.06±15.65	75.68±13.77
Hebron	66.52±4.38	76.81±13.89
Jenin	84.68±15.17	92.45±11.92
Nablus	85.99±13.2	87.7±10.9
Tulkarm	95.63±9.76	76.91±5.66

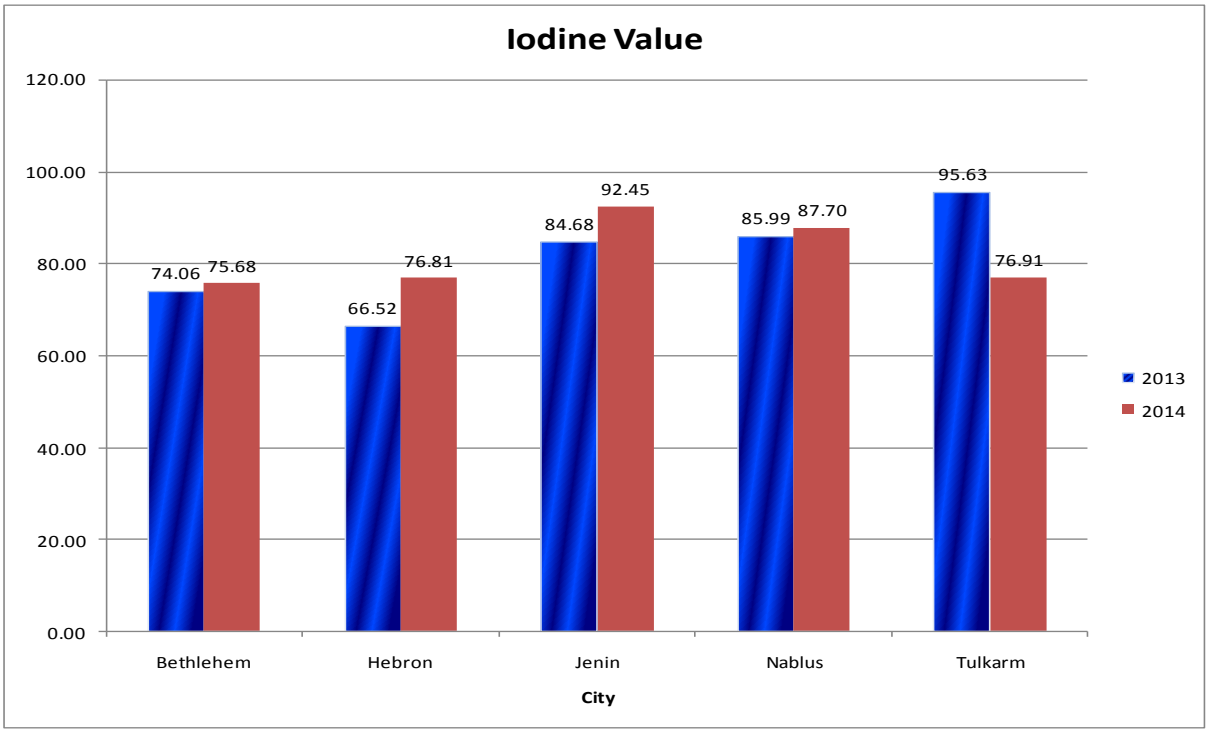


Figure 4.7: Mean values of iodine value assay (g iodine/100 g oil) in the different governorates during 2013 and 2014.

4.1.8. Acidity% values according to governorate and year

The acid value is defined as the number of milligrams of potassium hydroxide required to neutralize the free fatty acids present in one gram of fat or oil (Hamid, F., & Hamid, F. H.2016).

In 2013, the highest value (1.44) of acidity% was in Jenin and the lowest value (1.1) of acidity% was in Hebron. On the other hand, in 2014, the highest value (1.56) of acidity% was in Tulkarm and the lowest value (1.09) of Acidity% was in Hebron (Table 4.8).

The Acidity% values (expressed as % oleic acid) of olive oil samples were 1.12±0.38 and 1.11±0.27 respectively in 2013 and 2014 in Bethlehem, 1.1±0.35 and 1.09±0.37 respectively in Hebron, 1.44±0.32 and 1.35±0.12 respectively in Jenin, 1.27±0.3 and 1.41±0.32 respectively in Nablus and 1.35±0.48 and 1.56±0.12 respectively in Tulkarm (Table 4.8).

According to (Figure 4.8) we observed a decrease in Acidity% values in the olive oil during 2014 for all governorates except in Nablus and Tulkarm.

According to IOOC (2015), it can be observed that all our acidity results in both 2013 and 2014 categorized our oil samples as virgin olive oil.

Mansouri et al, (2013) stated that factors causing damage to the olive fruits affect acidity of olive oil, while (Salvador et al., 2001) considered that ripening stages affect acidity. Tamendjari, et al (2009) found that olive oils obtained from infested olives had higher acidity values than non infested olives. Méndez & Falqué (2002) found that during olive oil storage, acidity increased slightly in almost all oils tested and showed that the lowest degree of acidity was obtained with hand harvested olives and the highest level was obtained with olives fallen into the ground.

If the olives are healthy and processed soon after harvesting (within 24 hr), environmental conditions do not appear to have any substantial influence on the free acidity of the oil, which allow the classification of the oils as EVOOs (Pannelli et al. 1990a; Ripa et al. 2008).
There was no significant difference between Acidity% values in governerates.

Differences in our Acidity% values results can not be explained according to the difference in governerates alone.

Table 4.8: Average Acidity% values (expressed as % oleic acid) from different geographical regions in Palestine according to governorate and year; results are expressed as average ± SD.

City	Year	
	2013	**2014**
Bethlehem	1.12±0.38	1.11±0.27
Hebron	1.1±0.35	1.09±0.37
Jenin	1.44±0.32	1.35±0.12
Nablus	1.27±0.3	1.41±0.32
Tulkarm	1.35±0.48	1.56±0.12

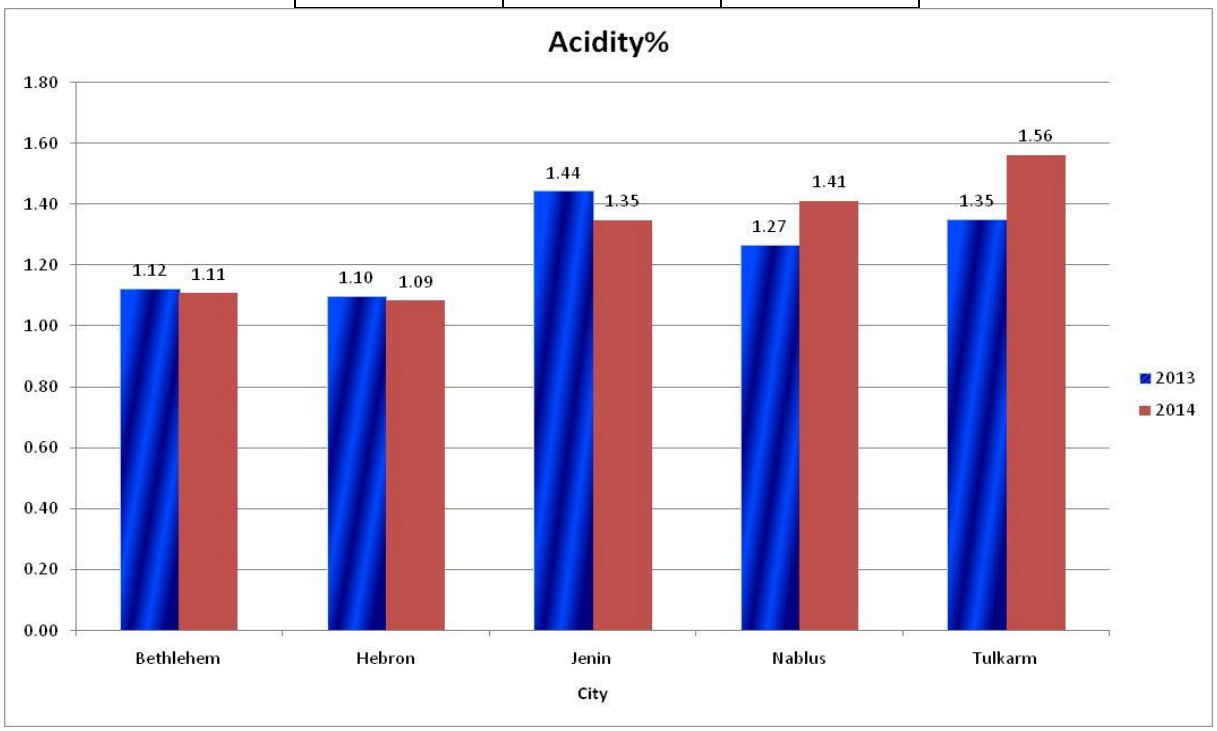


Figure 4.8: Mean values of Acidity% assay (expressed as % oleic acid) in the different governorates during 2013 and 2014.

4.1.9. Peroxide Values according to governorate and year

The peroxide value (PV) is an indicator of the initial stages of oxidative change (Ruíz, et al, 2001). The PV represents the total hydroperoxide content and is one of the most common quality indicators of fats and oils during production and storage (Antolovich et al, 2002; Ruíz et al, 2001). The peroxide value is determined by measuring the amount of iodine which is formed by the reaction of peroxides (formed in fat or oil) with iodide ion (Grossi et al, 2015).

In 2013, the highest peroxide value (17.38) was in Jenin and the lowest peroxide value (15.58) was in Tulkarm. On the other hand, In 2014, the highest peroxide value (17.26) was in Hebron and the lowest peroxide value (16.75) was in Jenin (Table 4.9).

The peroxide values (millequivalent O_2 kg^{-1}) of olive oil samples were 16.53±0.99 and 16.78±0.92 respectively in 2013 and 2014 in Bethlehem, 16.53±1.01 and 17.26±0.98 respectively in Hebron, 17.38±1.27 and 16.75±1.93 respectively in Jenin, 17.19±1.02 and 17.01±0.44 respectively in Nablus and 15.58±0.28 and 16.81±0.61 respectively in Tulkarm (Table 4.9).

According to (Figure 4.9) we observed an increase in peroxide values in the olive oil during 2014 for all governorates except in Jenin and Nablus there was a decrease in 2014 and it was observed that the increase in peroxide value in Tulkarmin 2014 was so high in comparison to 2013. Depending on IOOC (2015), all oil samples in both 2013 and 2014 are within EVOO and VOO.

According to Mansouri et al (2013) there are many factors affecting peroxide values of olive oil like factors causing damage to the olive fruits, while it is not affected by cultivar.

Storage time affect also peroxide value, where peroxide value decreased with storage time and then after 6 months of storage the peroxide value started to increase with storage time (Méndez & Falqué, 2002).

Fly-infected olives were found to increase the value of peroxide (Tamendjari et al, 2009).

If the olives are healthy and processed soon after harvesting (within 24 hr), environmental conditions do not appear to have any substantial influence on the peroxide number of the oil, which allow the classification of the oils as EVOOs (Pannelli et al, 1990; Ripa et al, 2008).

Table 4.9: Average Peroxide Values (millequivalent O_2 kg^{-1}oil) from different geographical regions in Palestine according to governorate and year; results are expressed as average ± SD.

City	Year	
	2013	2014
Bethlehem	16.53±0.99	16.78±0.92
Hebron	16.53±1.01	17.26±0.98
Jenin	17.38±1.27	16.75±1.93
Nablus	17.19±1.02	17.01±0.44
Tulkarm	15.58±0.28	16.81±0.61

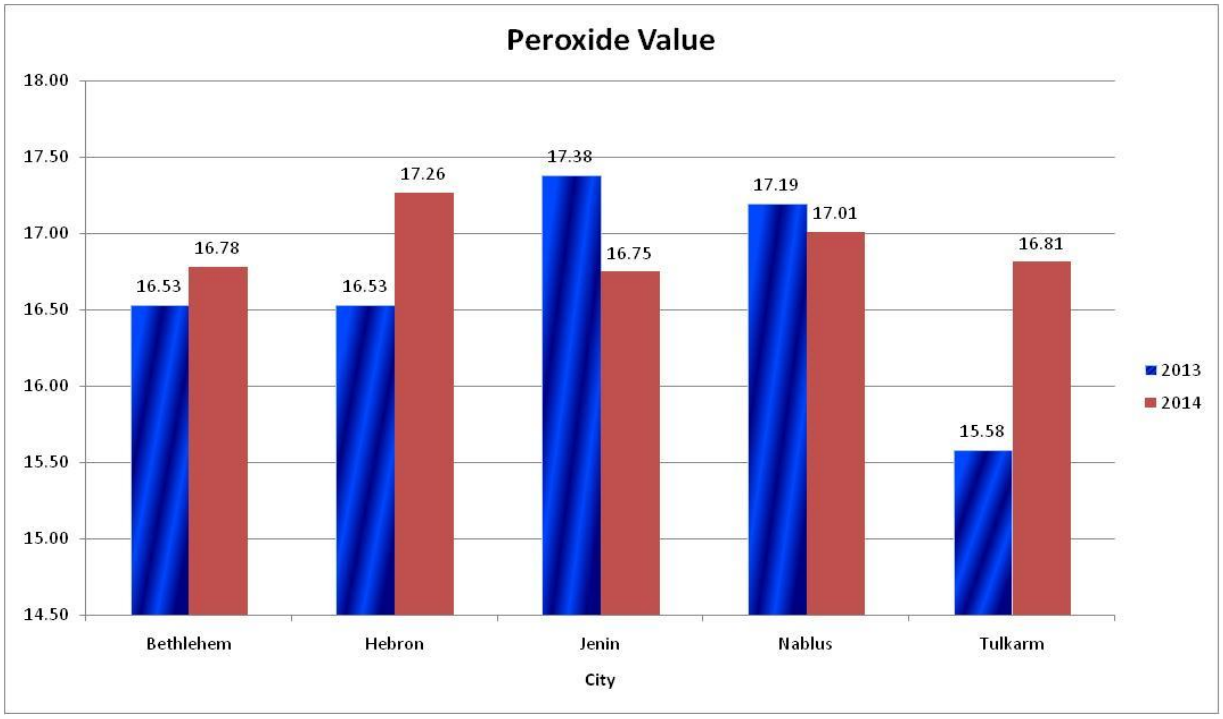


Figure 4.9: Mean values of peroxide value assay (millequivalent O_2 kg^{-1}) in the different governorates during 2013 and 2014.

4.1.10. Specific gravity values according to governorate and year

In 2013, the highest oil specific gravity value (0.9161) was in Tulkarm and the lowest oil specific gravity value (0.9113) was in Nablus. On the other hand, in 2014, the highest oil specific gravity value (0.9141) was in Hebron and the lowest oil specific gravity value (0.911) was in Bethlehem (Table 4.10).

The specific gravity values (dimensionless quantity) of olive oil samples were 0.9129±0.004 and 0.911±0.0015 respectively in 2013 and 2014 in Bethlehem 0.9145±0.0041 and 0.9141±0.0032 respectively in Hebron, 0.9126±0.004 and 0.9136±0.0052 respectively in Jenin, 0.9113±0.0043 and 0.9124±0.004 respectively in Nablus and 0.9161±0.0016 and 0.9118±0.0006 respectively in Tulkarm (Table 4.10).

According to (Figure 4.10) we observed a decrease in specific gravity values in the olive oil during 2014 for all governorates except in Jenin and Nablus there was an increase in 2014 and it was observed that there was a sharp decrease in specific gravity values in Tulkarm in 2014 in comparison with 2013.

Specific gravity varies with temperature and pressure; reference and sample must be compared at the same temperature and pressure, and since most important factor here is temperature it must be taken precisely.

There were no significant differences in specific gravity values since the density values of oil samples were so close to each other.

Table 4.10: Average oil specific gravity values (dimensionless quantity) from different geographical regions in Palestine according to governorate and year; results are expressed as average ± SD.

City	Year	
	2013	**2014**
Bethlehem	0.9129±0.004	0.911±0.0015
Hebron	0.9145±0.0041	0.9141±0.0032

Jenin	0.9126±0.004	0.9136±0.0052
Nablus	0.9113±0.0043	0.9124±0.004
Tulkarm	0.9161±0.0016	0.9118±0.0006

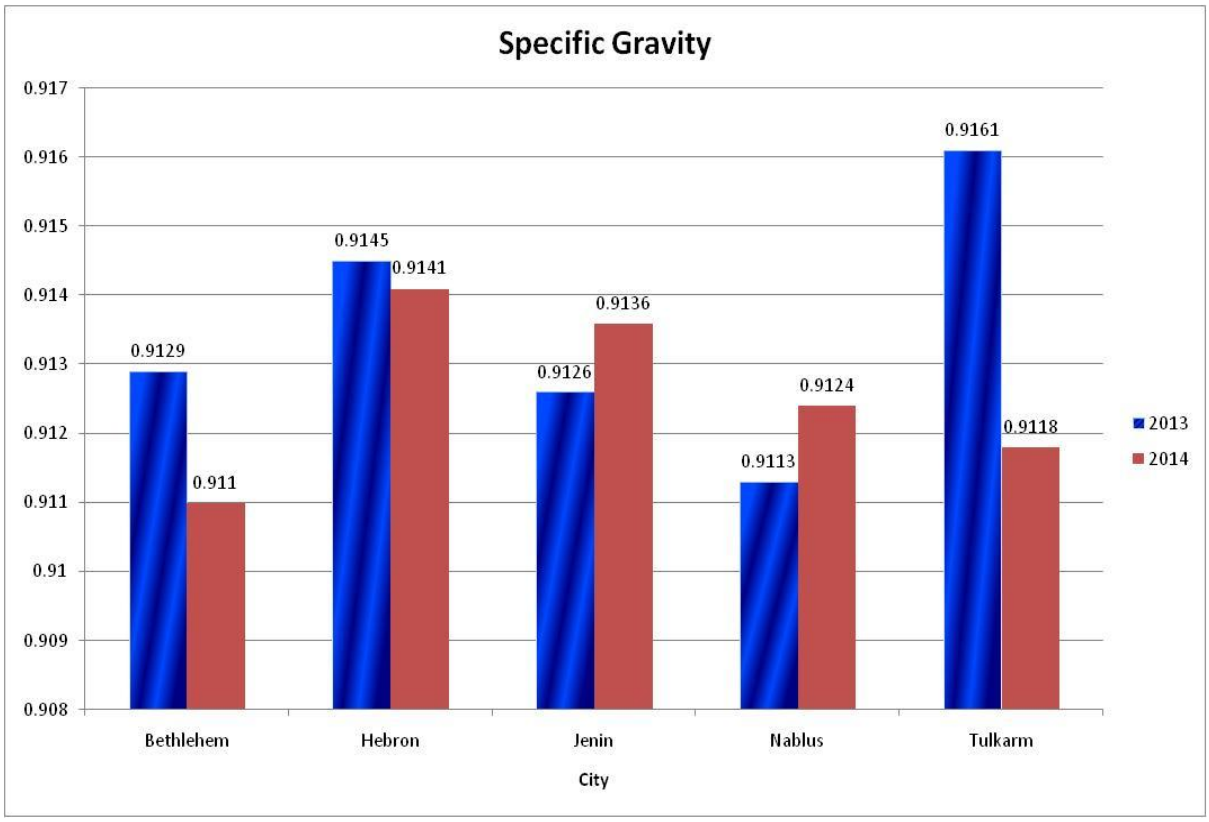


Figure 4.10: Mean values of oil specific gravity assay (dimensionless quantity) in the different governorates during 2013 and 2014.

4.1.11. Refractive Index values according to governorate and year

Refractive index is the ratio of velocity of light in vaccum to the velocity of light in the oil or fat. Refractive index varies with temperature and wave length (Hamid & Hamid, 2016).

In 2013, the highest refractive index value (1.4657) was in Hebron and the lowest refractive index value (1.4647) was in Jenin. On the other hand, in 2014, the highest refractive index value (1.4659) was in Nablus and the lowest refractive index value (1.4652) was in Jenin (Table 4.11).

The refractive index values (dimensionless quantity) of olive oil samples were 1.4656±0.0004 and 1.4654±0.0005 respectively in 2013 and 2014 in Bethlehem, 1.4657±0.0006 and 1.4656±0.0005 respectively in Hebron, 1.4647±0 and 1.4652±0.0007 respectively in Jenin, 1.4653±0.0005 and 1.4659±0.0007 respectively in Nablus and 1.4652±0.0007 and 1.4657±0 respectively in Tulkarm (Table 4.11).

According to (Figure 4.11) we observed an approximately equal refractive index values in the olive oil for all governorates.

Amarna et al (2011) found that there was a relation between high refractive index values and olive fly infection.

Table 4.11: Average refractive index values (dimensionless quantity) from different geographical regions in Palestine according to governorate and year; results are expressed as average ± SD (27°C).

City	**Year**	
	2013	**2014**
Bethlehem	1.4656±0.0004	1.4654±0.0005
Hebron	1.4657±0.0006	1.4656±0.0005
Jenin	1.4647±0	1.4652±0.0007
Nablus	1.4653±0.0005	1.4659±0.0007
Tulkarm	1.4652±0.0007	1.4657±0

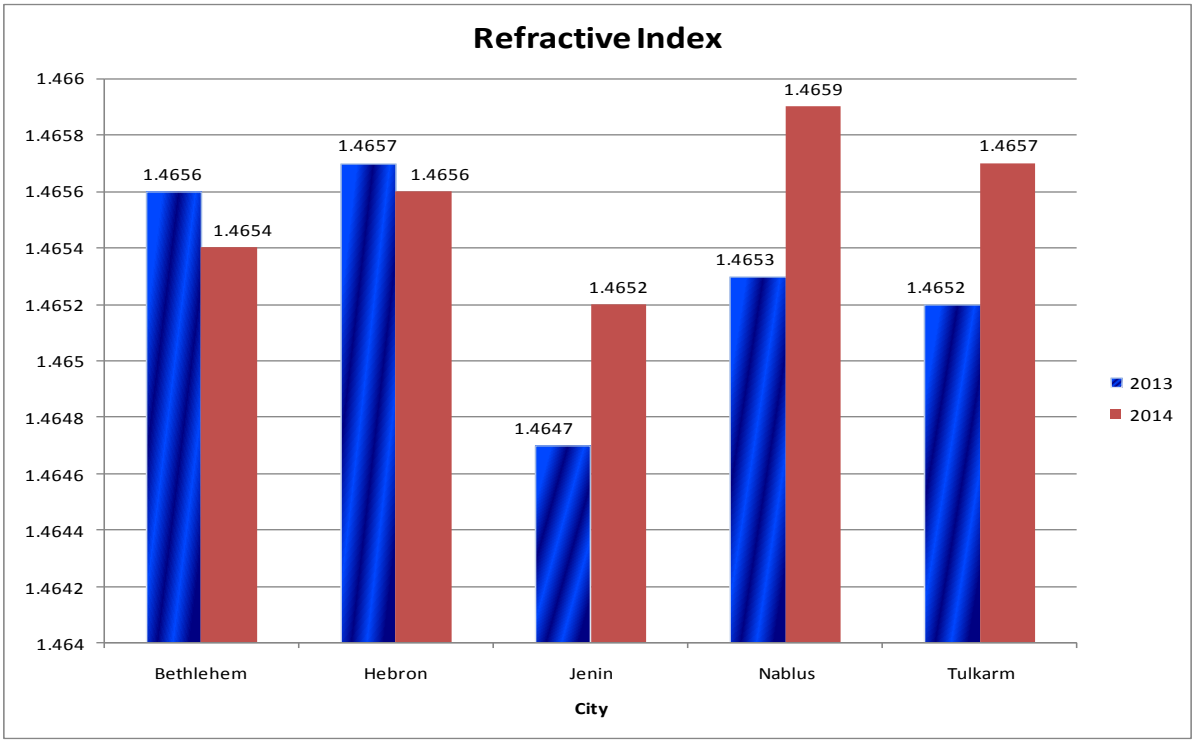


Figure 4.11: Mean values of refractive index assay (dimensionless quantity) in the different governorates during 2013 and 2014.

4.1.12. Average K_{270} Values according to governorate and year

The absorbances measured at 232 nm and 270 nm, namely K_{232} and K_{270}, provide an official method for olive oil quality control, which is capable of detecting product oxidation and adulteration by means of rectified oils (Mignan et al, 2012; Angerosa et al, 2006), since they can give an indication of the level of oxidation to produce primary and secondary products incurred during production and/or storage (Afaneh et al.2013).

In 2013, the highest K_{270} value (0.2315) was in Tulkarm and the lowest K_{270} value (0.2257) was in Hebron. On the other hand, in 2014, the highest K_{270} value (0.2312) was in Tulkarm and the lowest K_{270} value (0.2152) was in Jenin (Table 4.12).

The K_{270} values ($K_{1\%}$/1cm) of olive oil samples were 0.23±0.0097 and 0.218±0.0055 respectively in 2013 and 2014 in Bethlehem, 0.2257±0.0136 and 0.2245±0.0119 respectively in Hebron, 0.2274±0.0064 and 0.2152±0.0007 respectively in Jenin, 0.2296±0.0129 and 0.2193±0.0064 respectively in Nablus and 0.2315±0.0054 and 0.2312±0.012 respectively in Tulkarm (Table 4.12).

According to (Figure 4.12) we observed a decrease in average K_{270} values in the olive oil during 2014 for all governorates and it was observed that there was a sharp decrease in average K_{270} values in Bethlehem and Nablus in 2014 in comparison with 2013.
In 2013 and 2014, all olive oil samples are VOO category, while those from Bethlehem, Jenin and Nablus are EVOO category according to IOOC (2015).

Mansouri et al (2013) reported that K_{270} as one of the quality indices is affected by variety and factors causing damage to the olive fruits, while Abbadi et al (2014) reported that absorption coefficient K_{270} was the most sensitive determinant chemical test that determines the quality of stored olive oil and could be used as a rapid indicator test.

Pannelli et al (1990a); Ripa et al (2008) reported that if the olives are healthy and processed soon after harvesting (within 24 hr), environmental conditions do not appear to have any substantial influence on the UV absorbencies of the oil, which allow the classification of the oils as EVOOs.

Table 4.12: Average K_{270} values ($K_{1\%}$/1cm) from different geographical regions in Palestine according to governorate and year; results are expressed as average ± SD.

City	Year	
	2013	**2014**
Bethlehem	0.23±0.0097	0.218±0.0055
Hebron	0.2257±0.0136	0.2245±0.0119
Jenin	0.2274±0.0064	0.2152±0.0007
Nablus	0.2296±0.0129	0.2193±0.0064
Tulkarm	0.2315±0.0054	0.2312±0.012

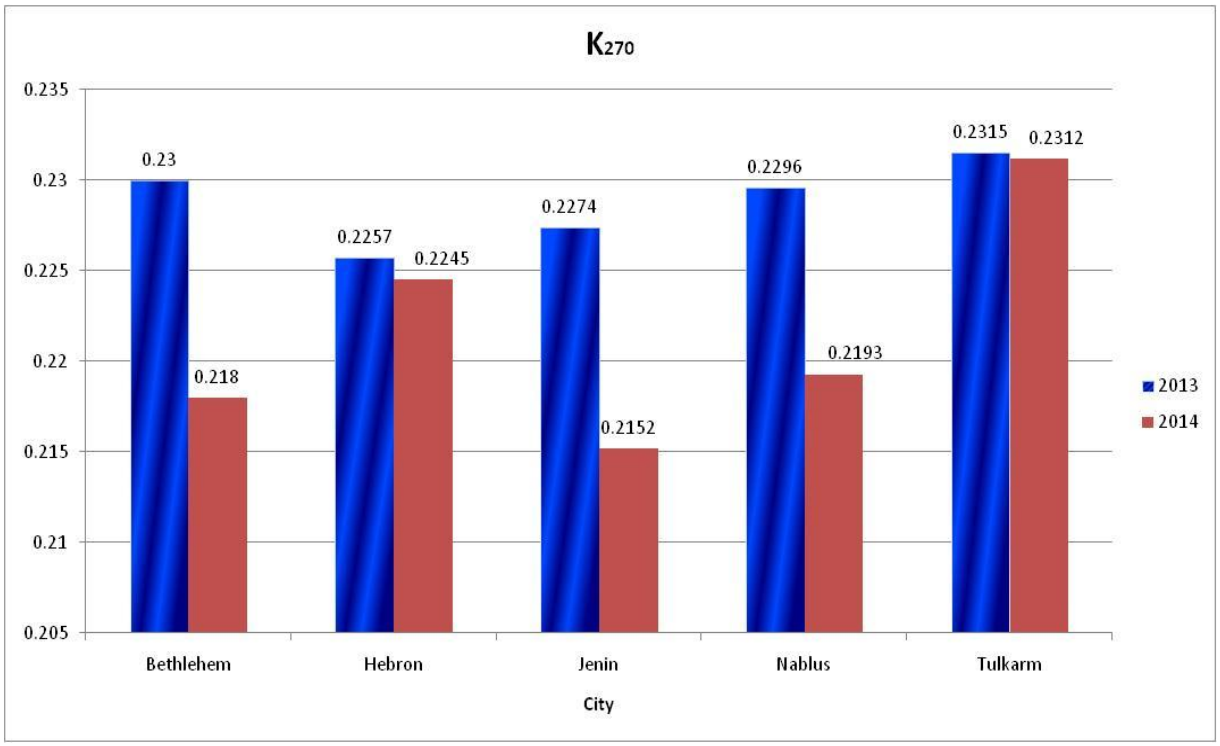


Figure 4.12: Mean values of K_{270} assay ($K_{1\%}$/1cm) in the different governorates during 2013 and 2014.

4.1.13. K_{232} Values according to governorate and year

The absorbances measured at 232 nm and 270 nm, namely K_{232} and K_{270}, provide an official method for olive oil quality control, which is capable of detecting product oxidation and adulteration by means of rectified oils, (Mignan et al, 2012; Angerosa et al, 2006) since they can give an indication of the level of oxidation to produce primary and secondary products incurred during production and/or storage (Afaneh et al.2013).

In 2013, the highest K_{232} value (1.66) was in Bethlehem and the lowest K_{232} value (1.56) was in Jenin. On the other hand, in 2014, the highest K_{232} value (1.58) was in Tulkarm and the lowest K_{232} value (1.48) was in Bethlehem (Table 4.13).

The K_{232} values ($K_{1\%}$/1cm) of olive oil samples were 1.66±0.02 and 1.48±0.02 respectively in 2013 and 2014 in Bethlehem, 1.64±0.06 and 1.55±0.08 respectively in Hebron, 1.56±0.05 and 1.53±0.13 respectively in Jenin, 1.6±0.08 and 1.49±0.06 respectively in Nablus and 1.65±0.02 and 1.58±0.01 respectively in Tulkarm (Table 4.13).

According to (Figure 4.13) we observed a decrease in average K_{232} values in the olive oil during 2014 for all governorates and it was observed that there was an observable decrease in average K_{232} values in Bethlehem in 2014 in comparison with 2013.

According to K_{232} results, all olive oil samples were EVOO category in 2013 and 2014.

K_{232} as one of the quality indices is affected by variety and factors causing damage to the olive fruits (Mansouri et al, 2013).

Gharbi et al (2015) reported that K_{232} value was affected with olive storage conditions.

Pannelli et al. 1990a and Ripa et al (2008) reported that if olives are healthy and processed soon after harvesting (within 24 hr), environmental conditions do not appear to have any substantial influence on the UV absorbencies of the oil, which are normally within the values that allow the classification of the oils as EVOOs.

Table 4.13: Average K_{232} values ($K_{1\%}$/1cm) from different geographical regions in Palestine according to governorate and year; results are expressed as average ± SD.

City	Year	
	2013	**2014**
Bethlehem	1.66±0.02	1.48±0.02
Hebron	1.64±0.06	1.55±0.08
Jenin	1.56±0.05	1.53±0.13
Nablus	1.6±0.08	1.49±0.06
Tulkarm	1.65±0.02	1.58±0.01

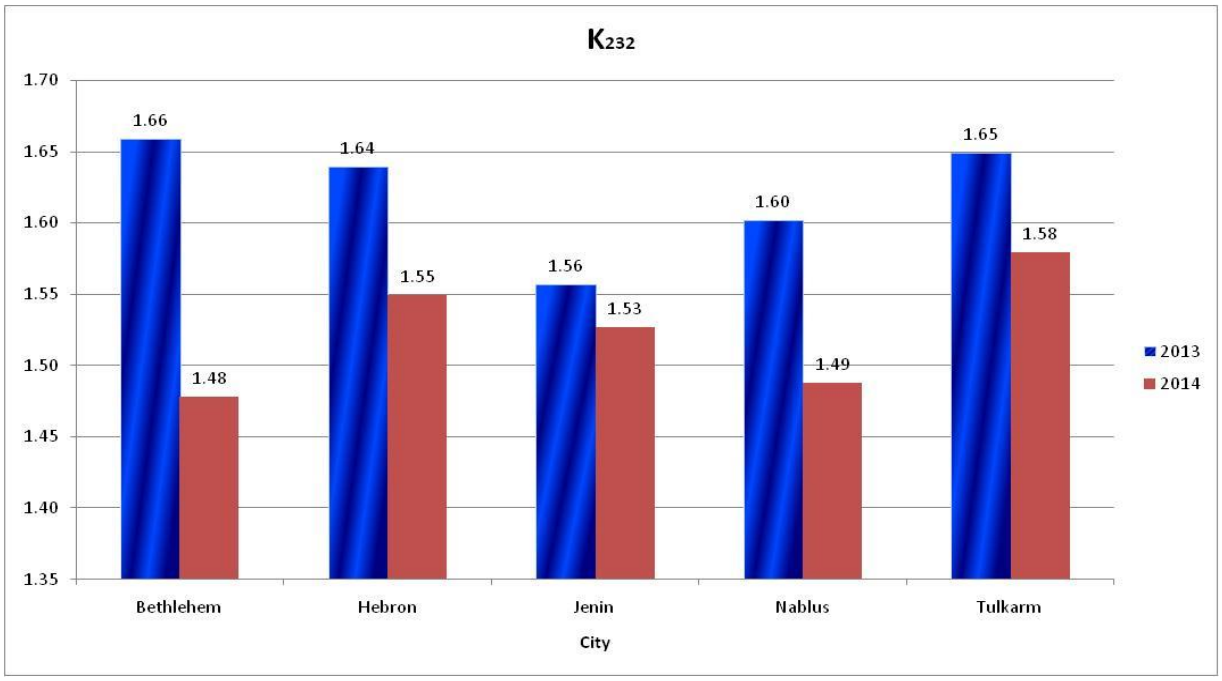


Figure 4.13: Mean values of K_{232} assay ($K_{1\%}$/1cm) in the different governorates during 2013 and 2014.

4.2. Variations of the studied parameters (TPC, TFC, FRAP, CUPRAC, ABTS, DPPH, Acidity%, peroxide value, K_{232}, K_{270}, Iodine value, Specific gravity and refractive index) among governorates

According to ANOVA test analysis and the Tukey HSD post hoc pair wise tests, the conclusions about governerates are as the following:

In 2013, there were significant differences at (α=0.05) between governorates whereas: Hebron have refractive higher than Jenin, Nablus has iodine value higher than Hebron, and Nablus has DPPH higher than Hebron.

In 2014, there were significant differences at (α=0.05) between governorates whereas: Nablus has DPPH higher than Hebron. Both Jenin and Hebron have ABTS higher than Nablus. Jenin has FRAP higher than each one of Nablus, Tulkarm, Bethlehem and Hebron. Hebron has TFC higher than Nablus.

4.3. Assays Results among regions

Olive oil samples from sixty farmers were collected in 2013 and 2014 freshly during milling their olive fruits from different geographical areas in the West Bank: Jenin (Burkin), Tulkarm

(Anabta), Nablus (Salfeet, North Asera, Burin and South Asera), Bethlehem (Bayt Jala and Dheisha) and Hebron (Sourif, Si'ir and Alshuokh).The samples were taken in late October 2013 and late October 2014 in similar conditions.

The samples were analyzed for their total Phenolic Contents, total flavonoids content, their antioxidant activity (FRAP, CUPRAC,ABTS and DPPH), Acidity%, peroxide value, Iodine value, Specific gravity, K_{232}, K_{270} and refractive index.

4.3.1. Total Phenolic Contents in different geographical regions

In 2013, the highest TPC value (851) was in Surif and the lowest TPC value (184) was in Asira Al-Shamaliya. On the other hand, in 2014, the highest TPC value (632) was in Surif and the lowest TPC value (273) was in Bayt Jala (Table 4.14).

The total Phenolic Contents (mg gallic acid/Kg of oil) of olive oil samples were 696±114 and 469±154 respectively in 2013 and 2014 in Anabta, 288±96 and 273±162 respectively in Bayt Jala, 589±118 and 606±66 respectively in Burkin, 379±10 in 2014 in Burin,764±194 and 448±125 respectively in Dheisha, and 184±54 in 2013 in Asira Al-Shamaliya, and 626±294 in 2013 in Si'ir, 647±429 and 380±8 respectively in Salfit, 576±119 in 2014 in Al-Shuyukh, 851±376 and 632±303 respectively in Surif and 419±239 in 2014 in Asira Al-Qibliya (Table 4.14).

According to (Figure 4.14) we observed that there was a high TPC values in Dheisha and Surif in 2013 and there was low TPC values in Bayt Jala and Asira Al-Shamaliya in the same year, while there was a high TPC values in Burkin and Surif in 2014 and there was a very low TPC values in Bayt Jala in 2014.

Houshia Orwa, et al (2014) reported that the total concentration of polyphenol in some samples of Palestinian olive oil from Jerusalem, Tulkarem and Jenin ranges from 150 to 300 mg/kg while our results were higher except Asira Al-Shamaliya TPC results were in agreement.

TPC values can be categorized into three categories, low (50-200 mg GAE/Kg oil), medium (200-500 mg GAE/Kg oil) and high (500-1000 mg GAE/Kg oil) according to (Kalogeropoulos & Tsimidou, 2014).

In 2013, Asira Al-Shamaliya was in low category, Bayt Jala was in medium category and all other regions were in high category. While in 2014, none in low category, most in medium and only Burkin, Al-Shuyukh and Surif were in high category.

Some factors affect the TPC of olive oil between which cultivar, climate and other environmental factors, harvesting time, the extraction process, the conditions of packing, distribution, and storage (Servili et al, 2004), so it is difficult to determine the specific reason for the different values of TPC according to geographical origin alone for it is not sufficient (Kalogeropoulos & Tsimidou, 2014).

Table 4.14: Average TPC values (mg gallic acid/Kg of oil) for different geographical regions in Palestine according to Region and year; results are expressed as average ± SD.

Region	**Year**	
	2013	**2014**
Anabta	696±114	469±154
Bayt Jala	288±96	273±162
Burkin	589±118	606±66
Burin		379±10
Dheisha	764±194	448±125
Asira Al-Shamaliya	184±54	
Si'ir	626±294	
Salfit	647±429	380±8
Al-Shuyukh		576±119
Surif	851±376	632±303
Asira Al-Qibliya		419±239

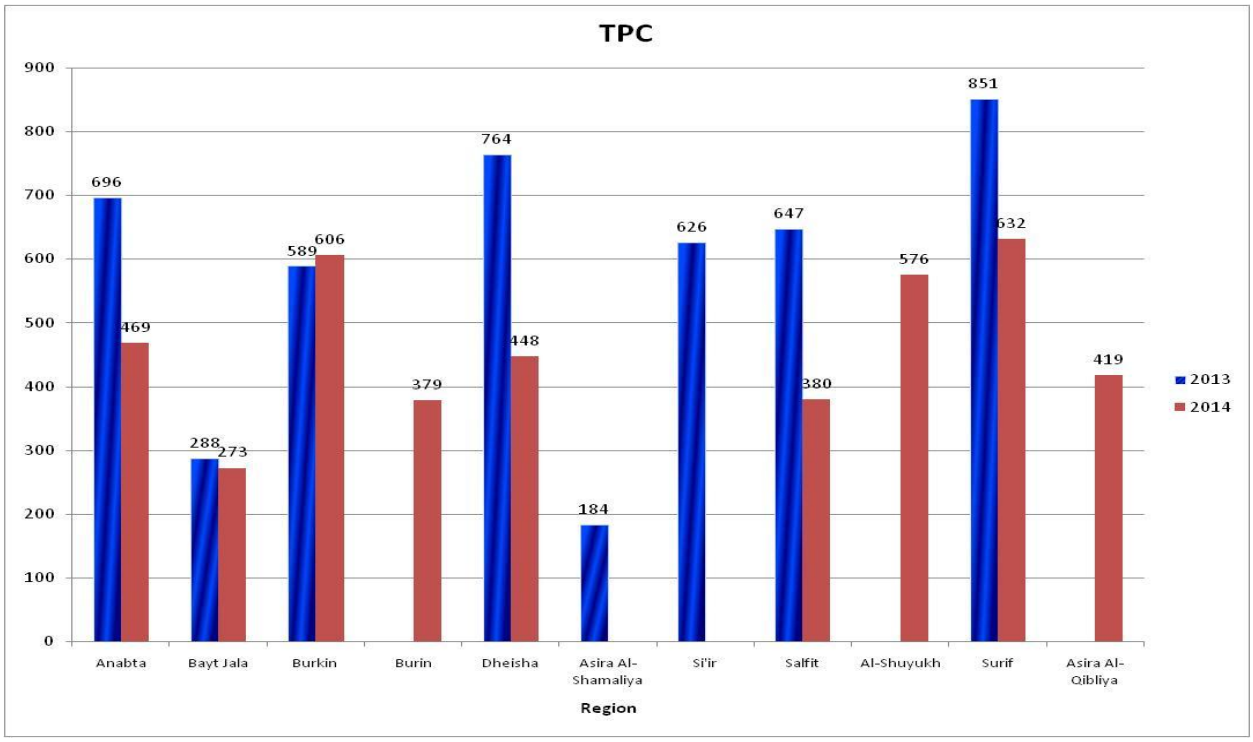


Figure 4.14: Average TPC values (mg gallic acid/Kg of oil) according to region and year.

4.3.2. Total flavonoids Content in different geographical regions

In 2013, the highest TFC value (129) was in Surif and the lowest TFC value (19) was in Asira Al-Shamaliya. On the other hand, in 2014, the highest TFC value (124) was in Surif and the lowest TFC value (24) was in Salfit (Table 4.15).

The total flavonoid content (mg catechin/Kg of oil) of olive oil samples were 106±30 and 116±7 respectively in 2013 and 2014 in Anabta, 50±1 and 63±13 respectively in Bayt Jala, 96.3±59 and 86±21 respectively in Burkin,122±2 in 2014 in Burin,114±33 and 76±10 respectively in Dheisha and 19±11 in 2013 in Asira Al-Shamaliya, and 81±46 in 2013 in Si'ir, 65±47 and 24±1 respectively in Salfit, 82±18 in 2014 in Al-Shuyukh, 129±52 and 124±35 respectively in Surif and 72.2±32 in 2014 in Asira Al-Qibliya (Table 4.15).

According to (Figure 4.15) it was observed that the highest TFC values in 2013 were in Dheisha and Surif, while the highest TFC values in 2014 were in Surif and Burin and Anabta and the lowest TFC value in 2013 was in Asira Al-Shamaliya, while the lowest TFC value in 2014 was in Salfit.

The phenolic composition of olive oil can be influenced by different factors such as the growing climate, harvest maturity, olive cultivar, agronomic practices including irrigation or application of fertilizers, ripening hormones and the techniques employed to process and extract the oil (Rwothomio, 2011), so it is difficult to determine the specific reason for the difference in TFC values between regions since geographical origin alone is not sufficient (Kalogeropoulos & Tsimidou, 2014).

Table 4.15: Average TFC values (mg catechin/Kg of oil) for different geographical regions in Palestine according to region and year; results are expressed as average ± SD.

Region	**Year**	
	2013	**2014**
Anabta	106±30	116±7
Bayt Jala	50±1	63±13
Burkin	96.3±59	86±21
Burin		122±2
Dheisha	114±33	76±10
Asira Al-Shamaliya	19±11	
Si'ir	81±46	
Salfit	65±47	24±1
Al-Shuyukh		82±18
Surif	129±52	124±35
Asira Al-Qibliya		72.2±32

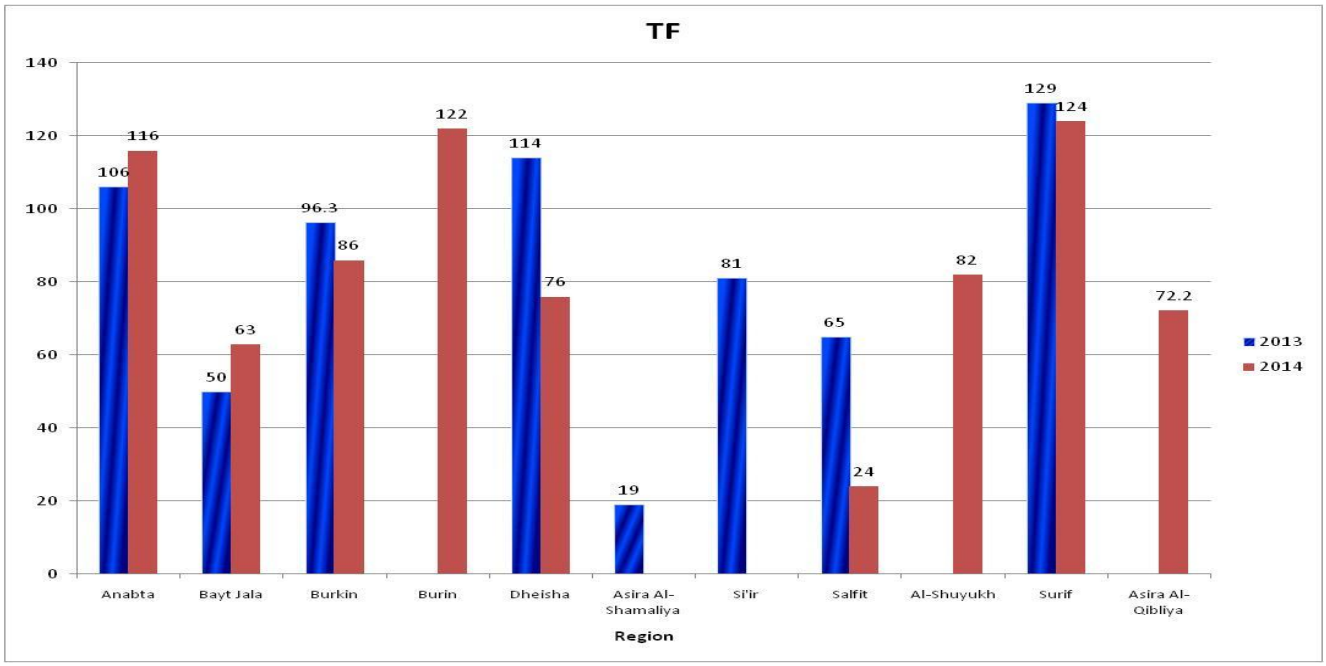


Figure 4.15: Average TFC values (mg catechin/Kg of oil) according to region and year.

4.3.3. FRAP values in different geographical regions

In 2013, the highest FRAP value (175.01) was in Burkin and the lowest FRAP value (39.17) was in Asira Al-Shamaliya. On the other hand, in 2014, the highest FRAP value (148.33) was in Burkin and the lowest FRAP value (47.22) was in Al-Shuyukh (Table 4.16).

The FRAP values (mmole Fe^{+2} /Kg of oil) of olive oil samples were 118.33±10.11 and 66.67±32.11 respectively in 2013 and 2014 in Anabta, 43.33±1.32 and 53.33±29.89 respectively in Bayt Jala, 175.01±61.21 and 148.33±11.12 respectively in Burkin, 93.33±1.39 in 2014 in Burin,110.67±51.23 and 73.33±10.28 respectively in Dheisha, and 39.17±19.96 in 2013 in Asira Al-Shamaliya, and 67.50±59.87 in 2013 in Si'ir, 121.11±91.42 and 70.00±1.98 respectively in Salfit, 47.22±20.34 in 2014 in Al-Shuyukh, 138.89±69.92 and 70.67±31.43 respectively in Surif and 79.44±32.14 in 2014 in Asira Al-Qibliya (Table 4.16).

According to (Figure 4.16) it was observed that the highest FRAP values both in 2013 and 2014 were in Burkin, while the lowest FRAP value in 2013 were in Asira Al-Shamaliya and Bayt Jala, while the lowest FRAP value in 2014 were in Bayt Jala and Al-Shuyukh.

It was observed that the higher the total phenolic compounds in the EVOO extracts, the higher the antioxidant capacities, regardless of the method antioxidant activity assay employed, so since FRAP is one of the antioxidant activity assays which is performed under acidic (pH 3.6) conditions and it has a high and significant positive correlation with the TPC, so the difference in FRAP values can not be explained according to different geographical regions since geographical origin alone is not sufficient to explain the TPC content and our results are in agreement with (Ballus et al, 2015; Yancheva et al, 2016).

Table 4.16: Average FRAP values (mmole Fe^{+2} /Kg of oil) for different geographical regions in Palestine according to Region and year; results are expressed as average ± SD.

Region	Year	
	2013	**2014**
Anabta	118.33±10.11	66.67±32.11
Bayt Jala	43.33±1.32	53.33±29.89
Burkin	175.01±61.21	148.33±11.12
Burin		93.33±1.39
Dheisha	110.67±51.23	73.33±10.28
Asira Al-Shamaliya	39.17±19.96	
Si'ir	67.50±59.87	
Salfit	121.11±91.42	70.00±1.98
Al-Shuyukh		47.22±20.34
Surif	138.89±69.92	70.67±31.43
Asira Al-Qibliya		79.44±32.14

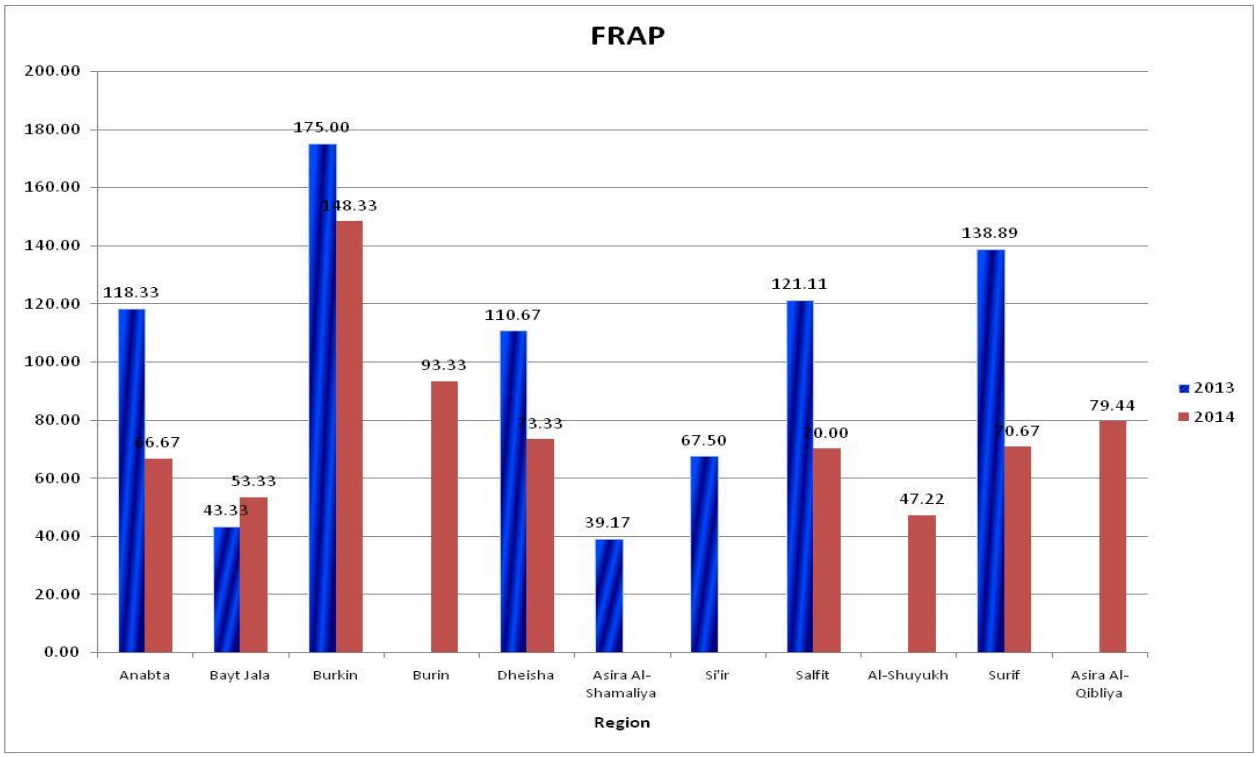


Figure 4.16: Average FRAP values (mmole Fe^{+2} /Kg of oil) according to region and year.

4.3.4. CUPRAC values in different geographical regions

In 2013, the highest CUPRAC value (22.2) was in Surif and the lowest CUPRAC value (6.47) was in Asira Al-Shamaliya. On the other hand, in 2014, the highest CUPRAC value (16.66) was in Anabta and the lowest CUPRAC value (8.9) was in Bayt Jala (Table 4.17).

The CUPRAC values (mg Torolox/g oil) of olive oil samples were 19.71±3.06 and 16.66±4.75 respectively in 2013 and 2014 in Anabta, 9.15±2.17 and 8.9±2.98 respectively in Bayt Jala, 20.08±9.89 and 14.13±2.08 respectively in Burkin,14.18±0 in 2014 in Burin,19.62±3.43 and 16.36±4.08 respectively in Dheisha, and 6.47±1.17 in 2013 in Asira Al-Shamaliya, and 14.15±6.98 in 2013 in Si'ir, 13.42±7.99 and 9.49±2.08 respectively in Salfit, 13.71±2.67 in 2014 in Al-Shuyukh, 22.2±3.06 and 15.34±4.41 respectively in Surif and 10.7±5.8 in 2014 in Asira Al-Qibliya (Table 4.17).

According to (Figure 4.17) it was observed that the highest CUPRAC value in 2013 was in Surif and the lowest CUPRAC value in 2013 was in Asira Al-Shamaliya, while the lowest CUPRAC values in 2014 were in Bayt Jala and Salfit.

It was observed that the higher the total phenolic compounds in the EVOO extracts, the higher the antioxidant capacities, regardless of the method antioxidant activity assay employed.

CUPRAC assay is performed under neutral (pH 7) conditions and it has a high and significant positive correlation with the TPC, so the difference in CUPRAC values can not be explained according to different geographical regions since geographical origin alone is not sufficient to explain the TPC content and our results are in agreement with (Ballus et al, 2015; Yancheva et al, 2016; Marques et al, 2014).

Table 4.17: Average CUPRAC values (mg Torolox/g oil) for different geographical regions in Palestine according to region and year; results are expressed as average ± SD.

Region	**Year**	
	2013	**2014**
Anabta	19.71±3.06	16.66±4.75
Bayt Jala	9.15±2.17	8.9±2.98
Burkin	20.08±9.89	14.13±2.08
Burin		14.18±0
Dheisha	19.62±3.43	16.36±4.08
Asira Al-Shamaliya	6.47±1.17	
Si'ir	14.15±6.98	
Salfit	13.42±7.99	9.49±2.08
Al-Shuyukh		13.71±2.67
Surif	22.2±3.06	15.34±4.41
Asira Al-Qibliya		10.7±5.8

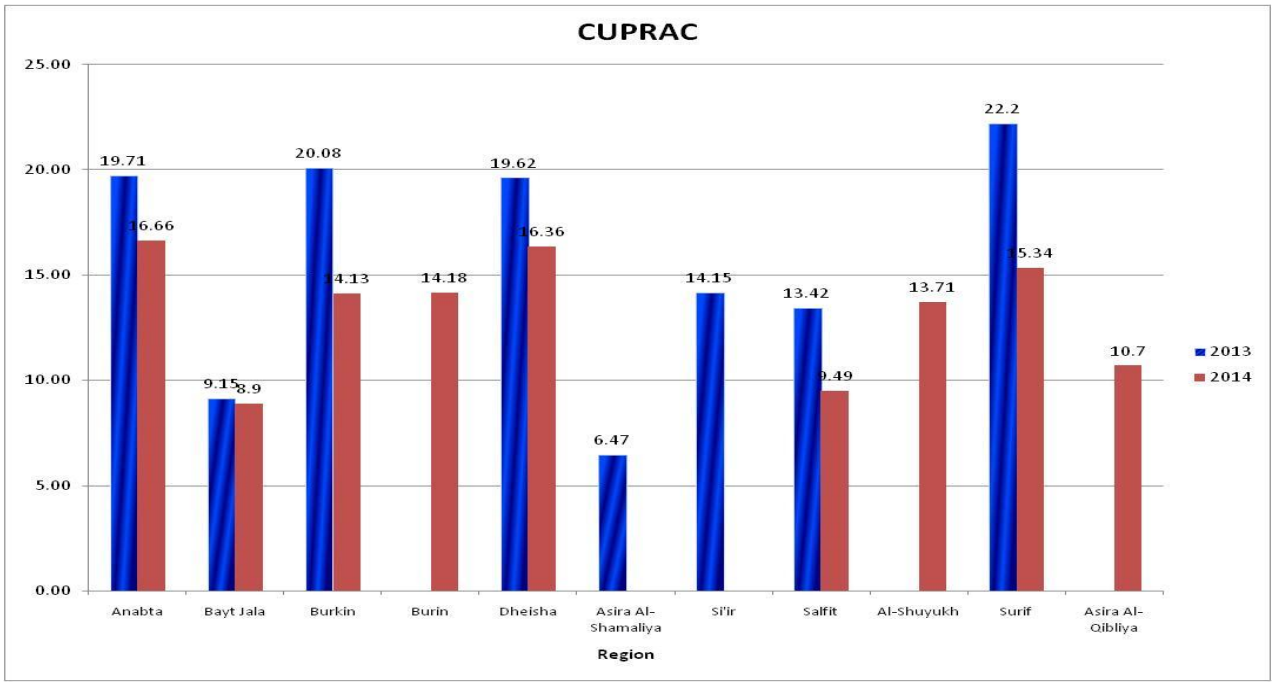


Figure 4.17: Average CUPRAC values (mg Torolox/g oil) according to region and year.

4.3.5. ABTS values in different geographical regions

In 2013, the highest ABTS value (1088.89) was in Surif and the lowest ABTS value (248.33) was in Bayt Jala. On the other hand, in 2014, the highest ABTS value (761.67) was in Burkin and the lowest ABTS value (305.02) was in Salfit (Table 4.18).

The ABTS values (mg Torolox/Kg oil) of olive oil samples were 406.67±21.01 and 316.67±181.22 respectively in 2013 and 2014 in Anabta, 248.33±32.08 and 344.44±51.32 respectively in Bayt Jala, 607.50±451.41 and 761.67±158.97 respectively in Burkin, 343.33±1.65 in 2014 in Burin, 856.67±291.87 and 736.67±19.98 respectively in Dheisha, and 293.33±141.32 in 2013 in Asira Al-Shamaliya, and 435.83±141.21 in 2013 in Si'ir, 760.56±381.31 and 305.02±10.09 respectively in Salfit, 670.13±178.89 in 2014 in Al-Shuyukh, 1088.89±219.97 and 714.67±223.01 respectively in Surif and 311.11±139.94 in 2014 in Asira Al-Qibliya (Table 4.18).

According to (Figure 4.18) it was observed that the highest ABTS value in 2013 was in Surif and the lowest ABTS value in 2013 was in Bayt Jala, while the highest ABTS values in 2014 were in Burkin, Dheisha and Surif, but the lowest ABTS values in 2014 were in Salfit and Asira Al-Qibliya.

The higher the total phenolic compounds in the EVOO extracts, the higher the antioxidant capacities, regardless of the method antioxidant activity assay employed.

ABTS assay has a high and significant positive correlation with the TPC, so the difference in ABTS values can not be explained according to different geographical regions since geographical origin alone is not sufficient to explain the TPC content and our results are in agreement with (Ballus et al, 2015; Yancheva et al, 2016) and the results will be discussed later when comparing farmers data within the same region according to their questionnaire.

Table 4.18: Average ABTS Values (mg Torolox/Kg oil) for different geographical regions in Palestine according to region and year; results are expressed as average ± SD.

Region	**Year**	
	2013	**2014**
Anabta	406.67±21.01	316.67±181.22
Bayt Jala	248.33±32.08	344.44±51.32
Burkin	607.50±451.41	761.67±158.97
Burin		343.33±1.65
Dheisha	856.67±291.87	736.67±19.98
Asira Al-Shamaliya	293.33±141.32	
Si'ir	435.83±141.21	
Salfit	760.56±381.31	305.02±10.09
Al-Shuyukh		670.13±178.89
Surif	1088.89±219.97	714.67±223.01
Asira Al-Qibliya		311.11±139.94

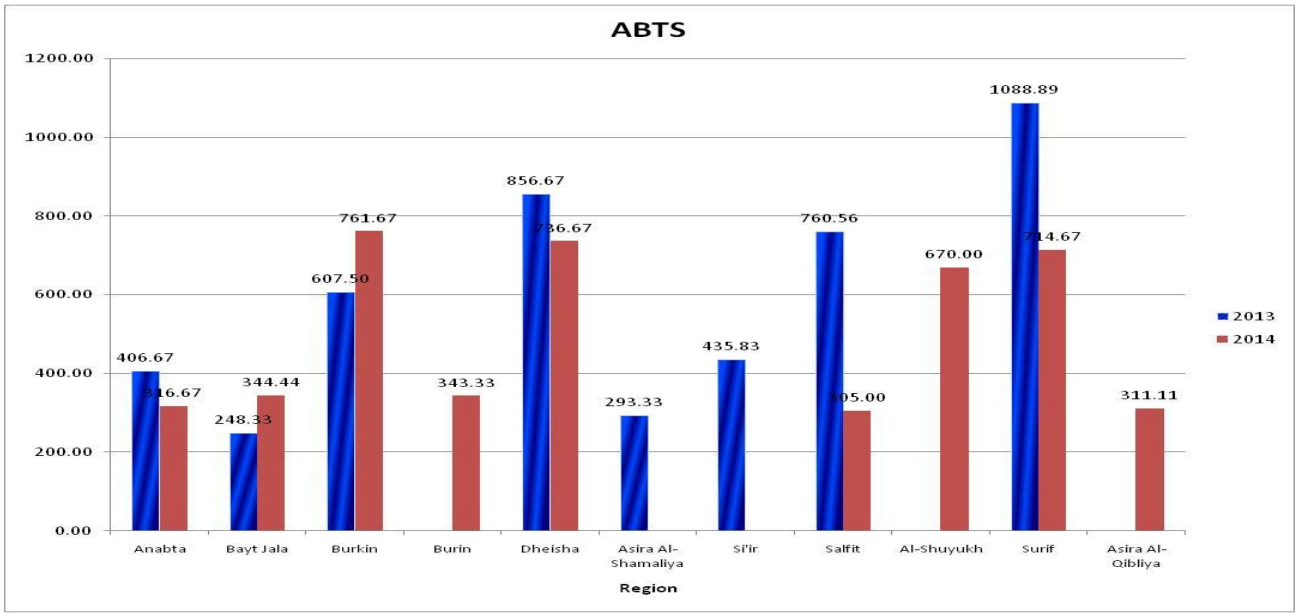


Figure 4.18: Average ABTS values (mg Torolox/Kg oil) according to region and year.

4.3.6. DPPH values in different geographical regions

In 2013, the highest DPPH value (743.61) was in Salfit and the lowest DPPH value (283.22) was in Surif. On the other hand, in 2014, the highest DPPH value (798.67) was in Burin and the lowest DPPH value (374.27) was in Surif (Table 4.19).

The DPPH values (mg Torolox/Kg oil) of olive oil samples were 351.33±11.21 and 445.67±251.03 respectively in 2013 and 2014 in Anabta, 351.50±87.98 and 419.33±78.23 respectively in Bayt Jala, 438.67±42.01 and 561.83±291.21 respectively in Burkin,798.67±1.32 in 2014 in Burin,564.27±305.01 and 498.11±37.43 respectively in Dheisha, and 497.25±188.11 in 2013 in Asira Al-Shamaliya, and 346.58±127.97 in 2013 in Si'ir, 743.61±120.01 and 616.83±41.21 respectively in Salfit, 466.39±141.09 in 2014 in Al-Shuyukh, 283.22±35.21 and 374.27±83.16 respectively in Surif and 691.33±250.13 in 2014 in Asira Al-Qibliya (Table 4.19).

According to (Figure 4.19) it was observed that the highest DPPH value in 2013 was in Salfit and the lowest DPPH value in 2013 was in Surif, while the highest DPPH value in 2014 was in Burin but the lowest DPPH value in 2014 was in Surif.

DPPH assay is an efficient electron donor, regardless of the reaction medium conditions and the compounds to be reduced.

The higher the total phenolic compounds in the EVOO extracts, the higher the antioxidant capacities, regardless of the method antioxidant activity assay employed.

There is a correlation between the total phenolic contents and DPPH$^{\bullet}$ for EVOO polar extracts.The difference in DPPH values can not be explained according to the differenence in geographical regions since geographical origin alone is not sufficient to explain the TPC values (Ballus et al, 2015; Yancheva et al, 2016; Samaniego Sánchez et al, 2007) and the results will be discussed later when comparing farmers data within the same region according to their questionnaire.

Table 4.19: Average DPPH values (mg Torolox/Kg oil) for different geographical regions in Palestine according to region and year; results are expressed as average ± SD.

Region	**Year**	
	2013	**2014**
Anabta	351.33±11.21	445.67±251.03
Bayt Jala	351.50±87.98	419.33±78.23
Burkin	438.67±42.01	561.83±291.21
Burin		798.67±1.32
Dheisha	564.27±305.01	498.11±37.43
Asira Al-Shamaliya	497.25±188.11	
Si'ir	346.58±127.97	
Salfit	743.61±120.01	616.83±41.21
Al-Shuyukh		466.39±141.09
Surif	283.22±35.21	374.27±83.16
Asira Al-Qibliya		691.33±250.13

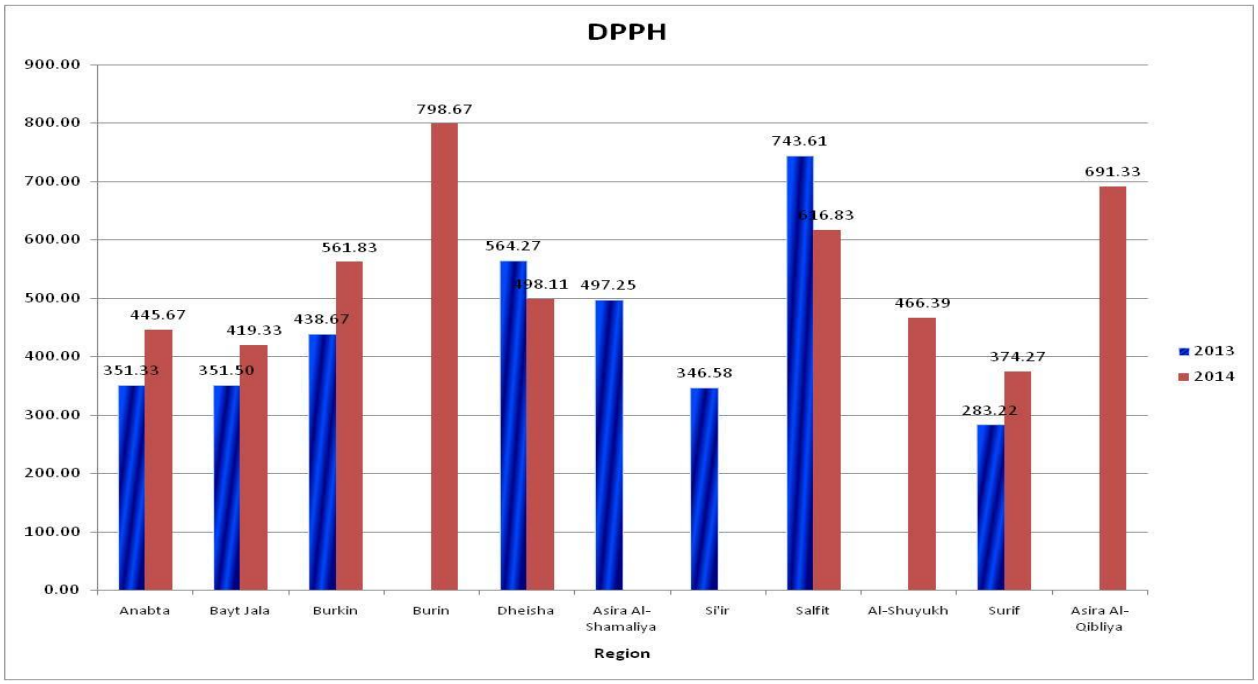


Figure 4.19: Average DPPH values (mg Torolox/Kg oil) according to region and year.

4.3.7. Iodine values in different geographical regions

In 2013, the highest Iodine value (95.63) was in Anabta and the lowest Iodine value (64.91) was in Si'ir. On the other hand, in 2014, the highest Iodine value (96.28) was in Salfit and the lowest Iodine value (64.37) was in Dheisha (Table 4.20).

The Iodine values (g Iodine/100 g oil) of olive oil samples were 95.63±9.76 and 76.91±5.66 respectively in 2013 and 2014 in Anabta, 83.54±8.57 and 87±5.7 respectively in Bayt Jala, 84.68±15.17 and 92.45±11.92 respectively in Burkin, 65.64±0 in 2014 in Burin,70.27±16.91 and 64.37±7.58 respectively in Dheisha, and 81.72±13.11 in 2013 in Asira Al-Shamaliya, and 64.91±4.5 in 2013 in Si'ir, 88.85±13.64 and 96.28±8.23 respectively in Salfit, 84.02±13.75 in 2014 in Al-Shuyukh, 68.67±3.9 and 68.15±8.6 respectively in Surif and 88.52±6.99 in 2014 in Asira Al-Qibliya (Table 4.20).

There are several factors that affect iodine value such as olive fly infection, ripening level and location of olive tree as reported in the paper of (Amarna et al, 2011).

Gharbi et al, (2015) found that the rate of polyunsaturated fatty acid synthesis are affected by the ripeness of the pressed olives.

Differences in our iodine value results can not be explained according to the difference in locations alone.

Table 4.20: Average iodine test values (g Iodine/100 g oil) for different geographical regions in Palestine according to region and year; results are expressed as average ± SD.

Region	Year	
	2013	**2014**
Anabta	95.63±9.76	76.91±5.66
Bayt Jala	83.54±8.57	87±5.7
Burkin	84.68±15.17	92.45±11.92
Burin		65.64±0
Dheisha	70.27±16.91	64.37±7.58
Asira Al-Shamaliya	81.72±13.11	
Si'ir	64.91±4.5	
Salfit	88.85±13.64	96.28±8.23
Al-Shuyukh		84.02±13.75
Surif	68.67±3.9	68.15±8.6
Asira Al-Qibliya		88.52±6.99

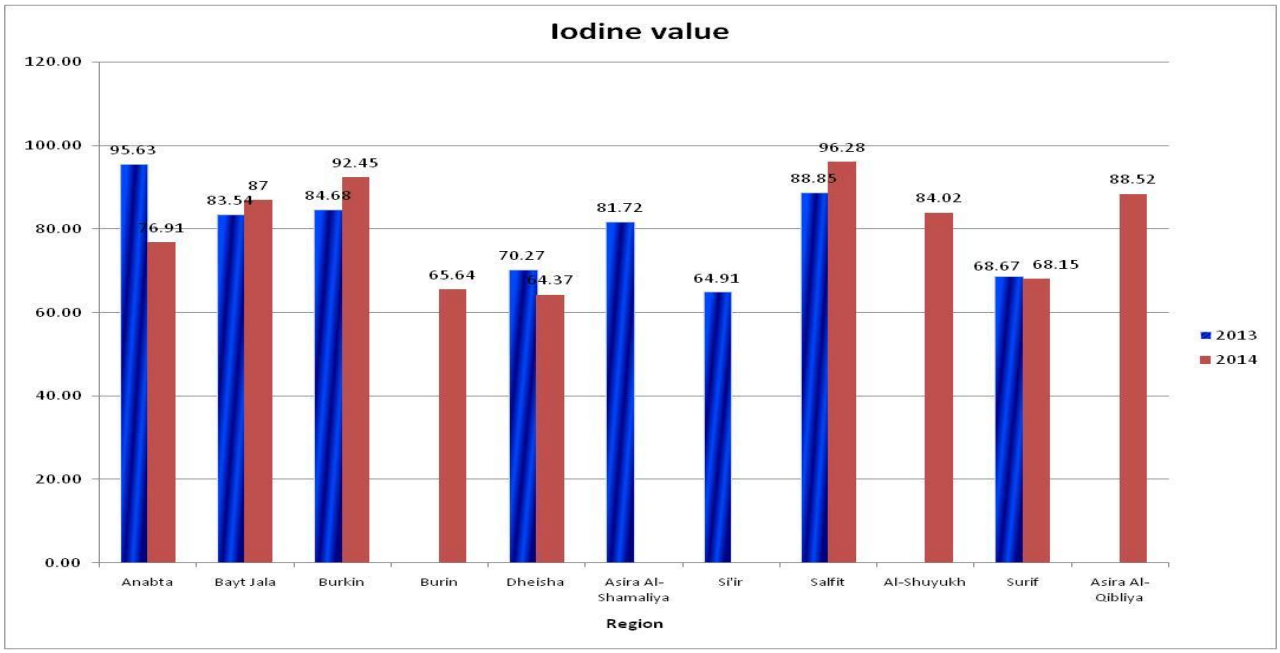


Figure 4.20: Average iodine values (g Iodine/100 g oil) according to region and year.

4.3.8. Acidity% Values in different geographical regions

In 2013, the highest Acidity% value (1.44) was in Burkin and the lowest Acidity% value (1.03) was in Dheisha. On the other hand, in 2014, the highest Acidity% value (1.7) was in Burin and the lowest Acidity% value (0.98) was in Dheisha (Table 4.21).

The Acidity% values (% as oleic acid) of olive oil samples were 1.35±0.48 and 1.56±0.12 respectively in 2013 and 2014 in Anabta, 1.35±0.14 and 1.24±0.35 respectively in Bayt Jala, 1.44±0.32 and 1.35±0.12 respectively in Burkin,1.7±0 in 2014 in Burin,1.03±0.41 and 0.98±0.11 respectively in Dheisha, and 1.28±0.34 in 2013 in Asira Al-Shamaliya, and 1.06±0.43 in 2013 in Si'ir, 1.26±0.3 and 1.34±0.38 respectively in Salfit, 1.11±0.45 in 2014 in Al-Shuyukh, 1.14±0.28 and 1.06±0.28 respectively in Surif and 1.39±0.34 in 2014 in Asira Al-Qibliya (Table 4.21).

According to (Figure 4.21) it was observed that the highest Acidity% value in 2013 was in Burkin and the lowest Acidity% value in 2013 was in Dheisha, while the highest Acidity% value in 2014 was in Burin but the lowest Acidity% value in 2014 was in Dheisha.

According to IOOC (2015), it can be observed that all our acidity results in both 2013 and 2014 categorized our oil samples as virgin olive oil.

Mansouri et al, (2013) stated that factors causing damage to the olive fruits affect acidity of olive oil, while (Salvador et al., 2001) considered that ripening stages affect acidity.

Tamendjari, et al. (2009) found that olive oils obtained from infested olives had higher acidity values than non infested olives.

Méndez & Falqué (2002) found that during olive oil storage, acidity increased slightly in almost all oils tested and showed that the lowest degree of acidity was obtained with hand harvested olives and the highest level was obtained with olives fallen into the ground.

If the olives are healthy and processed soon after harvesting (within 24 hr), environmental conditions do not appear to have any substantial influence on the free acidity of the oil, which allow the classification of the oils as EVOOs (Pannelli et al. 1990a; Ripa et al. 2008).
It was not be able to explain the results due to the difference among regions.
Differences in our Acidity% values results can not be explained according to the difference in locations alone.

Table 4.21-a: Average acidity% values (% as oleic acid) for different geographical regions in Palestine according to region and year; results are expressed as average ± SD.

Region	**Year**	
	2013	**2014**
Anabta	1.35±0.48	1.56±0.12
Bayt Jala	1.35±0.14	1.24±0.35
Burkin	1.44±0.32	1.35±0.12

Table 4.21-b: Average acidity% values (% as oleic acid) for different geographical regions in Palestine according to region and year; results are expressed as average ± SD.

Burin		1.7±0
Dheisha	1.03±0.41	0.98±0.11
Asira Al-Shamaliya	1.28±0.34	
Si'ir	1.06±0.43	
Salfit	1.26±0.3	1.34±0.38
Al-Shuyukh		1.11±0.45
Surif	1.14±0.28	1.06±0.28
Asira Al-Qibliya		1.39±0.34

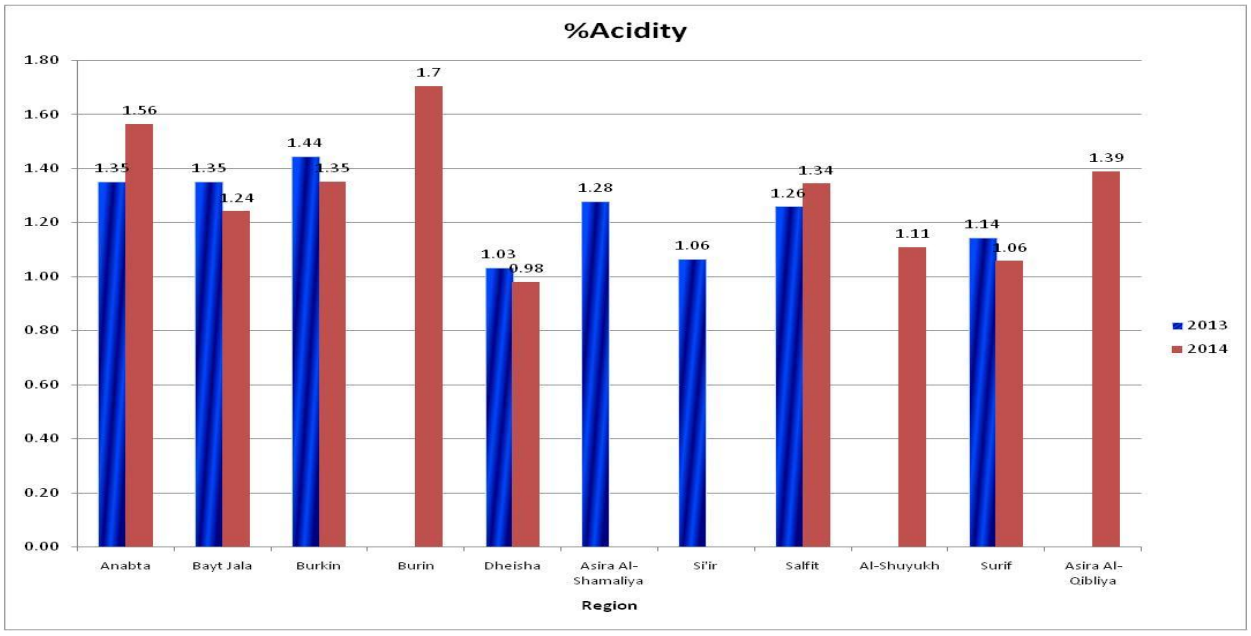


Figure 4.21: Average acidity% values (% as oleic acid) according to region and year.

4.3.9. Peroxide values in different geographical regions

In 2013, the highest peroxide value (17.76) was in Asira Al-Shamaliya and the lowest peroxide value (15.58) was in Anabta. On the other hand, in 2014, the highest peroxide value (17.45) was in Burin and the lowest peroxide value (16.71) was in Dheisha (Table 4.22).

The peroxide values (milliequivalents O_2 kg^{-1} oil) of olive oil samples were 15.58±0.28 and 16.81±0.61 respectively in 2013 and 2014 in Anabta, 17.28±0.52 and 16.85±1.21 respectively in Bayt Jala, 17.38±1.27 and 16.75±1.93 respectively in Burkin,17.45±0 in 2014 in Burin,16.23±1 and 16.71±0.81 respectively in Dheisha, and 17.76±0.48 in 2013 in Asira Al-Shamaliya, and 16.23±0.7 in 2013 in Si'ir, 16.81±1.14 and 17.08±0.14 respectively in Salfit, 17.19±0.9 in 2014 in Al-Shuyukh, 16.94±1.37 and 17.35±1.16 respectively in Surif and 16.91±0.51 in 2014 in Asira Al-Qibliya (Table 4.22).

According to (Figure 4.22) it was observed that the highest peroxide value in 2013 was in Asira Al-Shamaliya and the lowest peroxide value in 2013 was in Anabta, while the highest peroxide values in 2014 were in Burin and Surif.

Depending on IOOC (2015), all oil samples in both 2013 and 2014 are within EVOO and VOO.

According to Mansouri et al (2013) there are many factors affecting peroxide values of olive oil such as factors causing damage to the olive fruits, while it is not affected by cultivar.

Storage time affects also peroxide value, where peroxide value decreased with storage time and then after 6 months of storage the peroxide value started to increase with storage time (Méndez & Falqué, 2002).
Fly-infected olives were found to increase the value of peroxide (Tamendjari et al, 2009).
If the olives are healthy and processed soon after harvesting (within 24 hr), environmental conditions do not appear to have any substantial influence on the peroxide number of the oil, which allow the classification of the oils as EVOOs (Pannelli et al, 1990; Ripa et al, 2008).

Table 4.22: Average peroxide test values (milliequivalents O_2 kg^{-1} oil) for different geographical regions in Palestine according to region and year; results are expressed as average ± SD.

Region	Year	
	2013	**2014**
Anabta	15.58±0.28	16.81±0.61
Bayt Jala	17.28±0.52	16.85±1.21
Burkin	17.38±1.27	16.75±1.93
Burin		17.45±0
Dheisha	16.23±1	16.71±0.81
Asira Al-Shamaliya	17.76±0.48	
Si'ir	16.23±0.7	
Salfit	16.81±1.14	17.08±0.14
Al-Shuyukh		17.19±0.9
Surif	16.94±1.37	17.35±1.16
Asira Al-Qibliya		16.91±0.51

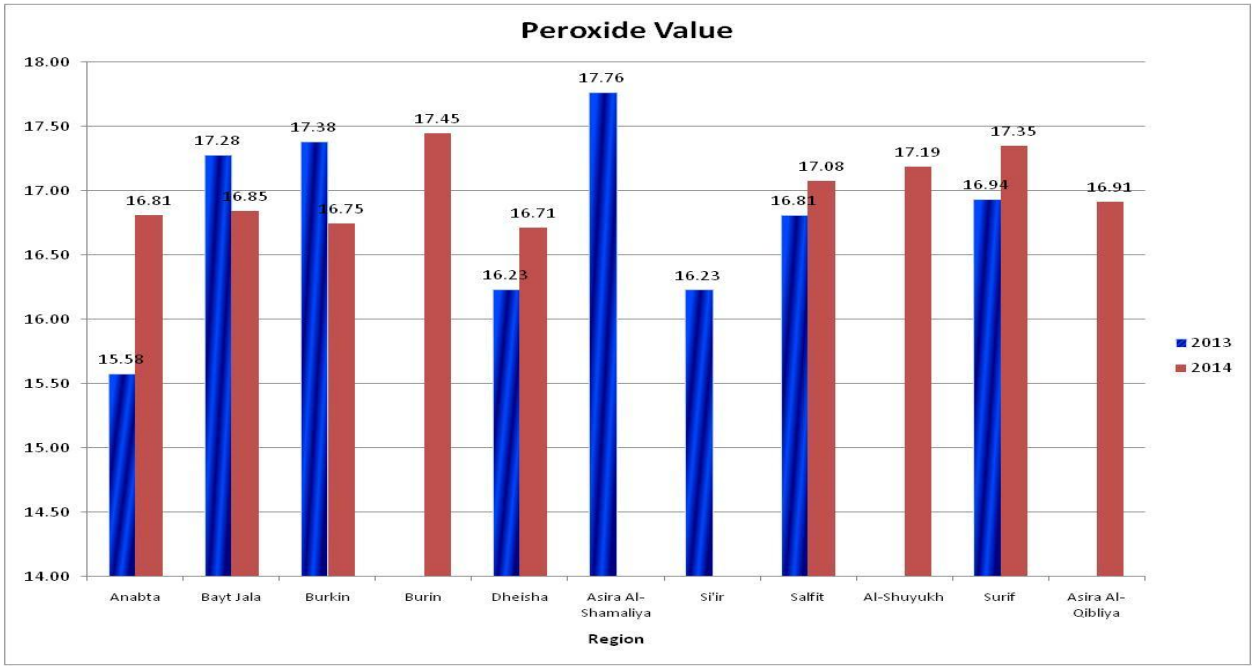


Figure 4.22: Average peroxide values (milliequivalents O_2 kg^{-1} oil) according to region and year.

4.3.10. Specific gravity values in different geographical regions

In 2013, the highest oil specific gravity value (0.9173) was in Bayt Jala and the lowest oil specific gravity value (0.9102) was in Salfit. On the other hand, in 2014, the highest oil specific gravity value (0.9175) was in Burin and the lowest oil specific gravity value (0.9106) was in Asira Al-Qibliya (Table 4.23).

The specific gravity values (dimensionless quantity) of olive oil samples were 0.9161±0.0016 and 0.9118±0.0006 respectively in 2013 and 2014 in Anabta, 0.9173±0.0024 and 0.9107±0.0015 respectively in Bayt Jala, 0.9126±0.004 and 0.9136±0.0052 respectively in Burkin, 0.9175±0 in 2014 in Burin, 0.9112±0.0031 and 0.9114±0.0018 respectively in Dheisha, and 0.9129±0.0023 in 2013 in Asira Al-Shamaliya, and 0.9162±0.0038 in 2013 in Si'ir, 0.9102±0.0052 and 0.9155±0.0036 respectively in Salfit, 0.9142±0.0036 in 2014 in Al-Shuyukh, 0.9121±0.0037 and 0.914±0.0029 respectively in Surif and 0.9106±0.0031 in 2014 in Asira Al-Qibliya (Table 4.23).

Specific gravity varies with temperature and pressure; reference and sample must be compared at the same temperature and pressure, and since most important factor here is temperature it

must be taken precisely. There were no significant differences in specific gravity values since the density values of oil samples were so close to each other. It was not easy to explain the slight differences in specific gravity values between regions.

Table 4.23: Average oil specific gravity values (dimensionless quantity) for different geographical regions in Palestine according to region and year; results are expressed as average ± SD.

Region	Year	
	2013	**2014**
Anabta	0.9161±0.0016	0.9118±0.0006
Bayt Jala	0.9173±0.0024	0.9107±0.0015
Burkin	0.9126±0.004	0.9136±0.0052
Burin		0.9175±0
Dheisha	0.9112±0.0031	0.9114±0.0018
Asira Al-Shamaliya	0.9129±0.0023	
Si'ir	0.9162±0.0038	
Salfit	0.9102±0.0052	0.9155±0.0036
Al-Shuyukh		0.9142±0.0036
Surif	0.9121±0.0037	0.914±0.0029
Asira Al-Qibliya		0.9106±0.0031

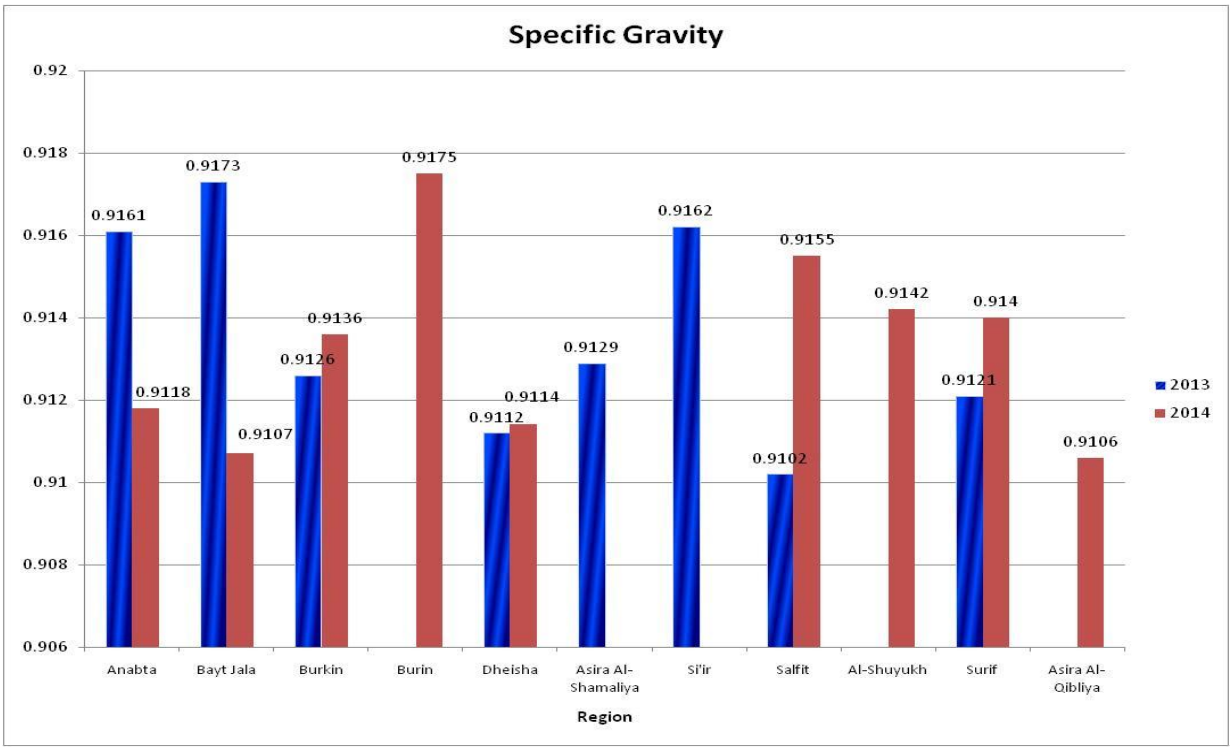


Figure 4.23: Average oil specific gravity values (dimensionless quantity) according to region and year.

4.3.11. Refractive index values in different geographical regions

In 2013, the highest refractive index value (1.4659) was in Si'ir and the lowest refractive value (1.4647) was in Burkin. On the other hand, in 2014, the highest refractive value (1.4667) was in Burin and the lowest refractive value (1.4652) was in Burkin (Table 4.24).

The refractive index values (dimensionless quantity) of olive oil samples were 1.4652±0.0007 and 1.4657±0 respectively in 2013 and 2014 in Anabta, 1.4657±0 and 1.4654±0.0006 respectively in Bayt Jala, 1.4647±0 and 1.4652±0.0007 respectively in Burkin, 1.4667±0 in 2014 in Burin, 1.4655±0.0004 and 1.4654±0.0006 respectively in Dheisha, and 1.4652±0.0006 in 2013 in Asira Al-Shamaliya, and 1.4659±0.0005 in 2013 in Si'ir, 1.4654±0.0005 and 1.4657±0 respectively in Salfit, 1.4657±0.0006 in 2014 in Al-Shuyukh, 1.4654±0.0006 and 1.4655±0.0005 respectively in Surif and 1.4659±0.0008 in 2014 in Asira Al-Qibliya (Table 4.24).

All refractive index values in both 2013 and 2014 were so close.

It was found that there were a relation between high refractive index values and olive fly infection (Amarna et al, 2011). Differences in our refractive index value results can not be explained according to the difference in locations.

Table 4.24: Average refractive index values (dimensionless quantity) for different geographical regions in Palestine according to region and year; results are expressed as average ± SD.

Region	**Year**	
	2013	**2014**
Anabta	1.4652±0.0007	1.4657±0
Bayt Jala	1.4657±0	1.4654±0.0006
Burkin	1.4647±0	1.4652±0.0007
Burin		1.4667±0
Dheisha	1.4655±0.0004	1.4654±0.0006
Asira Al-Shamaliya	1.4652±0.0006	
Si'ir	1.4659±0.0005	
Salfit	1.4654±0.0005	1.4657±0
Al-Shuyukh		1.4657±0.0006
Surif	1.4654±0.0006	1.4655±0.0005
Asira Al-Qibliya		1.4659±0.0008

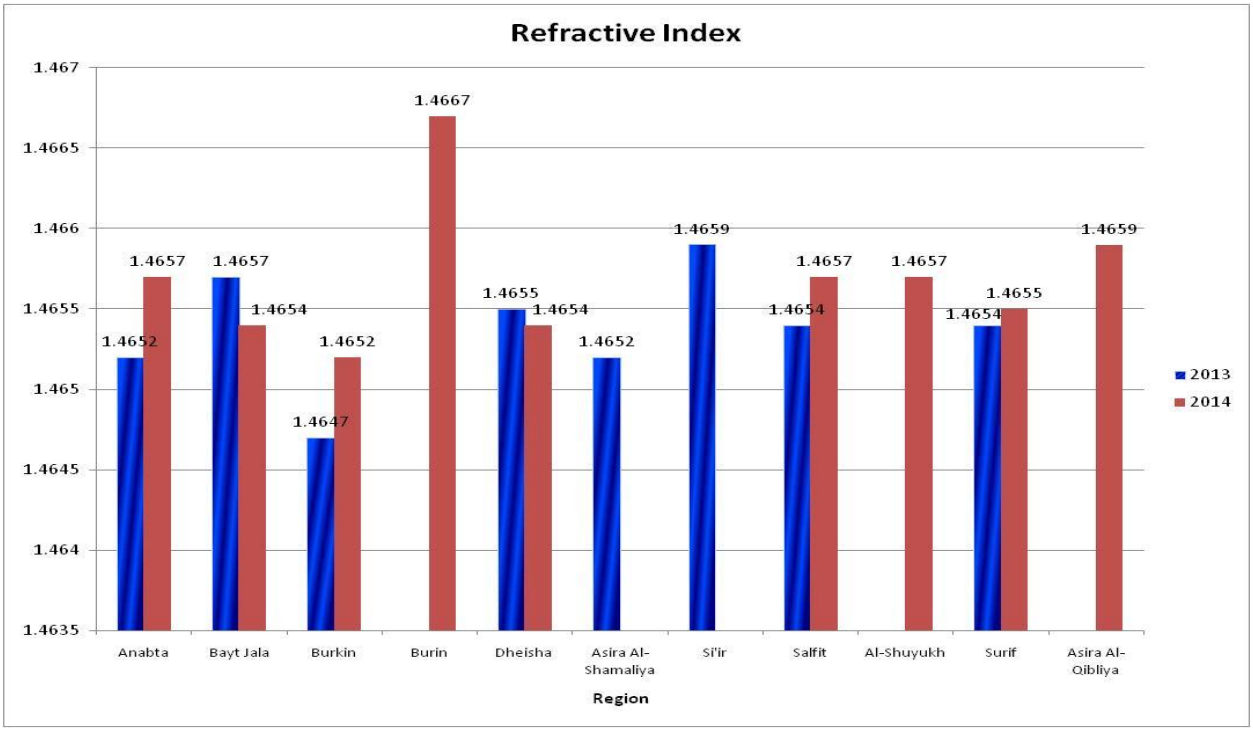


Figure 4.24: Average refractive index values (dimensionless quantity) according to region and year.

4.3.12. K_{270} values in different geographical regions

In 2013, the highest K_{270} value (0.2356) was in Asira Al-Shamaliya and the lowest K_{270} value (0.2238) was in Si'ir. On the other hand, in 2014, the highest K_{270} value (0.2344) was in Surif and the lowest K_{270} value (0.2135) was in Salfit (Table 4.25) and (Figure 4.25).

The K_{270} values ($K_{1\%}$/1cm) of olive oil samples were 0.2315±0.0054 and 0.2312±0.012 respectively in 2013 and 2014 in Anabta, 0.23±0.0052 and 0.2188±0.0077 respectively in Bayt Jala, 0.2274±0.0064 and 0.2152±0.0007 respectively in Burkin, 0.2307±0 in 2014 in Burin, 0.23±0.0116 and 0.2172±0.0037 respectively in Dheisha, and 0.2356±0.0095 in 2013 in Asira Al-Shamaliya, and 0.2238±0.0145 in 2013 in Si'ir, 0.2256±0.014 and 0.2135±0.0012 respectively in Salfit, 0.2163±0.0029 in 2014 in Al-Shuyukh, 0.2283±0.0149 and 0.2344±0.0111 respectively in Surif and 0.2193±0.0051 in 2014 in Asira Al-Qibliya (Table 4.25).

In 2013, all oil samples were in the VOO category, while in 2014, all the oil samples were in the VOO category also, while those from Bayt Jala, Burkin, Dheisha, Salfit, Al-Shuyukh and Asira Al-Qibliya were in the EVOO category according to IOOC (2015).

K_{270} as one of the quality indices is affected by variety and factors causing damage to the olive fruits (Mansouri et al, 2013).

If the olives are healthy and processed soon after harvesting (within 24 hr), environmental conditions do not appear to have any substantial influence on the UV absorbencies of the oil, which allow the classification of the oils as EVOOs (Pannelli et al. 1990a; Ripa et al. 2008).

Table 4.25: Average K_{270} values ($K_{1\%}$/1cm) for different geographical regions in Palestine according to region and year; results are expressed as average ± SD.

Region	Year	
	2013	2014
Anabta	0.2315±0.0054	0.2312±0.012
Bayt Jala	0.23±0.0052	0.2188±0.0077
Burkin	0.2274±0.0064	0.2152±0.0007
Burin		0.2307±0
Dheisha	0.23±0.0116	0.2172±0.0037
Asira Al-Shamaliya	0.2356±0.0095	
Si'ir	0.2238±0.0145	
Salfit	0.2256±0.014	0.2135±0.0012
Al-Shuyukh		0.2163±0.0029
Surif	0.2283±0.0149	0.2344±0.0111
Asira Al-Qibliya		0.2193±0.0051

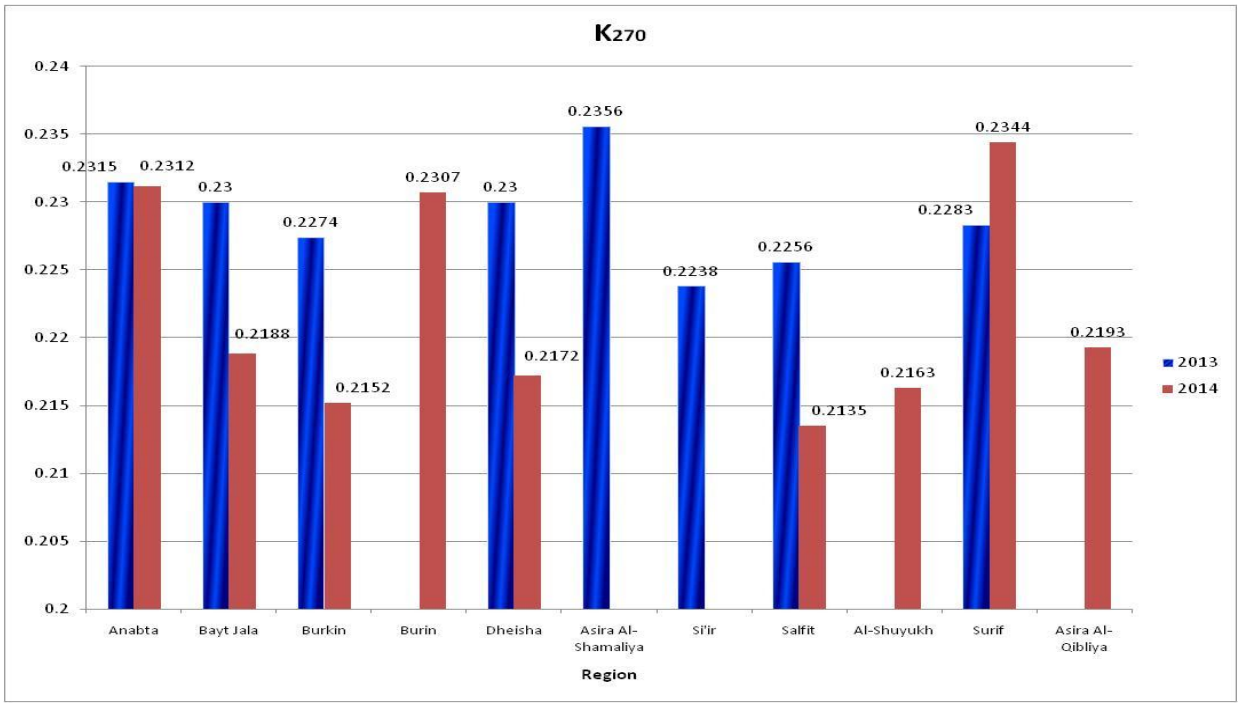


Figure 4.25: Average K_{270} Values ($K_{1\%}$/1cm) according to region and year.

4.3.13. K_{232} values in different geographical regions

In 2013, the highest K_{232} value (1.67) was both in Dheisha and Surif, while the lowest K_{232} value (1.56) was in Burkin. On the other hand, in 2014, the highest K_{232} value (1.6) was both in Surif and Burin, while the lowest K_{232} value (1.45) was in Salfit.

The K_{232} values ($K_{1\%}$/1cm) of olive oil samples were 1.65±0.02 and 1.58±0.01 respectively in 2013 and 2014 in Anabta, 1.63±0.01 and 1.48±0.02 respectively in Bayt Jala, 1.56±0.05 and 1.53±0.13 respectively in Burkin,1.6±0 in 2014 in Burin,1.67±0.02 and 1.48±0.02 respectively in Dheisha, and 1.65±0.02 in 2013 in Asira Al-Shamaliya, and 1.62±0.07 in 2013 in Si'ir, 1.57±0.09 and 1.45±0.01 respectively in Salfit, 1.51±0.08 in 2014 in Al-Shuyukh, 1.67±0.02 and 1.6±0.04 respectively in Surif and 1.48±0.05 in 2014 in Asira Al-Qibliya (Table 4.26).

In both 2013 and 2014 all olive oil samples were in the EVOO category according to IOOC (2015). K_{232} as one of the quality indices that is affected by variety of factors causing damage to the olive fruits (Mansouri et al, 2013) and is affected with olives storage conditions (Gharbi et al, 2015). If the olives are healthy and processed soon after harvesting (within 24 hr), environmental conditions do not appear to have any substantial influence on UV absorbencies

of the oil, which are normally within the values that allow the classification of the oils as EVOOs (Pannelli et al. 1990a; Ripa et al. 2008).

Table 4.26: Average K_{232} values ($K_{1\%}$/1cm) for different geographical regions in Palestine according to region and year; results are expressed as average ± SD.

Region	Year	
	2013	**2014**
Anabta	1.65±0.02	1.58±0.01
Bayt Jala	1.63±0.01	1.48±0.02
Burkin	1.56±0.05	1.53±0.13
Burin		1.6±0
Dheisha	1.67±0.02	1.48±0.02
Asira Al-Shamaliya	1.65±0.02	
Si'ir	1.62±0.07	
Salfit	1.57±0.09	1.45±0.01
Al-Shuyukh		1.51±0.08
Surif	1.67±0.02	1.6±0.04
Asira Al-Qibliya		1.48±0.05

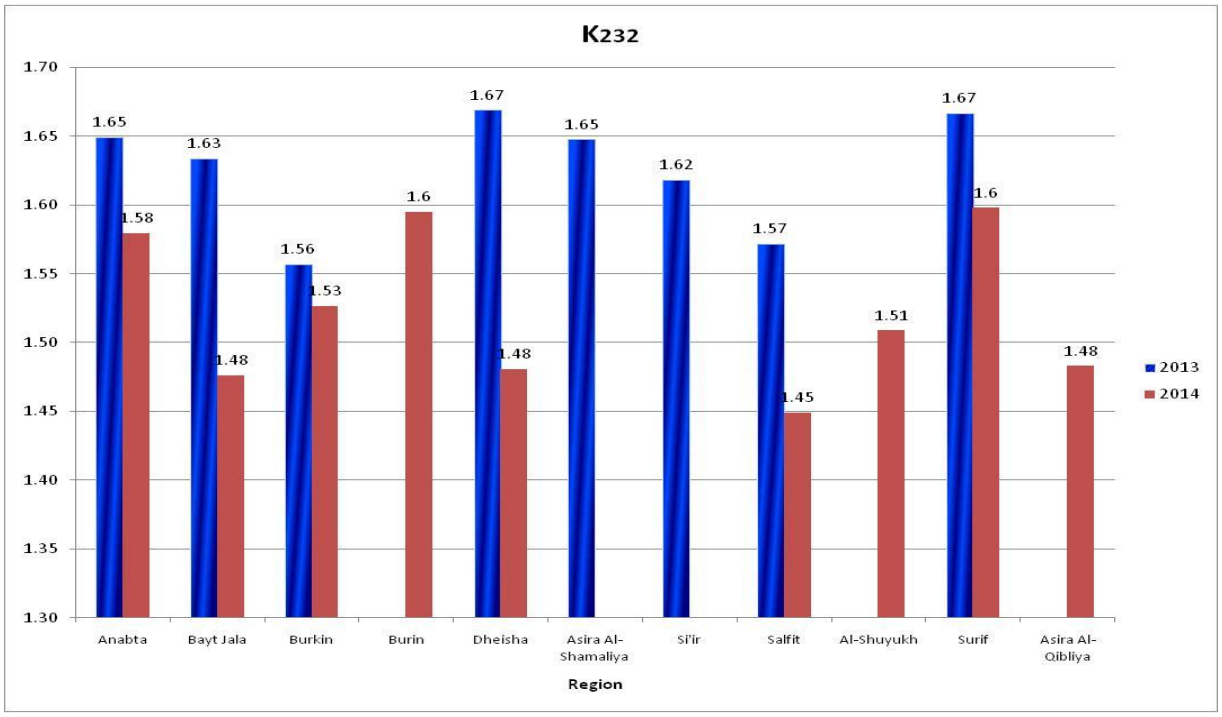


Figure 4.26: Average K_{232} values ($K_{1\%}$/1cm) according to region and year.

4.4. Variations of the studied parameters (TPC, TFC, FRAP, CUPRAC, ABTS, DPPH, Acidity%, peroxide value, K_{232}, K_{270}, iodine value, specific gravity and refractive index) among regions

According to ANOVA test analysis and the Tukey HSD post hoc pair wise tests, the conclusions about regions are as the following:

In 2013, there were significant differences at (α=0.05) between regions whereas: Si'ir has refractive higher than Burkin. Salfit has DPPH higher than both Surif and Si'ir. Surif has ABTS higher than Asira Al-Shamaliya. Dheisha has TFC higher than Asira Al-Shamaliya, and Surif has TFC higher than Asira Al-Shamaliya also.

In 2014, there were significant differences at (α=0.05) between regions whereas: Surif has K_{270} higher than each one of Burkin, Salfit, Asira Al-Qibliya, Dheisha, and Al-Shuyukh. Both Salfit and Asira Al-Qibliya have Iodine values higher than both Dheisha and Surif. Each one of Dheisha, Surif and Al-Shuyukh have ABTS higher than Asira Al-Qibliya. Burkin has FRAP higher than each one of Bayt Jala, Surif and Al-Shuyukh. Anabta has TFC higher than Salfit and Surif has TFC higher than each one of Salfit, Asira Al-Qibliya and Bayt Jala.

4.5. Assays results for farmers

Olive oil samples from sixty farmers were collected in 2013 and 2014 freshly during milling their olive fruits from different geographical areas in the West Bank: Jenin (Burkin), Tulkarm (Anabta), Nablus (Salfeet, North Asera, Burin and South Asera), Bethlehem (Bayt Jala and Dheisha) and Hebron (Sourif, Si'ir and Alshuokh).The samples were taken in late October 2013 and late October 2014 in similar conditions.

The samples were analyzed for their total phenolic contents, total flavonoids content, their antioxidant activity (FRAP, CUPRAC, ABTS and DPPH), Acidity%, peroxide value, iodine value, specific gravity, K_{232}, K_{270} and refractive index.

4.5.1. Average TPC Values according to region, farmer code and year

The amounts of total phenols show significant differences among the different farmers in both 2013 and 2014.

In 2013 it was observed that in Anabta there were two farmers and their oil contains TPC values were 777 and 615.7 respectively, in Bayt Jala there were two farmers and their TPC values were 219.3 and 355.7 respectively, in Burkin there were four farmers and their TPC values were 439.3, 728, 597.7 and 590.7 respectively, in Dheisha there were five farmers and their TPC values were 705.3**,** 517.3**,** 817.7**,** 730 and 1050 respectively and in Asira Al-Shamaliya there were four farmers and their TPC values were 259.7, 166.3, 134 and 176.7 respectively, in Si'ir there were four farmers and their TPC values were 324, 782, 957 and 441.3 respectively, in Salfit there were six farmers and their TPC values were 1229, 1134, 477, 480, 179.7 and 383.3 respectively and in Surif there were three farmers and their TPC values were 794.3, 1252 and 506 respectively (Table 4.27).

In 2014 it was observed that in Anabta there were two farmers and their TPC values were 577.7 and 359.7 respectively, in Bayt Jala there were three farmers and their TPC values were 204, 459 and 157.3 respectively, in Burkin there were two farmers and their TPC values were 560 and 652.7 respectively, in Burin there was one farmer and his TPC value was 379.3, in Dheisha there were three farmers and their TPC values were 559, 312 and 473.3 respectively, in Salfit there were two farmers and their TPC values were 374.3 and 385.3 respectively, in Al-Shuyukh there were six farmers and their TPC values were 577, 352, 563, 611.7, 672 and

678 respectively, in Surif there were five farmers and their TPC values were 553, 478.3, 358.7, 627 and 1144 respectively and in Asira Al-Qibliya there were six farmers and their TPC values were 140.7, 319.3, 202.7, 573.3, 761.7 and 517 respectively (Table 4.27).

Dağdelen (2016) reported that total phenolic of Edincik Su olive cultivar was found between 159.99 and 189.64 mg gallic acid equivalent/kg, and that was in agreement with our TPC values, while Houshia et al (2014) reported that the total concentration of polyphenol in some samples of Palestinian olive oil from Jerusalem, Tulkarem and Jenin ranges from 150 to 300 mg/kg which are in general lower than our results except Asira Al-Shamaliya particularly TPC results were in agreement and some results for all farmers in Asira Al-Qibliya in both years 2013 and 2014 and for some farmers in Bayt Jala in both years too.

However, it is possible to find ranges significantly different in the literature, as in the work of Sánchez et al (2007) and Ballus et al (2015) who reported that total phenolic contents range between 1085 and 1406 mg GAE kg^{-1} were found for 39 samples of Picual EVOO in Spain and that was in agreement with some of our results like 1229, 1134 in Salfit in 2013 and 1144 in Surif in 2014.

Statistical analysis showed that olive fruit percentage yield (olive fruit percentage yield in comparison with the highest years yield) has a positive significant correlation with total phenolics content in 2014 since the correlation coefficient was equal to (0.449) ($p < 0.05$) and since the yield percentage of our samples were from 10% to 100%, and some of our samples were from green olives, others from black and most of them were mixture between green and black in different proportions, therefore that may have affected the results since Tetik (2005) stated that green table cultivars should be harvested at green maturity whereas black table cultivars should be harvested at black maturity while Kaynas et al (2002) reported that green maturity started at the end of September or the beginning of october in the Marmara region and the latest green maturity cultivars were 'Domat' and 'Manzanilla de Sevilla', while black maturity begins in the last week of November and Toplu et al (2009) was in agreement with the same results and stated that there were some fluctuations in yield between growing seasons and reported that result may be explained as being the result of the application of good cultural practice, while Leitao (1990) in Portugal and Rio D. & Caballero (1994) and Tous et al (2002)

in Spain, reported that there were significant differences between cultivars in productivity and that ecological factors also had significant impacts on yield.

Mailer et al (2005) and Kalogeropoulos & Tsimidou (2014) reported that TPC increased progressively as olives matured and decreased in the final ripening stage,while El Sohaimy et al (2016) emphasized the previous and in addition reported that the higher the moisture content in olive fruit is the less polyphenols levels are, but Servili et al (2004) showed that some factors affect the TPC of olive oil between which cultivar, climate and other environmental factors, harvesting time, the extraction process, the conditions of packing, distribution, and storage and Baiano et al (2014) reported that there a strong positive linear correlation was observed between the phenolic content and antioxidant activity measured according to the ABTS+ to indicate a noticeable radical scavenging ability of phenolic compounds.

Pearson correlations were done between some agronomic and olive fruits treatments (k_{232}, k_{270}, RI, Specific gravity, Peroxide value, Acidity%, Iodine value, DPPH, ABTS, CUPRAC, FRAP, TFC, TPC) with studied quality indices (olive fly infection, days of storage, green to black %, oil %, drop % and olive yield %) obtained from farmers and oil tests in 2013 and 2014.

A close look at the results in 2013 reveals that the degree of olive fruit infection with olive fly, days of storage before pressing, drop percentage and yield percentage were not significantly correlated with any of the studied olive oil quality parameters.

Olive fly infection and olive fruit percentage yield were positively correlated with TPC but the correlation was statistically not significant since pearson coefficient for olive fly infection (0.147) and pearson coefficient for olive fruit percentage yield (0.282).

Days of storage, oil percentage and dropped olive percentage were negatively correlated with TPC but the correlation was statistically not significant since pearson coefficient for Days of storage (-0.216), pearson coefficient for oil percentage (-0.0368) and pearson coefficient for dropped olive percentage (-0.009).

Only green to black olive ratio has a negative significant correlation with total phenolics content since the correlation coefficient was equal to (-0.4337) ($p < 0.05$) and that was in agreement with (Gharbi et al, 2015) who stated that oil obtained from green olives is less rich in phenolic compounds which have antioxidant properties (Table 4.40).

While a close look at the results in 2014 reveals that the degree of olive fruit infection with olive fly, days of storage before pressing and drop percentage were not significantly correlated with any of the studied olive oil quality parameters.

Olive fly infection and days of storage were positively correlated with TPC but the correlation was statistically not significant since pearson coefficient for olive fly infection (0.116) and pearson coefficient for days of storage (0.158).

Green to black olive ratio, oil percentage and dropped olive percentage were negatively correlated with TPC but the correlation was statistically not significant since pearson coefficient for green to black olive ratio (-0.068), pearson coefficient for oil percentage (-0.102) and pearson coefficient for dropped olive percentage (-0.202).

Only olive fruit percentage yield has a positive significant correlation with total phenolics content since the correlation coefficient was equal to (0.449) ($p < 0.05$) (Table 4.41).

Table4.27: Average TPC values (mg gallic acid/Kg of oil) in different regions in Palestine according to region, farmer code and year; results are expressed as average only since farmers in 2013 in the same region are not themselves in 2014 in the same region.

2013			2014		
Region and significant symbols	**Farmer Code**	**TPC**	**Region and significant symbols**	**Farmer Code**	**TPC**
Anabta: **D**	1	777	Anabta**: C,D,E,F**	1	577.7
E,F,G	2	615.7	**I,J,K**	2	359.7
Bayt Jala**: N,O**	1	219.3	Bayt Jala**:L,M,N**	1	204
K,L,M	2	355.7	**G,H,I,J**	2	459
Burkin**: I,J,K,L**	1	439.3	**N**	3	157.3
D,E	2	728	Burkin**: D,E,F,G**	1	560
E,F,G,H	3	597.7	**B,C,D,E**	2	652.7
F,G,H	4	590.7	Burin**: H,I,J,K**	1	379.3
Dheisha**: D,E,F**	1	705.3	Dheisha**: D,E,F,G**	1	559
G,H,I	2	517.3	**K,L,M**	2	312

D	3	817.7
D,E	4	730
B,C	5	1050
Asira Al Shamaliya **M,N,O**	1	259.7
O	2	166.3
O	3	134
O	4	176.7
Si'ir: **L,M,N**	1	324
D	2	782
C	3	957
I,J,K,L	4	441.3
Salfit**: A**	1	1229
A,B	2	1134

F,G,H,I	3	473.3
Salfit**:H,I,J,K**	1	374.3
H,I,J,K	2	385.3
Al-Shuyukh**:** **C,D,E,F**	1	577
J,K	2	352
C,D,E,F,G	3	563
C,D,E	4	611.7
B,C,D	5	672
B,C	6	678
Surif**: E,F,G**	1	553
F,G,H	2	478.3
I,J,K	3	358.7
C,D,E	4	627

H,I,J,K	3	477
H,I,J,K	4	480
O	5	179.7
J,K,L,M	6	383.3
Surif**: D**	1	794.3
A	2	1252
G,H,I,J	3	506

A	5	1144
Asira Al-Qibliya: **N**	1	140.7
K,L	2	319.3
M,N	3	202.7
C,D,E,F,G	4	573.3
B	5	761.7
B	6	517

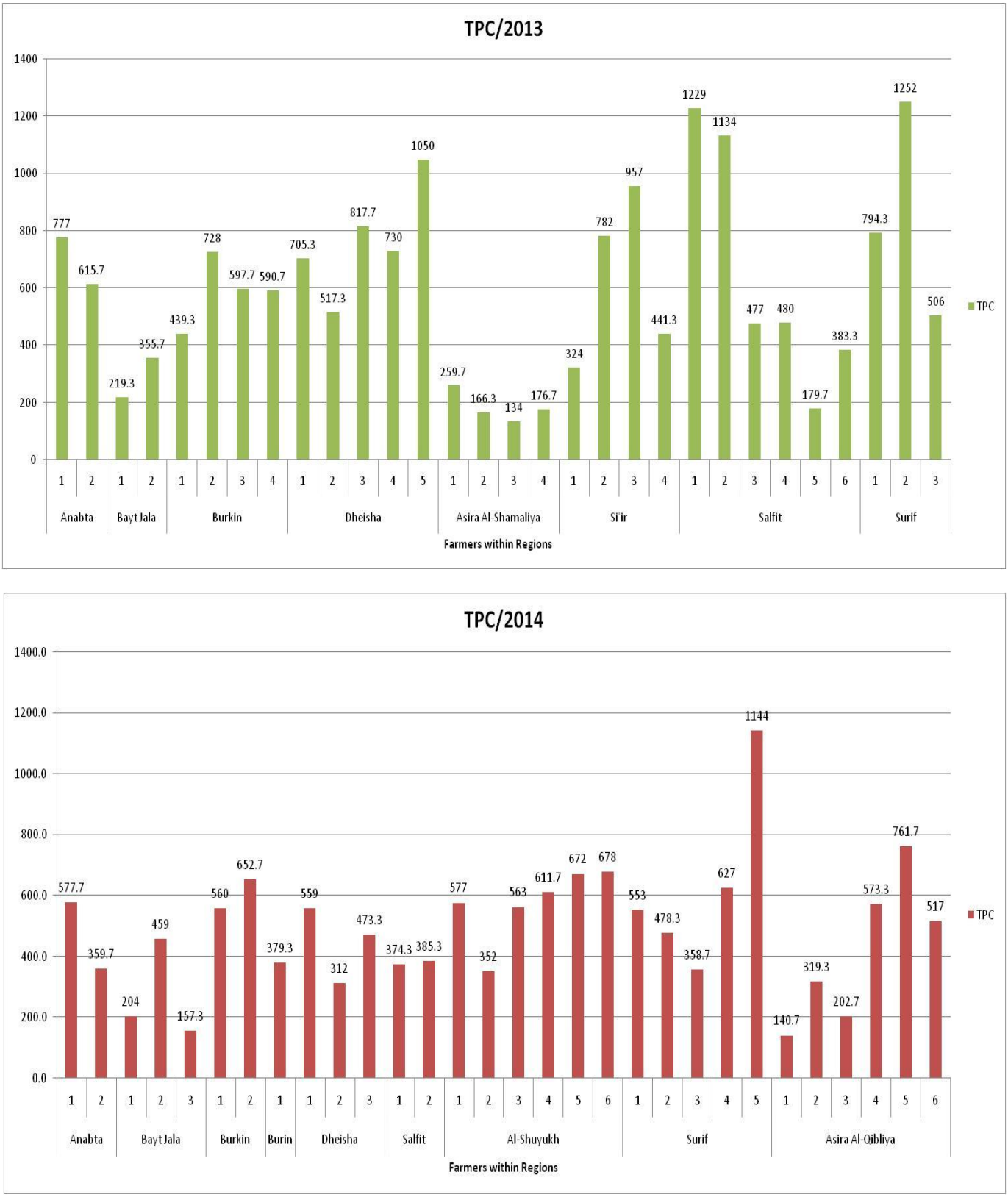


Figure 4.27: Average TPC values (mg gallic acid/Kg of oil) according to region, farmer code and year.

4.5.2. Average TFC values according to region, farmer code and year

In 2013 it was observed that in Anabta there were two farmers and their TFC values were 84.7 and 127.7 respectively, in Bayt Jala there were two farmers and their TFC values were 51 and 49 respectively, in Burkin there were four farmers and their TFC values were 171, 94.7, 94 and 25.7 respectively, in Dheisha there were five farmers and their TFC values were 92.7, 65.7, 140.3, 130.3 and 139.7 respectively and in Asira Al-Shamaliya there were four farmers and their TFC values were 18,13, 9 and 34 respectively, in Si'ir there were four farmers and their TFC values were 49.3, 120.3, 120.7 and 33 respectively, in Salfit there were six farmers and their TFC values were 114.3, 132.7, 33.7, 59, 25.3 and 24.3 respectively and in Surif there were three farmers and their TFC values were 100, 189 and 98 respectively (Table 4.28).

In 2014 it was observed that in Anabta there were two farmers and their TFC values were 121 and 110.7 respectively, in Bayt Jala there were three farmers and their TFC values were 78.3, 56.7 and 53.7 respectively, in Burkin there were two farmers and their TFC values were 70.3 and100.7 respectively, in Burin there was one farmer and his TFC value was122, in Dheisha there were three farmers and their TFC values were 80, 64.7 and 84.7 respectively, in Salfit there were two farmers and their TFC values were 24 and 23 respectively, in Al-Shuyukh there were six farmers and their TFC values were 91.3, 84.7, 106, 52, 78.3 and 81.3 respectively, in Surif there were five farmers and their TFC values were 116.7, 95.3, 105.3, 184.7 and116.7 respectively and in Asira Al-Qibliya there were six farmers and their TFC values were 24.7, 61.7, 76.3, 66.3, 123.7 and 80.3 respectively (Table 4.28).

The total flavonoids content values of our study ranged from 9-189 mg catechin/Kg of oil. El Sohaimy et al (2016) reported that the total flavonoids content of extracted oil from Manzanilla variety ranged from 61.62±1.74 to 139.43±1.63 µg catechol/g, while the flavonoids content of Kalamata oil was varied from 56.33±1.93 to 134.60±0.94 µg catechol/g and reported that flavonoids level in early maturation stages was higher than late maturation stages since high levels of total phenolics and flavonoids in the early maturation stages might refer to the accumulation of these compounds in metabolic processes with the maturation developments and in late stages the phenolase enzyme may cause degradation of phenolic compounds and decreasing their concentrations.

Oil percentage (ratio between oil weight and olive fruit weight) has a negative significant correlation with TFC in 2013 and the correlation coefficient was equal to (-0.416) ($p < 0.05$).

The oil percentage of our samples were from 16% to 35% which were in agreement with Toplu et al (2009) who stated that oil content varied significantly between cultivars ranging from 16.7% to 31.2%, while Mailer et al (2005) stated that oil yields ranging from 5% to 30% by weight and reported that low yields have been attributed to a range of reasons such as incorrect variety, immature trees, harvesting too early, high fruit moisture contents and poor extraction efficiency. Salvador et al (2001) and Beltran et al (2004) reported that numerous studies in the mediterranean have shown that during the ripening period, oil percentage increases dramatically during early fruit ripening then slows as full ripeness approaches and declines slightly as fruits become over ripe.

In 2013, olive fly infection, dropped olive percentage and olive fruit percentage yield were positively correlated with TFC but the correlation was statistically not significant since pearson coefficient for olive fly infection (0.093), pearson coefficient for dropped olive percentage (0.009) and pearson coefficient for olive fruit percentage yield (0.044).

Days of storage and green to black olive ratio were negatively correlated with TFC but the correlation was statistically not significant since pearson coefficient for days of storage (-0.169) and pearson coefficient for green to black olive ratio (-0.356).

Only oil percentage has a negative significant correlation with total phenolics content since the correlation coefficient was equal to (-0.416) ($p < 0.05$) (Table 4.40).

While a close look at the results in 2014 revealed that days of storage and olive fruit percentage yield were positively correlated with TFC but the correlation was statistically not significant since pearson coefficient for days of storage (0.246) and pearson coefficient for olive fruit percentage yield (0.209).

Olive fly infection, green to black olive ratio, oil percentage and dropped olive percentage were negatively correlated with TFC but the correlation was statistically not significant since pearson coefficient for olive fly infection (-0.318), pearson coefficient for green to black olive

ratio (-0.227), coefficient for oil percentage (-0.102) and pearson coefficient for dropped olive percentage (-0.24) (Table 4.41).

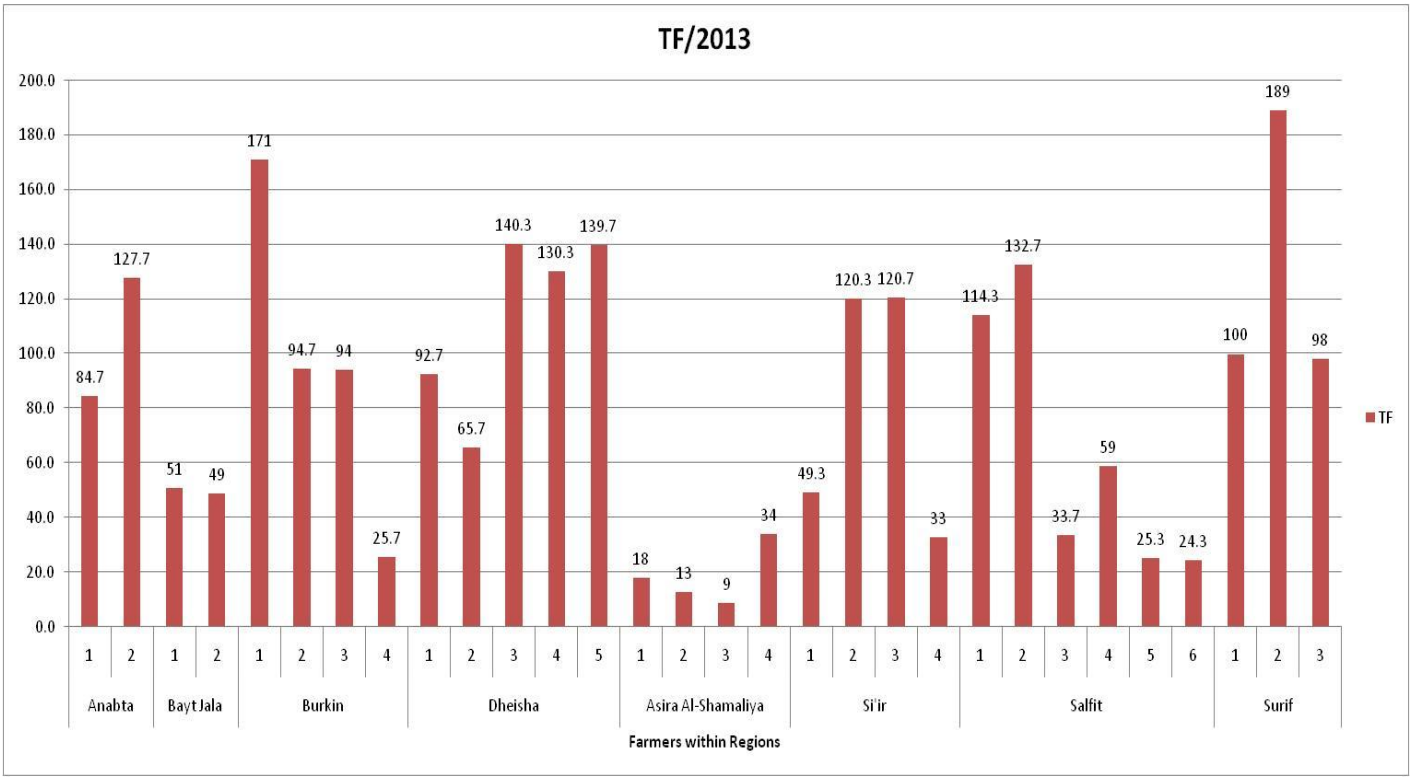
Table 4.28: Average TFC values (mg catechin/Kg of oil) in different regions in Palestine according to region, farmer code and year; results are expressed as average only since farmers in 2013 in the same region are not themselves in 2014 in the same region.

2013			2014		
Region and significant symbols	**Farmer Code**	**TFC**	**Region and significant symbols**	**Farmer Code**	**TFC**
Anabta: E,F,G	1	84.7	Anabta: B,C	1	121
B,C	2	127.7	B,C,D	2	110.7
Bayt Jala: H,I,J	1	51	Bayt Jala: E,F,G,H,I,J	1	78.3
H,I,J	2	49	I,J	2	56.7
Burkin: A	1	171	J,K	3	53.7
D,E,F	2	94.7	Burkin: F,G,H,I,J	1	70.3
D,E,F	3	94	B,C,D,E,F	2	100.7
J,K	4	25.7	Burin: B	1	122
Dheisha:D,E,F	1	92.7	Dheisha: E,F,G,H,I,J	1	80

F,G,H	2	65.7	H,I,J	2	64.7
B	3	140.3	D,E,F,G,H,I	3	84.7
B	4	130.3	Salfit:K,L	1	24
B	5	139.7	L	2	23
Asira Al-Shamaliya: K	1	18	Al-Shuyukh: C,D,E,F,G,H	1	91.3
K	2	13	D,E,F,G,H,I	2	84.7
K	3	9	B,C,D,E	3	106
I,J,K	4	34	J,K,L	4	52
Si'ir: H,I,J	1	49.3	E,F,G,H,I,J	5	78.3
B,C,D	2	120.3	D,E,F,G,H,I,J	6	81.3
B,C,D	3	120.7	Surif: B,C	1	116.7
I,J,K	4	33	B,C,D,E,F,G	2	95.3
Salfit: B,C,D,E	1	114.3	B,C,D,E	3	105.3
B	2	132.7	A	4	184.7

I,J,K	3	33.7
H,I,G	4	59
J,K	5	25.3
J,K	6	24.3
Surif: C,D,E	1	100
A	2	189
C,D,E	3	98

B,C	5	116.7
Asira Al-Qibliya: K,L	1	24.7
H,I,J	2	61.7
E,F,G,H,I,J	3	76.3
G,H,I,J	4	66.3
B	5	123.7
B	6	80.3



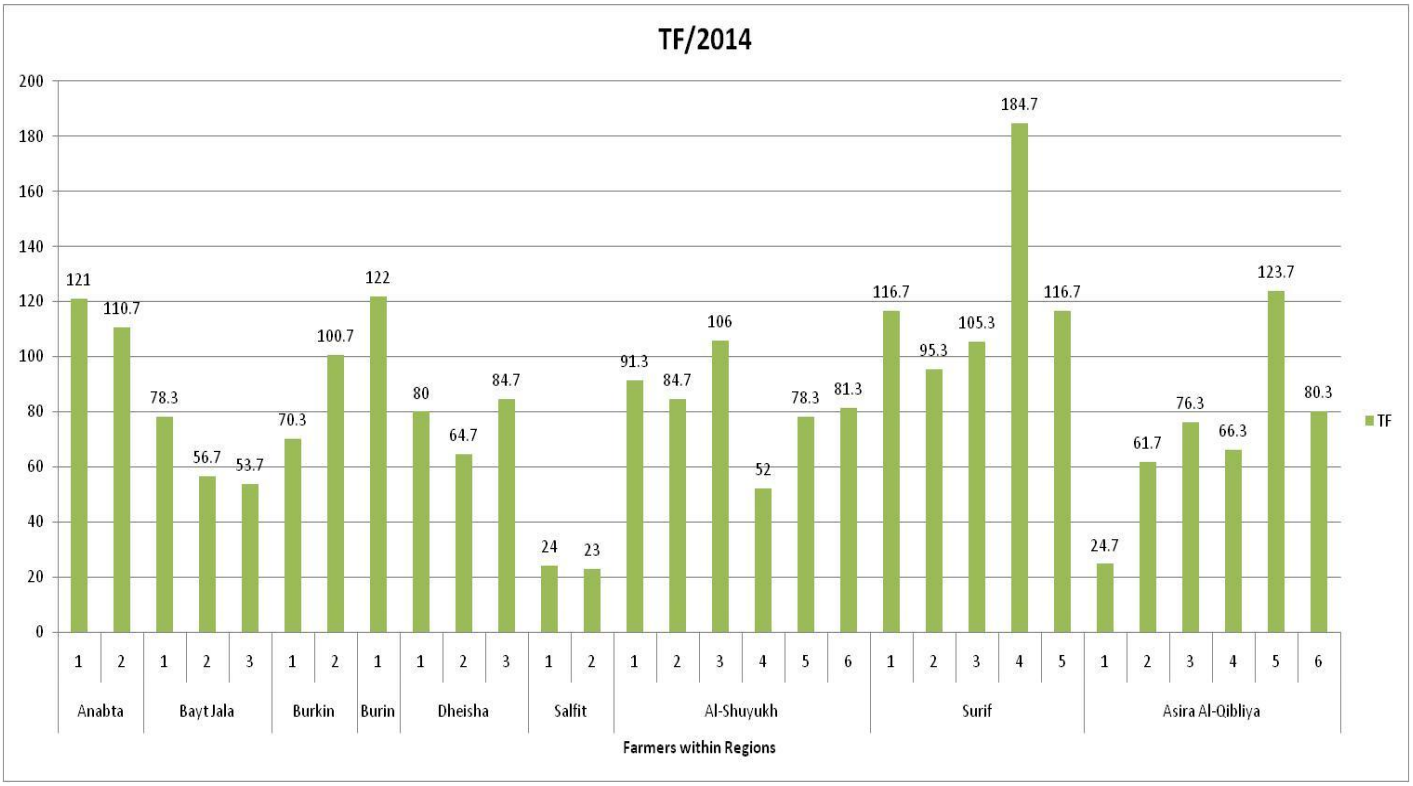


Figure 4.28: Average TFC values (mg catechin/Kg of oil) according to region, farmer code and year.

4.5.3. Average FRAP values according to region, farmer code and year

In 2013 it was observed that in Anabta there were two farmers and their FRAP values were 110.00 and 126.67 respectively, in Bayt Jala there were two farmers and their FRAP values were 40.00 and 46.67 respectively, in Burkin there were four farmers and their FRAP values were 230.00, 203.33, 183.33 and 83.33 respectively, in Dheisha there were five farmers and their FRAP values were 73.33, 46.67, 126.67, 146.67 and 160.00 respectively and in Asira Al-Shamaliya there were four farmers and their FRAP values were 56.67, 23.33, 26.67 and 50.00 respectively, in Si'ir there were four farmers and their FRAP values were 16.67, 106.67, 133.33 and 13.33 respectively, in Salfit there were six farmers and their FRAP values were 230.00, 233.33, 70.00, 96.67, 36.67 and 60.00 respectively and in Surif there were three farmers and their FRAP values were 113.33, 216.67 and 86.67 respectively (Table 4.29).

In 2014 it was observed that in Anabta there were two farmers and their FRAP values were 90.00 and 43.33 respectively, in Bayt Jala there were three farmers and their FRAP values were 53.33, 80.00 and 26.67 respectively, in Burkin there were two farmers and their FRAP values were 153.33 and 143.33 respectively, in Burin there was one farmer and his FRAP value was 93.33,in Dheisha there were thre farmers and their FRAP values were 83.33, 70.00 and 66.67 respectively, in Salfit there were two farmers and their FRAP values were 66.67 and 73.33 respectively, in Al-Shuyukh there were six farmers and their FRAP values were 80.00, 33.33, 60.00, 30.00, 56.67 and 23.33 respectively, in Surif there were five farmers and their FRAP values were 70.00, 60.00, 33.33, 96.67 and 93.33 respectively and in Asira Al-Qibliya there were six farmers and their FRAP values were 36.67, 53.33, 60.00, 100.00, 126.67 and 100.00 respectively (Table 4.29).

The FRAP values of our study ranged from 13.33-233.33 mmole Fe^{+2} /Kg of oil, and jelkovic et al (2009) found that antioxidant activity (expressed as FRAP values in mmol $FeSO_4$/Kg oil) in olive oil samples produced in 2005 and 2006 crop season were 45.0 ± 3.5 and 45.8 ± 0.7 respectively which were in agreement with our results and stated that the early ripening stages showed the highest antioxidant capacity while significantly decreased with the developing of ripening stages, while the higher the moisture content is, the higher possibility of deterioration of the oil and might also be a loss of its flavor and reduced levels of antioxidants.

El Sohaimy et al (2016) and Ninfali et al (2001) reported that olive oil obtained from mid-period of maturation and stored for two weeks had an antioxidant capacity significantly lower than the top level brand oil.

In 2013, olive fly infection, dropped olive percentage and olive fruit percentage yield were positively correlated with FRAP but the correlation was statistically not significant (pearson coefficient for olive fly infection (0.064) and pearson coefficient for olive fruit percentage yield (0.009).

Days of storage, green to black olive ratio, oil percentage and olive fruit percentage yield were negatively correlated with FRAP but the correlation was statistically not significant since pearson coefficient for days of storage (-0.164), pearson coefficient for green to black olive ratio (-0.202), pearson coefficient for oil percentage (-0.044) and pearson coefficient for olive fruit percentage yield (-0.023) (Table 4.40).

While a close look at the results in 2014 revealed that olive fly infection, oil percentage and olive fruit percentage yield were positively correlated with FRAP but the correlation was statistically not significant since pearson coefficient for olive fly infection (0.069), pearson coefficient for oil percentage (0.108) and pearson coefficient for olive fruit percentage yield (0.18).

Days of storage, green to black olive ratio and olive fruit percentage yield were negatively correlated with FRAP but the correlation was statistically not significant since pearson coefficient for days of storage (-0.045), pearson coefficient for green to black olive ratio (-0.023) and pearson coefficient for olive fruit percentage yield (-0.104) (Table 4.41).

Table4.29: Average FRAP values (mmole Fe^{+2} /Kg of oil) in different regions in Palestine according to region, farmer code and year; results are expressed as average only since farmers in 2013 in the same region are not themselves in 2014 in the same region.

2013			2014		
Region and significant symbols	**Farmer Code**	**FRAP**	**Region and significant symbols**	**FarmerCode**	**FRAP**
Anabta: E,F,G,H,I	1	110.00	Anabta: B, C, D,E,F	1	90.00
D,E,F,G,H	2	126.67	G,H,I,J,K	2	43.33
Bayt Jala: K,L,M,N,O	1	40.00	Bayt Jala: F,G,H,I,J,K	1	53.33
K,L,M,N,O	2	46.67	C, D,E,F,G	2	80.00
Burkin: A	1	230.00	K	3	26.67
A,B,C	2	203.33	Burkin: A	1	153.33
A,B,C,D	3	183.33	A	2	143.33
G,H,I,J,K,L,M	4	83.33	Burin: B, C, D,E	1	93.33
Dheisha: H,I,J,K,L,M,N	1	73.33	Dheisha: C, D,E,F	1	83.33
K,L,M,N,O	2	46.67	C, D,E,F,G,H,I	2	70.00

D,E,F,G,H	3	126.67
C,D,E,F	4	146.67
B,C,D,E	5	160.00
Asira Al-Shamaliya: I,J,K,L,M,N,O	1	56.67
N,O	2	23.33
M,N,O	3	26.67
J,K,L,M,N,O	4	50.00
Si'ir: N,O	1	16.67
E,F,G,H,I,J	2	106.67
D,E,F,G	3	133.33
O	4	13.33
Salfit: A	1	230.00
A	2	233.33

C, D,E,F,G,H,I,J	3	66.67
Salfit: C, D,E,F,G,H,I,J	1	66.67
C, D,E,F,G,H	2	73.33
Al-Shuyukh: C, D,E,F,G	1	80.00
I,J,K	2	33.33
D,E,F,G,H,I,J,K	3	60.00
J,K	4	30.00
E,F,G,H,I,J,K	5	56.67
K	6	23.33
Surif: C, D,E,F,G,H,I	1	70.00
D,E,F,G,H,I,J,K	2	60.00
I,J,K	3	33.33
B, C, D	4	96.67

H,I,J,K,L,M,N,O	3	70.00
F,G,H,I,J,K	4	96.67
L,M,N,O	5	36.67
I,J,K,L,M,N,O	6	60.00
Surif: E,F,G,H,I	1	113.33
A,B	2	216.67
G,H,I,J,K,L	3	86.67

B, C, D,E	5	93.33
Asira Al-Qibliya: H,I,J,K	1	36.67
F,G,H,I,J,K	2	53.33
D,E,F,G,H,I,J,K	3	60.00
B,C	4	100.00
A,B	5	126.67
A,B	6	100.00

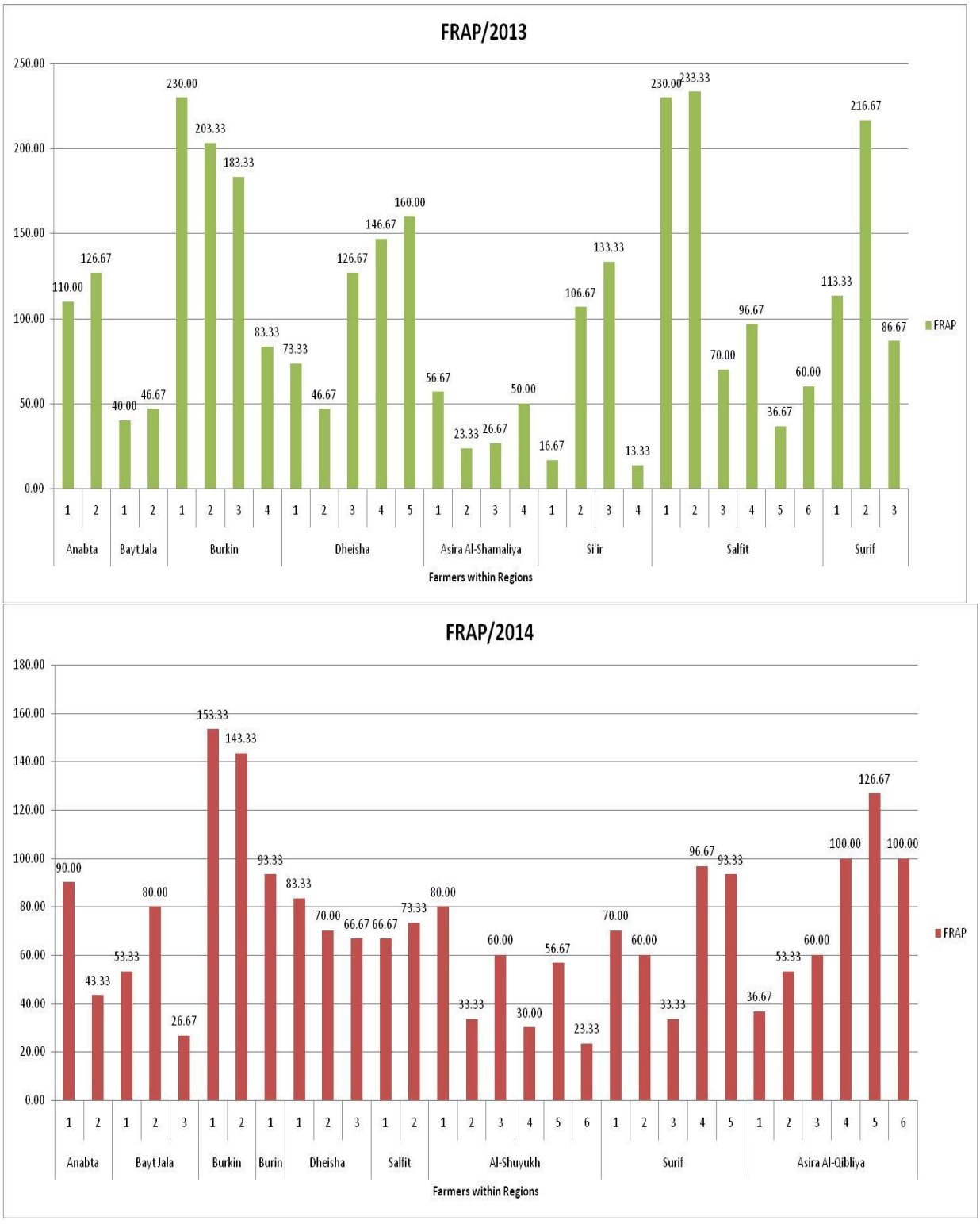


Figure 4.29: Average FRAP values (mmole Fe^{+2} /Kg of oil) according to region, farmer code and year.

4.5.4. Average CUPRAC values according to region, farmer code and year

In 2013 it was observed that in Anabta there were two farmers and their CUPRAC values were 17.54 and 21.88 respectively, in Bayt Jala there were two farmers and their CUPRAC values were 7.61 and 10.68 respectively, in Burkin there were four farmers and their CUPRAC values were 34.14, 17.75, 17.51 and 10.93 respectively, in Dheisha there were five farmers and their CUPRAC values were 15.14, 17.46, 21.43, 20.11 and 23.96 respectively and in Asira Al-Shamaliya there were four farmers and their CUPRAC values were 7.03, 5.08, 6.03 and 7.75 respectively, in Si'ir there were four farmers and their CUPRAC values were 6.78, 21.04, 19.10 and 9.68 respectively, in Salfit there were six farmers and their CUPRAC values were 22.35, 24.14, 10.77, 11.35, 4.92 and 7.01 respectively and in Surif there were three farmers and their CUPRAC values were 19.07, 25.18 and 22.35 respectively (Table 4.30).

In 2014 it was observed that in Anabta there were two farmers and their CUPRAC values were 13.29 and 20.02 respectively, in Bayt Jala there were three farmers and their CUPRAC values were 7.79, 12.28 and 6.64 respectively, in Burkin there were two farmers and their CUPRAC values were 15.60 and 12.65 respectively, in Burin there was one farmer and his CUPRAC value was14.18, in Dheisha there were thre farmers and their CUPRAC values were 20.55, 16.11 and 12.41 respectively, in Salfit there were two farmers and their CUPRAC values were 8.01 and 10.96 respectively, in Al-Shuyukh there were six farmers and their CUPRAC values were 16.79, 11.86, 14.72, 10.95, 16.60 and 11.32 respectively, in Surif there were five farmers and their CUPRAC values were 16.50, 12.02, 9.54, 19.52 and 19.13 respectively and in Asira Al-Qibliya there were six farmers and their CUPRAC values were 5.42, 7.74, 7.28, 7.54, 18.19 and 18.03 respectively (Table 4.30).

The CUPRAC values of our study ranged from 4.92-34.14 mg Torolox/g oil.

ÇELİK et al (2009) found that antioxidant activity (expressed as CUPRAC values) in olive oil samples produced in 2009 crop season was 0.16 mg Torolox/g in methanol: H_2O solution of Tariş virgin olive oil extracts and found that early ripening stages showed the highest antioxidant capacity while significantly decreased with the developing of ripening stages and the higher the moisture content is the higher possibility of deterioration of the oil and might also be a loss of its flavor and reduced levels of antioxidants.

El Sohaimy et al (2016) and Ninfali et al (2001) reported that oil obtained from mid-period of maturation and stored for two weeks had an antioxidant capacity significantly lower than the top level brand oil.

In 2013, olive fly infection, green to black olive ratio, dropped olive percentage and olive fruit percentage yield were positively correlated with CUPRAC but the correlation was statistically not significant since pearson coefficient for olive fly infection (0.01), pearson coefficient for green to black olive ratio (0.027), pearson coefficient for dropped olive percentage (0.007) and pearson coefficient for olive fruit percentage yield (0.138).

Days of storage and oil percentage were negatively correlated with CUPRAC but the correlation was statistically not significant (pearson coefficient for days of storage (-0.077) and pearson coefficient for oil percentage (-0.331) (Table 4.40).

While a close look at the results in 2014 revealed that days of storage, green to black olive ratio, oil percentage and olive fruit percentage yield were positively correlated with CUPRAC but the correlation was statistically not significant since pearson coefficient for days of storage (0.054), pearson coefficient for green to black olive ratio (0.104), pearson coefficient for oil percentage (0.045) and pearson coefficient for olive fruit percentage yield (0.291).

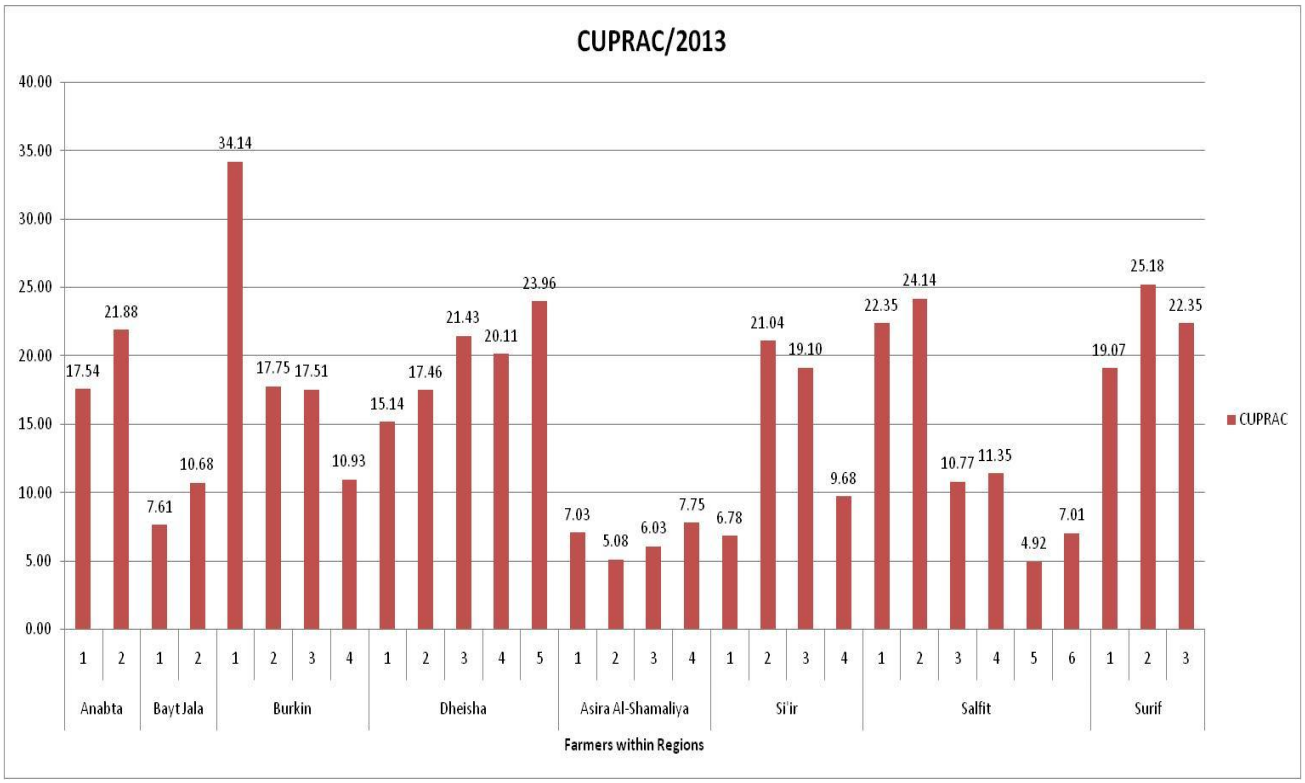
Olive fly infection and dropped olive percentage were negatively correlated with CUPRAC but the correlation was statistically not significant since pearson coefficient for olive fly infection (-0.104) and pearson coefficient for dropped olive percentage (-0.267) (Table 4.41).

Table 4.30: Average CUPRAC values (mg Torolox/g oil) in different regions in Palestine according to region, farmer code and year; results are expressed as average only since farmers in 2013 in the same region are not themselves in 2014 in the same region.

2013			2014		
Region and significant symbols	**Farmer Code**	**CUPRAC**	**Region and significant symbols**	**Farmer Code**	**CUPRAC**
Anabta: E,F	1	17.54	Anabta:A,B,C,D,E,F,G,H	1	13.29
B,C,D,E	2	21.88	A,B	2	20.02
Bayt Jala: H,I,J	1	7.61	Bayt Jala:G,H,I	1	7.79
G,H	2	10.68	C, D,E,F,G,H,I	2	12.28
Burkin: A	1	34.14	H,I	3	6.64
D,E,F	2	17.75	Burkin: A, B, C, D,E,F	1	15.60
E,F	3	17.51	B,C,D,E,F,G,H,I	2	12.65
G,H	4	10.93	Burin:A,B,C,D,E,F,G,H	1	14.18
Dheisha: F,G	1	15.14	Dheisha: A	1	20.55
E,F	2	17.46	A,B,C, D,E	2	16.11
B,C,D,E	3	21.43	B,C,D,E,F,G,H,I	3	12.41
C,D,E	4	20.11	Salfit: F,G,H,I	1	8.01
B,C	5	23.96	D,E,F,G,H,I	2	10.96
Asira Al-Shamaliya: H,I,J	1	7.03	Al-Shuyukh: A,B,C, D,E	1	16.79

H,I,J	2	5.08
I,J	3	6.03
I,J	4	7.75
Si'ir: H,I,J	1	6.78
B,C,D,E	2	21.04
D,E,F	3	19.10
H,I	4	9.68
Salfit: B,C,D	1	22.35
B,C	2	24.14
G,H	3	10.77
G,H	4	11.35
J	5	4.92
H,I,J	6	7.01
Surif: D,E,F	1	19.07
B	2	25.18
B,C,D	3	22.35

C,D,E,F,G,H,I	2	11.86
A,B,C,D,E,F,G	3	14.72
D,E,F,G,H,I	4	10.95
A,B,C, D,E	5	16.60
D,E,F,G,H,I	6	11.32
Surif: A,B,C, D,E	1	16.50
C,D,E,F,G,H,I	2	12.02
E,F,G,H,I	3	9.54
A,B, C	4	19.52
So14A,B, C	5	19.13
Asira Al-Qibliya:I	1	5.42
G,H,I	2	7.74
G,H,I	3	7.28
G,H,I	4	7.54
A,B,C,D	5	18.19
A,B,C,D	6	18.03



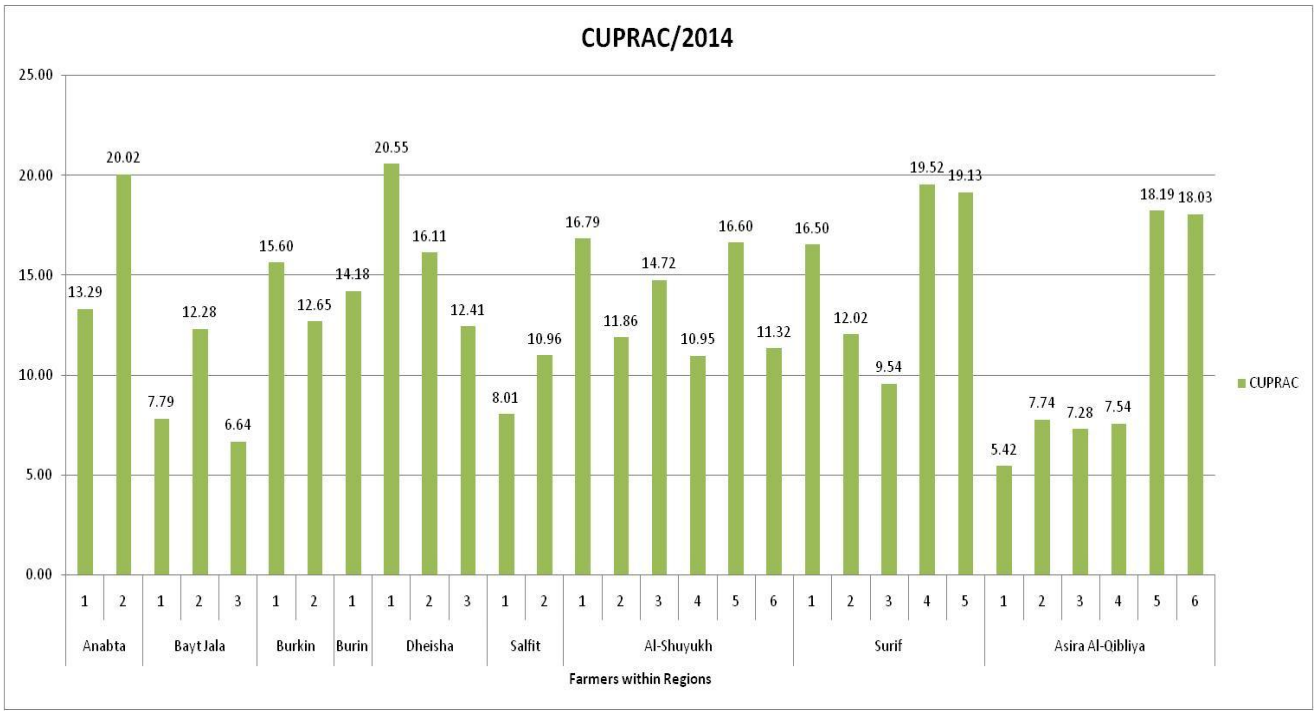


Figure 4.30: Average CUPRAC values (mg Torolox/g oil) according to region, farmer code and year.

4.5.5. Average ABTS values according to region, farmer code and year

In 2013 it was observed that in Anabta there were two farmers and their ABTS values were 393.33 and 420.00 respectively, in Bayt Jala there were two farmers and their ABTS values were 270.00 and 226.67 respectively, in Burkin there were four farmers and their ABTS values were 1030.00, 63.33, 926.67 and 410.00 respectively, in Dheisha there were five farmers and their ABTS values were 513.33, 603.33, 936.67, 1046.67 and 1183.33 respectively and in Asira Al-Shamaliya there were four farmers and their ABTS values were 480.00, 183.33, 196.67 and 313.33 respectively, in Si'ir there were four farmers and their ABTS values were 363.33, 616.67, 286.67 and 476.67 respectively, in Salfit there were six farmers and their ABTS values were 900.00, 1453.33, 620.00, 666.67, 370.00 and 553.33 respectively and in Surif there were three farmers and their ABTS values were 1036.67, 1333.33 and 896.67 respectively (Table 4.31).

In 2014 it was observed that in Anabta there were two farmers and their ABTS values were 443.33 and 190.00 respectively, in Bayt Jala there were three farmers and their ABTS values were 326.67, 400.00 and 306.67 respectively, in Burkin there were two farmers and their ABTS values were 873.33 and 650.00 respectively, in Burin there was one farmer and his ABTS value was 343.33, in Dheisha there were thre farmers and their ABTS values were 896.67, 800.00 and 513.33 respectively, in Salfit there were two farmers and their ABTS values were 300.00 and 310.00 respectively, in Al-Shuyukh there were six farmers and their ABTS values were 620.00, 690.00, 876.67, 466.67, 880.00 and 486.67 respectively, in Surif there were five farmers and their ABTS values were 606.67, 993.33, 530.00, 523.33 and 920.00 respectively and in Asira Al-Qibliya there were six farmers and their ABTS values were 276.67, 103.33, 226.67, 436.67, 483.33 and 340.00 respectively (Table 4.31).

The ABTS-persulphate method values of our study ranged from 63.33-1453.33 mg Torolox/kg oil.

ÇELİK et al (2009) found that antioxidant activity using (ABTS-persulphate method with values expressed in mmol Torolox/g oil) in olive oil samples produced in 2009 crop season was 0.1 mg Torolox/g in methanol: H_2O solution of Tariş virgin olive oil extracts, while Minioti et al (2010) reported that antioxidant capacities determined in the hydrophilic fraction

range between 5.42 - 22.5 mM gallic acid Kg^{-1} olive oil for the ABTS method and found that early ripening stages showed the highest antioxidant capacity while significantly decreased with the developing of ripening stages and reported that the higher the moisture content is, the higher possibility of deterioration of the oil and might also be a loss of its flavor and reduced levels of antioxidants, while El Sohaimy et al (2016) and Ninfali et al (2001), showed that olive oil obtained from mid-period of maturation and stored for two weeks had an antioxidant capacity significantly lower than the top level brand oil and Baiano et al (2014) reported that there were a strong positive linear correlation between the phenolic content and antioxidant activity measured by ABTS+ method which indicate a noticeable radical scavenging ability of phenolic compounds.

In 2013, olive fly infection, dropped olive percentage and olive fruit percentage yield were positively correlated with ABTS but the correlation was statistically not significant since pearson coefficient for olive fly infection (0.194), pearson coefficient for dropped olive percentage (0.019), and pearson coefficient for olive fruit percentage yield (0.33).

Days of storage, green to black olive ratio and oil percentage were negatively correlated with ABTS but the correlation was statistically not significant since pearson coefficient for days of storage (-0.093), pearson coefficient for green to black olive ratio (-0.284) and pearson coefficient for oil percentage (-0.212) (Table 4.40).

While a close look at the results in 2014 revealed that days of storage and olive fruit percentage yield were positively correlated with ABTS but the correlation was statistically not significant since pearson coefficient for days of storage (0.307) and pearson coefficient for olive fruit percentage yield (0.326).

Olive fly infection, green to black olive ratio, oil percentage and dropped olive percentage were negatively correlated with ABTS but the correlation was statistically not significant since pearson coefficient for olive fly infection (-0.105), pearson coefficient for green to black olive ratio (-0.129), pearson coefficient for oil percentage (-0.191) and pearson coefficient for dropped olive percentage (-0.169) (Table 4.41).

Table 4.31: Average ABTS values (mg Torolox/Kg oil) in different regions in Palestine according to region, farmer code and year; results are expressed as average only since farmers in 2013 in the same region are not themselves in 2014 in the same region.

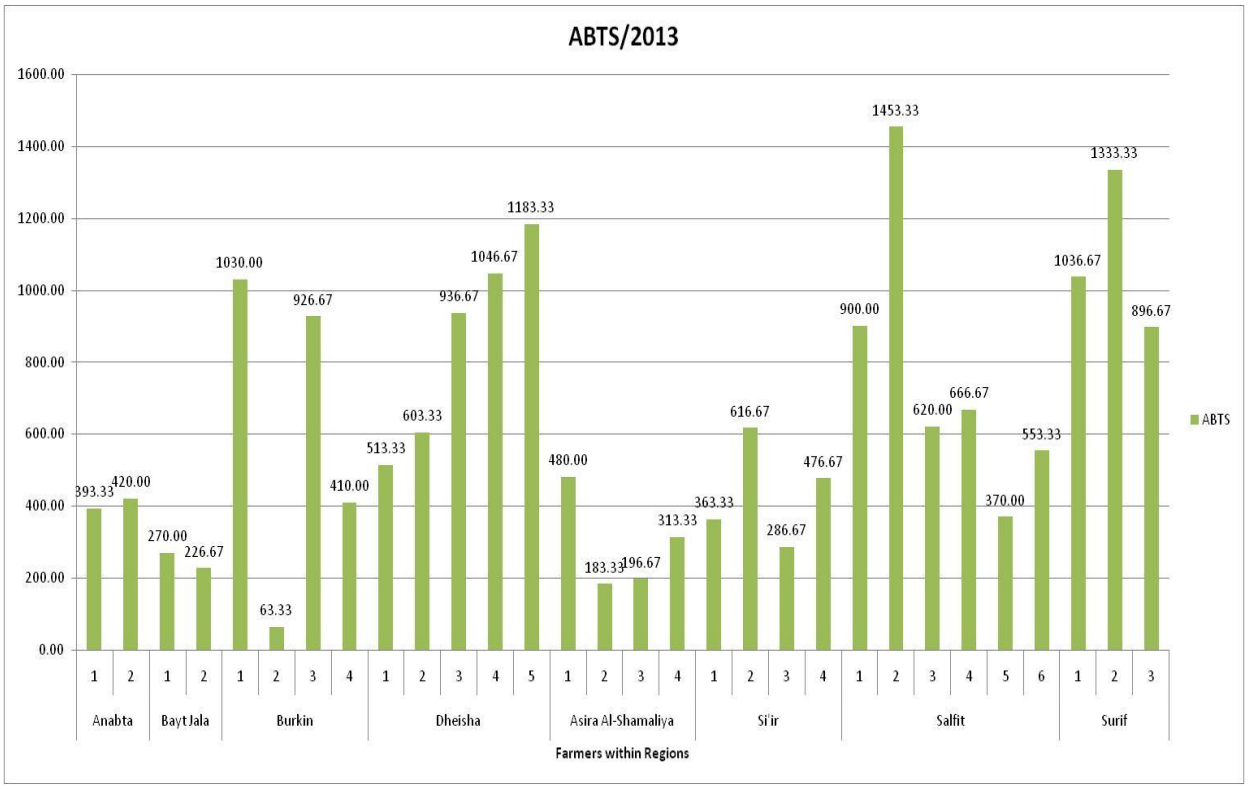
2013			2014		
Region and significant symbols	**Farmer Code**	**ABTS**	**Region and significant symbols**	**Farmer Code**	**ABTS**
Anabta: G,H,I,J,K	1	393.33	Anabta: G,H,I	1	443.33
G,H,I,J	2	420.00	M,N	2	190.00
Bayt Jala: J, K,L,M	1	270.00	Bayt Jala: I,J,K,L,M	1	326.67
K,L,M,N	2	226.67	G,H,I,J,K	2	400.00
Burkin: C,D	1	1030.00	I,J,K,L,M	3	306.67
N	2	63.33	Burkin: A,B	1	873.33
D	3	926.67	D,E	2	650.00
G,H,I,J	4	410.00	Burin: H,I,J,K,L	1	343.33
Dheisha: E,F,G,H	1	513.33	Dheisha: A,B	1	896.67
E,F	2	603.33	B,C	2	800.00

D	3	936.67
C,D	4	1046.67
B,C	5	1183.33
Asira Al-Shamaliya : F,G,H,I	1	480.00
M,N	2	183.33
L,M,N	3	196.67
I,J,K,L,M	4	313.33
Si'ir: H,I,J,K,L	1	363.33
E,F	2	616.67
J,K,L,M	3	286.67
F,G,H,I	4	476.67
Salfit: D	1	900.00
A	2	1453.33

E,F,G	3	513.33
Salfit: J,K,L,M	1	300.00
I,J,K,L,M	2	310.00
Al-Shuyukh: D,E,F	1	620.00
C,D	2	690.00
A,B	3	876.67
G,H	4	466.67
A,B	5	880.00
F,G	6	486.67
Surif: D,E,F	1	606.67
A	2	993.33
E,F,G	3	530.00
E,F,G	4	523.33

E,F	3	620.00
E	4	666.67
H,I,J,K	5	370.00
E,F,G	6	553.33
Surif: C,D	1	1036.67
A,B	2	1333.33
D	3	896.67

A,B	5	920.00
Asira Al-Qibliya: K,L,M	1	276.67
N	2	103.33
L,M,N	3	226.67
G,H,I,J	4	436.67
F,G	5	483.33
F,G	6	340.00



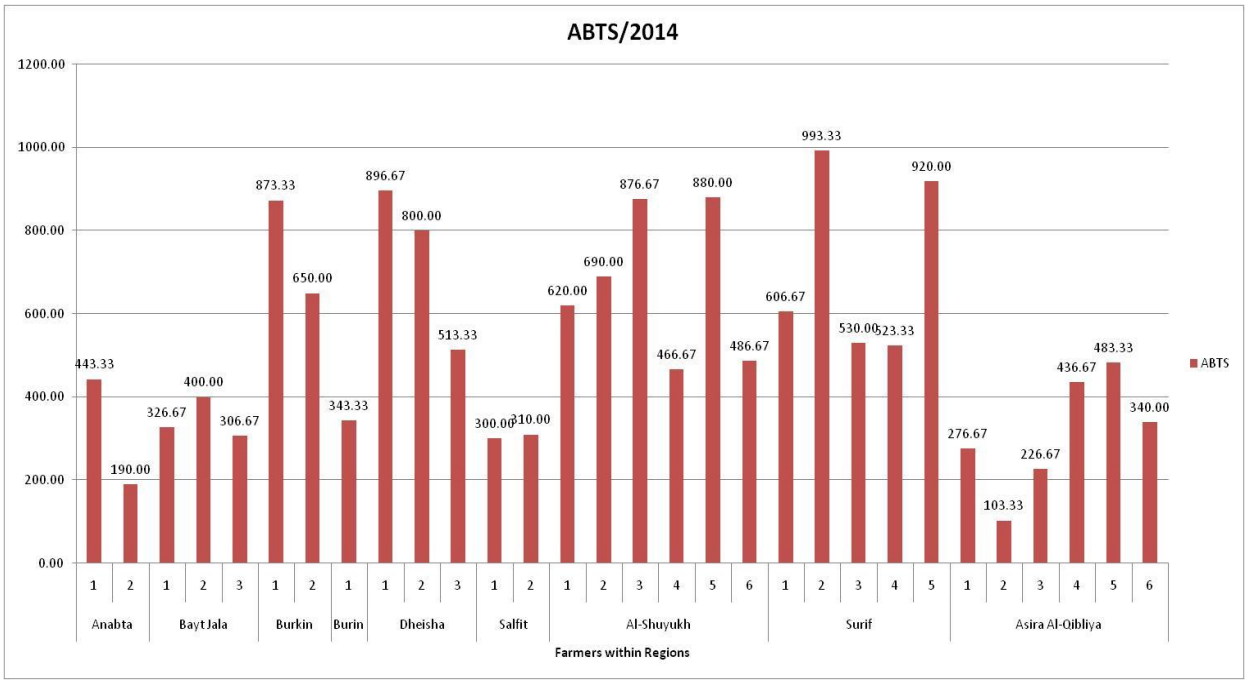


Figure 4.31: Average ABTS values (mg Torolox/Kg oil) according to region, farmer code and year.

4.5.6. Average DPPH values according to region, farmer code and year

In 2013 it was observed that in Anabta there were two farmers and their DPPH values were 359.00 and 343.67 respectively, in Bayt Jala there were two farmers and their DPPH values were 413.67 and 289.33 respectively, in Burkin there were four farmers and their DPPH values were 422.33, 472.00, 473.67 and 386.67 respectively, in Dheisha there were five farmers and their DPPH values were 550.67, 1093.00, 366.00, 442.33 and 369.33 respectively and in Asira Al-Shamaliya there were four farmers and their DPPH values were 411.67, 390.67, 779.67 and 407.00 respectively, in Si'ir there were four farmers and their DPPH values were 265.33, 534.67, 321.33 and 265.00 respectively, in Salfit there were six farmers and their DPPH values were 774.33, 771.33, 740.67, 715.00, 545.00 and 915.33 respectively and in Surif there were three farmers and their DPPH values were 263.67, 262.33 and 323.67 respectively (Table 4.32).

In 2014 it was observed that in Anabta there were two farmers and their DPPH values were 268.33 and 623.00 respectively, in Bayt Jala there were three farmers and their DPPH values were 475.00, 453.00 and 330.00 respectively, in Burkin there were two farmers and their DPPH values were 356.33 and 767.33 respectively, in Burin there was one farmer and his DPPH value was 798.67, in Dheisha there were thre farmers and their DPPH values were 472.33, 481.33 and 540.67 respectively, in Salfit there were two farmers and their DPPH values were 588.00 and 645.67 respectively, in Al-Shuyukh there were six farmers and their DPPH values were 588.67, 389.67, 293.00, 618.00, 343.00 and 566.00 respectively, in Surif there were five farmers and their DPPH values were 339.00, 512.33, 388.67, 305.33 and 326.00 respectively and in Asira Al-Qibliya there were six farmers and their DPPH values were 606.33, 532.67, 811.67, 328.67, 844.33 and 1024.33 respectively (Table 4.32).

The DPPH values of our study ranged from 262.33-1093 mg Torolox/kg oil.

Minioti et al (2010) reported that antioxidant capacities determined in the hydrophilic fraction range between 1.29 - 9.95 mM Kg^{-1} for the DPPH method and El Sohaimy et al (2016) and Ninfali et al (2001) reported that olive oil obtained from mid-period of maturation and stored for two weeks had an antioxidant capacity significantly lower than the top level brand oil.

Only oil percentage has a positive significant correlation with DPPH since the correlation coefficient was equal to (0.468) ($p < 0.05$).

The oil percentage of our samples were from 16% to 35% which were in agreement with Toplu et al (2009) who stated that oil content varied significantly between cultivars ranging from 16.7% to 31.2%, while Mailer et al (2005) stated that oil yields ranging from 5% to 30% by weight and said that low yields have been attributed to a range of reasons such as incorrect variety, immature trees, harvesting too early, high fruit moisture contents and poor extraction efficiency. Salvador et al (2001) and Beltran et al (2004) showed that numerous studies in the mediterranean have shown that during the ripening period, oil percentage increases dramatically during early fruit ripening then slows as full ripeness approaches and declines slightly as fruit becomes over ripe.

In 2013, olive fly infection, days of storage, green to black olive ratio, oil percentage and olive fruit percentage yield were positively correlated with DPPH but the correlation was statistically not significant since pearson coefficient for olive fly infection (0.047), pearson coefficient for days of storage (0.067), pearson coefficient green to black olive ratio (0.02), pearson coefficient for oil percentage (0.365), and pearson coefficient for olive fruit percentage yield (0.485).

Dropped olive percentage was negatively correlated with DPPH but the correlation was statistically not significant since pearson coefficient for dropped olive percentage (-0.205) (Table 4.40).

While a close look at the results in 2014 revealed that olive fly infection, days of storage, green to black olive ratio, dropped olive percentage and olive fruit percentage yield were negatively correlated with DPPH but the correlation was statistically not significant since pearson coefficient for olive fly infection (-0.01), pearson coefficient for days of storage (-0.315), pearson coefficient for green to black olive ratio (-0.174), pearson coefficient for dropped olive percentage (-0.119) and pearson coefficient for olive fruit percentage yield (-0.291) (Table 4.41).

Only oil percentage has a positive significant correlation with DPPH (the correlation coefficient was equal to (0.468) ($p < 0.05$) (Table 4.41)).

Table 4.32: Average DPPH values (mg Torolox/Kg oil) in different regions in Palestine according to region, farmer code and year; results are expressed as average only since farmers in 2013 in the same region are not themselves in 2014 in the same region.

2013			2014		
Region and significant symbols	**Farmer Code**	**DPPH**	**Region and significant symbols**	**Farmer Code**	**DPPH**
Anabta:N,O	1	359.00	Anabta: Q	1	268.33
O,P	2	343.67	D,E	2	623.00
Bayt Jala: I,J	1	413.67	Bayt Jala:J, K	1	475.00
Q	2	289.33	K	2	453.00
Burkin:H,I	1	422.33	N	3	330.00
G	2	472.00	Burkin:M	1	356.33
G	3	473.67	C	2	767.33
K,L,M	4	386.67	Burin: B	1	798.67
Dheisha:F	1	550.67	Dheisha:J, K	1	472.33
A	2	1093.00	J	2	481.33

M,N,O	3	366.00
H	4	442.33
L,M,N	5	369.33
Asira Al-Shamaliya :I,J	1	411.67
J,K,L	2	390.67
C	3	779.67
I,J,K	4	407.00
Si'ir:R	1	265.33
F	2	534.67
P	3	321.33
R	4	265.00
Salfit: C	1	774.33
C	2	771.33
D	3	740.67

H	3	540.67
Salfit:F,G	1	588.00
D	2	645.67
Al-Shuyukh:F,G	1	588.67
L	2	389.67
P	3	293.00
E	4	618.00
M,N	5	343.00
G	6	566.00
Surif:M,N	1	339.00
I	2	512.33
L	3	388.67
O,P	4	305.33
N,O	5	326.00

E	4	715.00
F	5	545.00
B	6	915.33
Surif:R	1	263.67
R	2	262.33
P	3	323.67

Asira Al-Qibliya:E,F	1	606.33
H,I	2	532.67
B	3	811.67
N,O	4	328.67
A	5	844.33
A	6	1024.33

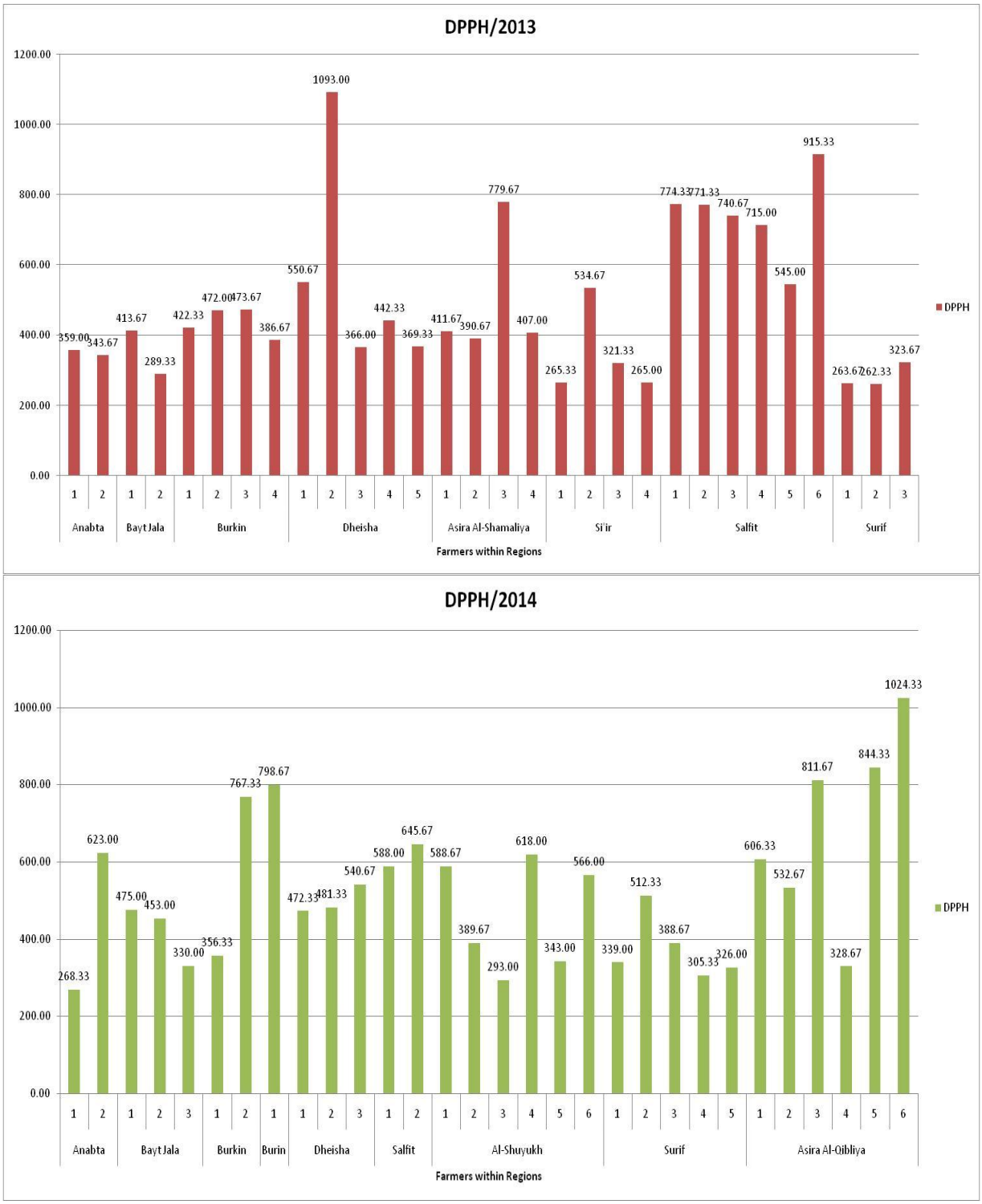


Figure 4.32: Average DPPH values (mg Torolox/Kg oil) according to region, farmer code and year.

4.5.7. Average iodine values according to region, farmer code and year

In 2013 it was observed that in Anabta there were two farmers and their iodine values were 88.73 and 102.53 respectively, in Bayt Jala there were two farmers and their iodine values were 77.48 and 89.60 respectively, in Burkin there were four farmers and their iodine values were 99.77, 79.53, 65.79 and 93.62 respectively, in Dheisha there were five farmers and their Iodine values were 65.12, 55.77, 65.08, 65.76 and 99.59 respectively and in Asira Al-Shamaliya there were four farmers and their iodine values were 64.47, 84.36, 81.79 and 96.25 respectively, in Si'ir there were four farmers and their iodine values were 66.44, 70.40, 62.77 and 60.04 respectively, in Salfit there were six farmers and their iodine values were 92.01, 87.73, 110.28, 86.67, 88.87 and 67.52 respectively and in Surif there were three farmers and their Iodine values were 64.17, 70.88 and 70.96 respectively (Table 4.33).

In 2014 it was observed that in Anabta there were two farmers and their iodine values were 80.91 and 72.91 respectively, in Bayt Jala there were three farmers and their iodine values were 85.34, 93.34 and 82.31 respectively, in Burkin there were two farmers and their iodine values were 84.02 and 100.88 respectively, in Burin there was one farmer and his iodine value was 65.64, in Dheisha there were three farmers and their iodine values were 71.62, 56.49 and 64.99 respectively, in Salfit there were two farmers and their iodine values were 102.10 and 90.46 respectively, in Al-Shuyukh there were six farmers and their iodine values were 76.09, 92.38, 104.94, 86.52, 78.60 and 65.60 respectively, in Surif there were five farmers and their iodine values were 53.52, 72.94, 69.44, 75.65 and 69.19 respectively and in Asira Al-Qibliya there were six farmers and their iodine values were 80.26, 88.53, 89.23, 97.39, 80.91 and 94.78 respectively (Table 4.33).

The iodine values of our study ranged from 53.52-110.28 g iodine/100 g oil.

According to Codex Alimentarius Commission (2001), iodine value (Wijs) range between 75 – 94g iodine/100 g oil.

Amarna et al (2011) showed that average iodine number for their oil samples was 91.8 g I_2/100g oil while Christopher & Island (2015) found that olive oil iodine value was 81.01 g I_2/100g oil. In the other hand El Sohaimy et al (2016) found that the iodine value was significantly decreased with ripening development. Lotfy et al (2015) found that iodine value

using "Wijs method" was (86.3 mg I_2/100 g oil), while Madhavi & Saroja (2014) found that olive oil iodine value was 83.412 using "Hanus method" and Amarna et al (2011) found that average iodine number of the studied olive oil samples was 91.8 cg/g.

Only oil percentage has a positive significant correlation with iodine values since the correlation coefficient was equal to (0.48) ($p < 0.01$).

In 2013, olive fly infection, days of storage and dropped olive percentage were positively correlated with iodine values but the correlation was statistically not significant since pearson coefficient for olive fly infection (0.133), pearson coefficient for days of storage (0.095), and pearson coefficient for dropped olive percentage (0.305).

Green to black olive ratio and olive fruit percentage yield were negatively correlated with Iodine values but the correlation was statistically not significant since pearson coefficient green to black olive ratio (-0.091) and pearson coefficient for olive fruit percentage yield (-0.107).

Only oil percentage has a positive significant correlation with iodine values since the correlation coefficient was equal to (0.48) ($p < 0.01$) (Table 4.40).

While a close look at the results in 2014 revealed that olive fly infection, oil percentage and dropped olive percentage were positively correlated with Iodine values but the correlation was statistically not significant since pearson coefficient for olive fly infection (0.027), pearson coefficient for oil percentage (0.139), and pearson coefficient for dropped olive percentage (0.123).

Dropped olive percentage were negatively correlated with Iodine values but the correlation was statistically not significant since pearson coefficient for days of storage (-0.135), pearson coefficient for green to black olive ratio (-0.157) and pearson coefficient for olive fruit percentage yield (-0.209) (Table 4.41).

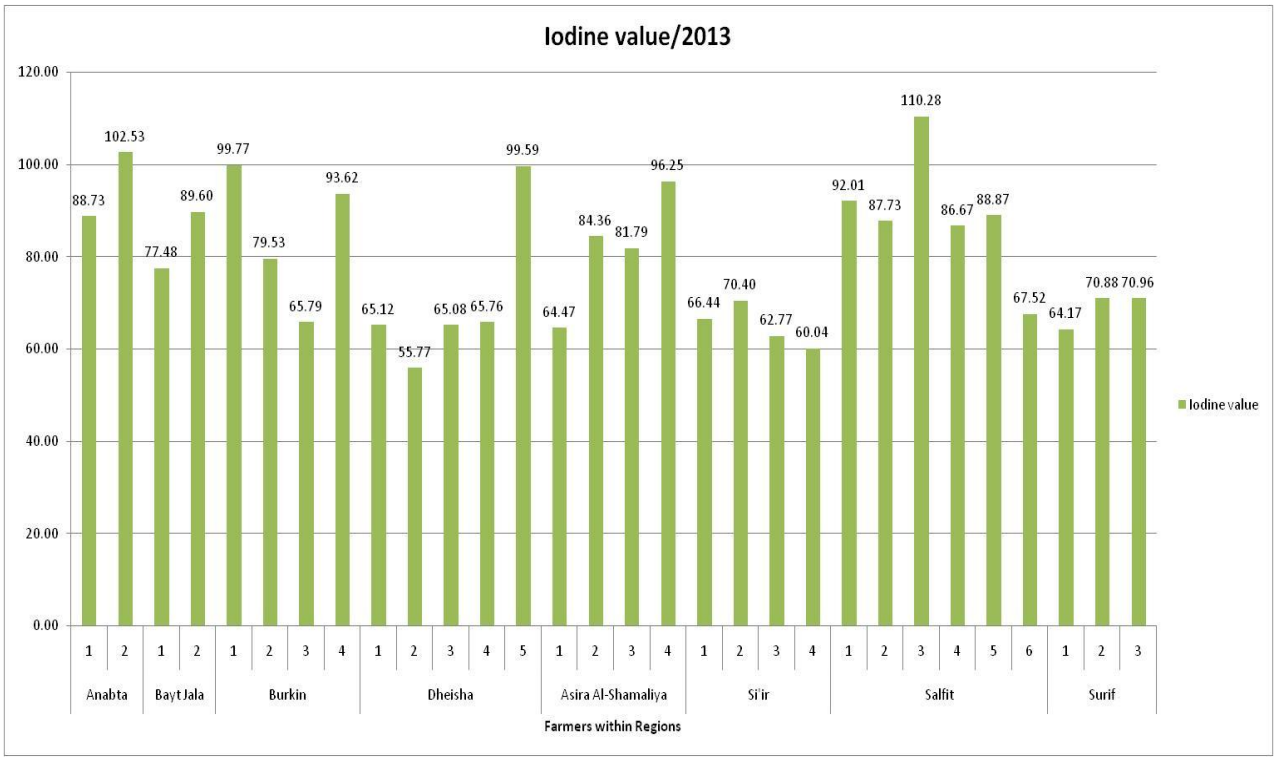
Fakhri & Qadir (2011) reported that in comparison between the specific gravity and iodine value, it was suggested that as the specific gravity is lower represent that the iodine value is higher. Also the study shows that when the peroxide value is high and has abnormal range, the iodine value is also high and has abnormal range but not vice versa.

Table 4.33: Average iodine values (g Iodine/100 g oil)in different regions in Palestine according to region, farmer code and year; results are expressed as average only since farmers in 2013 in the same region are not themselves in 2014 in the same region.

2013			2014		
Region and significant symbols	**Farmer Code**	**Iodine value**	**Region and significant symbols**	**Farmer Code**	**Iodine value**
Anabta :E,F,G,H	1	88.73	Anabta: F,G,H,I,J,K	1	80.91
A,B	2	102.53	I,J,K,L	2	72.91
Bayt Jala:I,J,K,L	1	77.48	Bayt Jala: E,F,G,H	1	85.34
C,D,E,F,G,H	2	89.60	A,B,C,D,E	2	93.34
Burkin: A,B,C	1	99.77	E,F,G,H,I,J	3	82.31
H,I,J,K	2	79.53	Burkin: E,F,G,H,I	1	84.02
M,N,O	3	65.79	A,B,C	2	100.88
B,C,D,E,F	4	93.62	Burin: L,M	1	65.64
Dheisha: M,N,O	1	65.12	Dheisha: J,K,L	1	71.62
O	2	55.77	M,N	2	56.49
M,N,O	3	65.08	L,M,N	3	64.99
M,N,O	4	65.76	Salfit: A,B	1	102.10
A,B,C,D	5	99.59	B,C,D,E,F,G	2	90.46

Asira Al-Shamaliya: M,N,O	1	64.47
F,G,H,I	2	84.36
G,H,I,J	3	81.79
B,C,D,E	4	96.25
Si'ir: M,N,O	1	66.44
K,L,M,N	2	70.40
M,N,O	3	62.77
N,O	4	60.04
Salfit: B,C,D,E,F,G	1	92.01
E,F,G,H,I	2	87.73
A	3	110.28
E,F,G,H,I	4	86.67
D,E,F,G,H	5	88.87
L,M,N	6	67.52
Surif: M,N,O	1	64.17
K,L,M,N	2	70.88
J,K,L,M	3	70.96

Al-Shuyukh: H,I,J,K,L	1	76.09
B,C,D,E,F	2	92.38
A	3	104.94
D,E,F,G,H	4	86.52
G,H,I,J,K	5	78.60
L,M	6	65.60
Surif: N	1	53.52
I,J,K,L	2	72.94
K,L	3	69.44
H,I,J,K,L	4	75.65
K,L	5	69.19
Asira Al-Qibliya: G,H,I,J,K	1	80.26
D,E,F,G	2	88.53
C,D,E,F,G	3	89.23
A,B,C,D	4	97.39
F,G,H,I,J,K	5	80.91
F,G,H,I,J,K	6	94.78



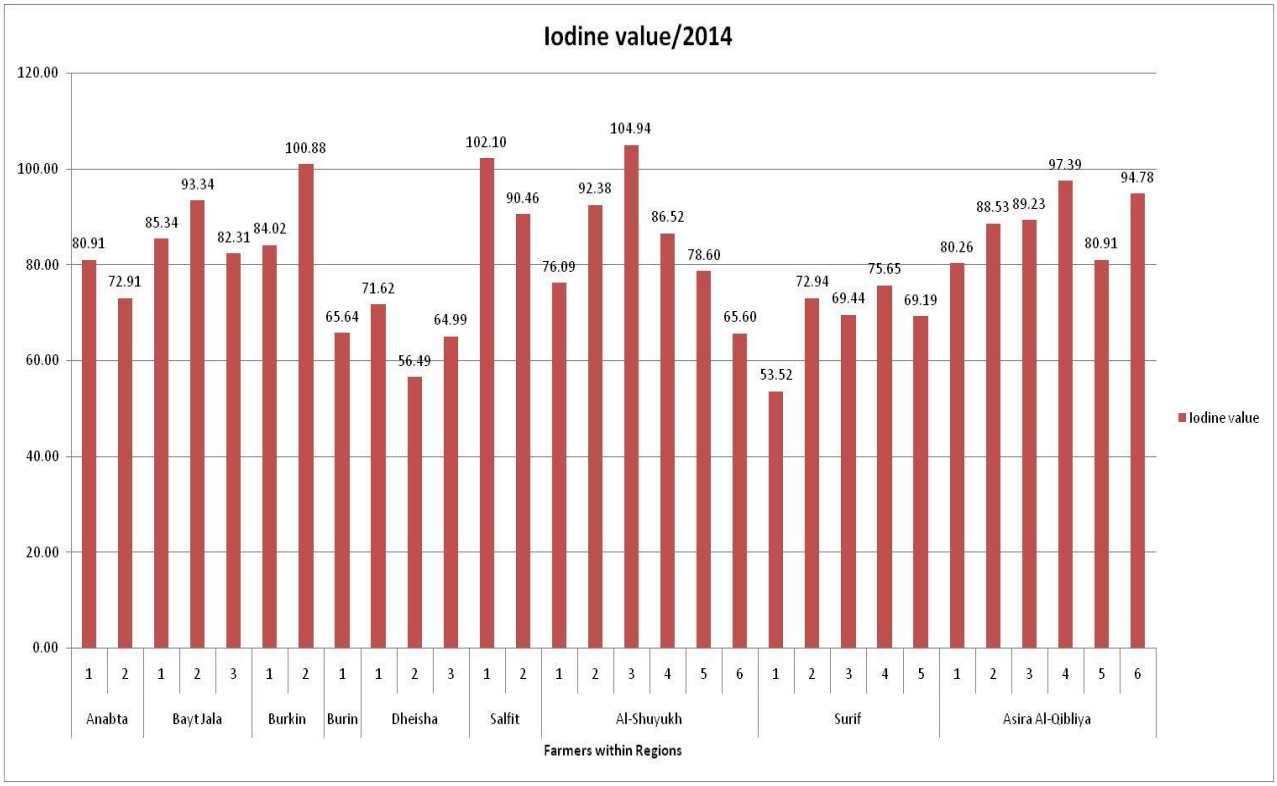


Figure 4.33: Average iodine values (g Iodine/100 g oil) according to region, farmer code and year.

4.5.8. Average Acidity% values according to region, farmer code and year

In 2013 it was observed that in Anabta there were two farmers and their Acidity% values were 1.01 and 1.69 respectively, in Bayt Jala there were two farmers and their Acidity% values were 1.25 and 1.45 respectively, in Burkin there were four farmers and their Acidity% values were 1.48, 1.62, 0.98 and 1.69 respectively, in Dheisha there were five farmers and their Acidity% values were 1.06, 0.60, 0.78, 1.02 and 1.69 respectively and in Asira Al-Shamaliya there were four farmers and their Acidity% values were 0.84, 1.66, 1.34 and 1.26 respectively, in Si'ir there were four farmers and their Acidity% values were 1.04, 1.64, 0.59 and 1.00 respectively, in Salfit there were six farmers and their Acidity% values were 1.04, 1.41, 1.62, 1.52, 1.06 and 0.90 respectively and in Surif there were three farmers and their Acidity% values were 1.00, 0.97 and 1.46 respectively (Table 4.34).

In 2014 it was observed that in Anabta there were two farmers and their Acidity% values were 1.65 and 1.48 respectively, in Bayt Jala there were three farmers and their Acidity% values were 1.45, 0.84 and 1.44 respectively, in Burkin there were two farmers and their Acidity% values were 1.26 and 1.44 respectively, in Burin there was one farmer and his Acidity% value was1.70, in Dheisha there were three farmers and their Acidity% values were 1.08, 0.86 and 1.00 respectively, in Salfit there were two farmers and their Acidity% values were 1.08 and 1.61 respectively, in Al-Shuyukh there were six farmers and their Acidity% values were 1.66, 1.61, 0.89, 0.51, 0.92 and 1.06 respectively, in Surif there were five farmers and their Acidity% values were 1.34, 0.90, 1.38, 0.77 and 0.89 respectively and in Asira Al-Qibliya there were six farmers and their Acidity% values were 1.65, 1.42, 1.68, 0.90, 1.64 and 1.04 respectively (Table 4.34).

The average acidity% values of our samples were ranged from 0.51-1.70 (% as oleic acid).

according to Codex Alimentarius Commission (2001) Acidity maximum % of virgin olive oil (expressed as oleic acid) equals 3.3, so our acidity% results showed that our oil in EVOO category. Amarna et al (2011) showed that average free acid value of their olive oil samples was 1.22%. Essiari & Chimi (2014) reported that acidity of olive oil was a function of geographical area and found that oils produced from olives grown on calcareous soils have a lower acidity than those obtained from olives cultivated on clay soils, while Desouky et al

(2009) noticed that the acidity increased during maturation progress, especially in black stage, which had the highest acidity percentage and the reason according to Bengana et al (2013), Arslan & Schreiner (2012) and Youssef et al (2010) that free acidity increased slightly as fruit ripening progress, as during the olive ripening there is progressive activation of lipolytic activity and olives are more sensitive to pathogenic infection and mechanical damage, which result in oils with higher acidity values, while El Sohaimy et al (2016) reported that the oil showed an unstable trend in the relation between the acid value and ripening stages and concluded that the reddish ripening stage was the best stage for harvesting of the olive fruits to get the high quality of oil.

Only oil percentage of our samples has a positive significant correlation with Acidity% values since the correlation coefficient was equal to (0.476) ($p < 0.05$).

The oil percentage of our samples were from 16% to 35%.

In 2013, olive fly infection, days of storage, green to black olive ratio, oil percentage and dropped olive percentage were positively correlated with Acidity% values but the correlation was statistically not significant since pearson coefficient for olive fly infection (0.04), pearson coefficient for days of storage (0.021), pearson coefficient for green to black olive ratio (0.097), pearson coefficient for oil percentage (0.329) and pearson coefficient for dropped olive percentage (0.051).

Olive fruit percentage yield was negatively correlated with Acidity% values but the correlation was statistically not significant since pearson coefficient for olive fruit percentage yield (-0.194) (Table 4.40).

While a close look at the results in 2014 revealed that olive fly infection, days of storage, green to black olive ratio, olive fruit percentage yield and dropped olive percentage were negatively correlated with Acidity% values but the correlation was statistically not significant since pearson coefficient for olive fly infection (-0.268), pearson coefficient for days of storage (-0.412), pearson coefficient for green to black olive ratio (-0.195), pearson coefficient for olive fruit percentage yield (-0.009), and pearson coefficient for olive fruit percentage yield (-0.191). Only oil percentage has a positive significant correlation with Acidity% values since the correlation coefficient was equal to (0.476) ($p < 0.05$) (Table 4.41).

Table 4.34: Average Acidity% values (% as oleic acid) in different regions in Palestine according to region, farmer code and year; results are expressed as average only since farmers in 2013 in the same region are not themselves in 2014 in the same region.

2013			2014		
Region and significant symbols	**Farmer Code**	**Acidity%**	**Region and significant symbols**	**Farmer Code**	**Acidity%**
Anabta: E,F,G,H	1	1.01	Anabta: A,B,C	1	1.65
A	2	1.69	A,B,C,D,E	2	1.48
Bayt Jala: D,E,F	1	1.25	Bayt Jala: B,C,D,E	1	1.45
A,B,C,D	2	1.45	G,H	2	0.84
Burkin: A,B,C,D	1	1.48	B,C,D,E	3	1.44
A,B	2	1.62	Burkin: E,F	1	1.26
G,H	3	0.98	B,C,D,E	2	1.44
A	4	1.69	Burin: A	1	1.70
Dheisha: E,F,G	1	1.06	Dheisha F,G	1	1.08
I	2	0.60	G,H	2	0.86
H,I	3	0.78	G,H	3	1.00
E,F,G,H	4	1.02	Salfit:F,G	1	1.08
A	5	1.69	A,B,C,D	2	1.61

Asira Al-Shamaliya: G,H,I	1	0.84
A,B	2	1.66
C,D	3	1.34
C,D,E	4	1.26
Si'ir : E,F,G,H	1	1.04
A,B	2	1.64
I	3	0.59
F,G,H	4	1.00
Salfit: E,F,G,H	1	1.04
B,C,D	2	1.41
A,B	3	1.62
A,B,C	4	1.52
E,F,G	5	1.06
G,H	6	0.90
Surif: F,G,H	1	1.00
G,H	2	0.97
A,B,C,D	3	1.46

Al-Shuyukh: A,B,C	1	1.66
A,B,C,D	2	1.61
G,H	3	0.89
I	4	0.51
G,H	5	0.92
F,G	6	1.06
Surif: E	1	1.34
G,H	2	0.90
D,E	3	1.38
H	4	0.77
G,H	5	0.89
Asira Al-Qibliya: A,B,C	1	1.65
C,D,E	2	1.42
A,B	3	1.68
G,H	4	0.90
A,B,C	5	1.64
A,B,C	6	1.04

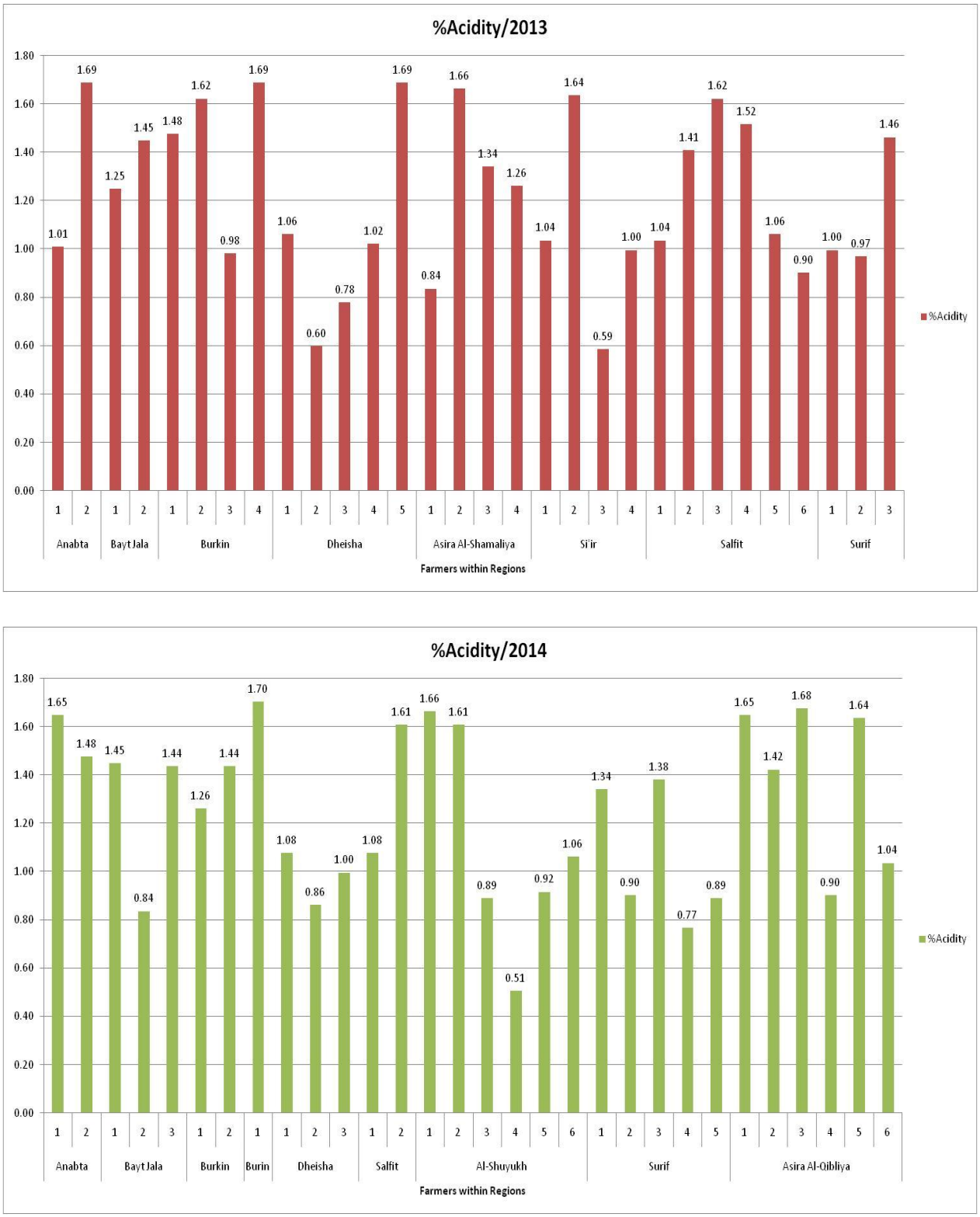


Figure 4.34: Average acidity% values (% as oleic acid) according to region, farmer code and year.

4.5.9. Average peroxide values according to region, farmer code and year

In 2013 it was observed that in Anabta there were two farmers and their Peroxide values were 15.38 and 15.78 respectively, in Bayt Jala there were two farmers and their Peroxide values were 16.91 and 17.65 respectively, in Burkin there were four farmers and their Peroxide values were 18.31, 18.58, 16.65 and 15.98 respectively, in Dheisha there were five farmers and their Peroxide values were 17.65, 15.38, 16.78, 15.25 and 16.11 respectively and in Asira Al-Shamaliya there were four farmers and their Peroxide values were 18.31, 17.25, 17.98 and 17.51 respectively, in Si'ir there were four farmers and their Peroxide values were 16.38, 16.91, 15.25 and 16.38 respectively, in Salfit there were six farmers and their Peroxide values were 16.98, 16.11, 14.98, 17.58, 16.98 and 18.25 respectively and in Surif there were three farmers and their Peroxide values were 15.51, 18.25 and 17.05 respectively (Table 4.35).

In 2014 it was observed that in Anabta there were two farmers and their Peroxide values were 16.38 and 17.25 respectively, in Bayt Jala there were three farmers and their Peroxide values were 17.98, 15.58 and 16.98 respectively, in Burkin there were two farmers and their Peroxide values were 18.11 and 15.38 respectively, in Burin there was one farmer and his Peroxide value was17.45, in Dheisha there were three farmers and their Peroxide values were 17.18, 15.78 and 17.18 respectively, in Salfit there were two farmers and their Peroxide values were 16.98 and 17.18 respectively, in Al-Shuyukh there were six farmers and their Peroxide values were 16.25, 17.18, 16.51, 18.78, 17.51 and 16.91 respectively, in Surif there were five farmers and their Peroxide values were 15.58, 18.05, 18.51, 17.78 and 16.85 respectively and in Asira Al-Qibliya there were six farmers and their Peroxide values were 17.38, 16.98, 16.78, 16.11, 16.71 and 17.51 respectively (Table 4.35).

Peroxide value for our samples range between 14.98-18.78 (milliequivalents O_2 kg^{-1} oil).

According to Codex Alimentarius Commission (2001), peroxide value for virgin olive oil (in milliequivalents O_2/kg oil) ≤ 20.

Peroxide values of our samples when compared with the limits fixed in the Codex Alimentarius Commission (2001), it can be seen that all the samples analysed comply with the standard and can therefore be graded as extra virgin (PV$\leq$20).

Amarna et al (2011) showed that average peroxide value of their olive oil samples was 19.1 meq O_2/kg which was in agreement with our results.

Fakhri & Qadir (2011) reported that in comparison between the specific gravity and iodine value, it was suggested that as the specific gravity is lower represent that the iodine value is higher values, also when the peroxide value is high and has abnormal range value, the iodine value is also high and has abnormal range, but not vice versa, while Mailer et al (2005) reported that peroxide value was shown to be higher in young olives than later in the season although that was not understood and also it was influenced by years ($p = 0.010$ to < 0.001), but from another point of view Essiari et al (2014) reported that there were a clear effect of oil extraction immediately after the olives had been harvested and they emphasize the effect of geographical origin and year on peroxide values, while El Sohaimy et al (2016) reported that peroxide values increased significantly with developing in the ripening process for the examined varieties of olive fruits which was in agreement with Desouky et al (2009) who remarked that peroxide values in extracted oils in purple as well as in black fruits were significantly higher than those from green fruits, while Rahmani et al (1997) mentioned that peroxide values did not change significantly during the maturation periods.

Only green to black olive ratio of our samples has a positive significant correlation with peroxide values since the correlation coefficient was equal to (0.49) ($p < 0.01$).

Some of our samples were from green olives, others from black and most of them were mixture between green and black in different proportions, therefore that may have affected the results since (Tetik 2005) stated that green table cultivars should be harvested at green maturity whereas black table cultivars should be harvested at black maturity since Kaynas et al. (2002) reported that green maturity started at the end of September or the beginning of october in the marmara region and the latest green maturity cultivars were 'Domat' and 'Manzanilla de Sevilla', while black maturity begins in the last week of November and Toplu et al (2009) was in agreement with the same results.

In 2013, olive fly infection, oil percentage and dropped olive percentage were positively correlated with peroxide values but the correlation was statistically not significant since

pearson coefficient for olive fly infection (0.133), pearson coefficient for oil percentage (0.184) and pearson coefficient for dropped olive percentage (0.111).

Days of storage and olive fruit percentage yield were negatively correlated with Peroxide values but the correlation was statistically not significant since pearson coefficient days of storage (-0.069) and pearson coefficient for olive fruit percentage yield (-0.343).

Only green to black olive ratio has a positive significant correlation with Peroxide values since the correlation coefficient was equal to (0.49) ($p < 0.01$) (Table 4.40).

While a close look at the results in 2014 revealed that green to black olive ratio was positively correlated with Peroxide values but the correlation was statistically not significant since pearson coefficient for green to black olive ratio (0.124).

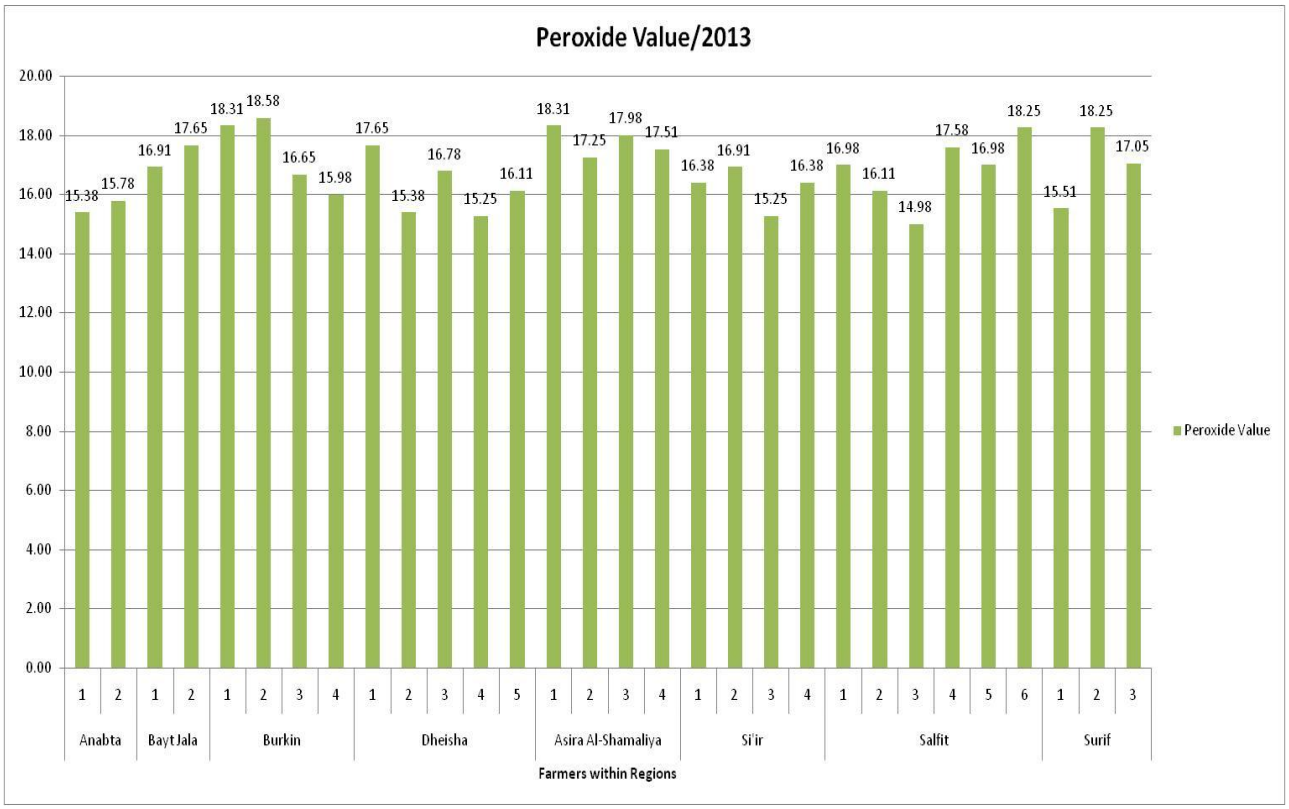
Olive fly infection, days of storage, oil percentage dropped olive percentage and olive fruit percentage yield were negatively correlated with Peroxide values but the correlation was statistically not significant since pearson coefficient for olive fly infection (-0.129), pearson coefficient for days of storage (-0.105), pearson coefficient for oil percentage (-0.167), pearson coefficient for dropped olive percentage (-0.169), and pearson coefficient for olive fruit percentage yield (-0.091) (Table 4.41).

Table 4.35: Average peroxide values (milliequivalents O_2 kg^{-1} oil) in different regions in Palestine according to region, farmer code and year; results are expressed as average only since farmers in 2013 in the same region are not themselves in 2014 in the same region.

2013			2014		
Region and significant symbols	**Farmer Code**	**Peroxide Value**	**Region and significant symbols**	**FarmerCode**	**Peroxide Value**
Anabta: N,O	1	15.38	Anabta: K,L,M,N	1	16.38
L,M,N	2	15.78	F,G,H,I,J	2	17.25
Bayt Jala: G,H,I	1	16.91	Bayt Jala: B,C,D,E	1	17.98
C,D	2	17.65	O,P	2	15.58
Burkin : A,B	1	18.31	G,H,I,J,K	3	16.98
A	2	18.58	Burkin: B,C	1	18.11
H,I,J	3	16.65	O	2	15.38
K,L,M	4	15.98	Burin: D,E,F,G,H	1	17.45
Dheisha: C,D	1	17.65	Dheisha: F,G,H,I,J	1	17.18
N,O	2	15.38	N,O,P	2	15.78
G,H,I	3	16.78	F,G,H,I,J	3	17.18
N,O	4	15.25	Salfit:G,H,I,J,K	1	16.98
J,K,L	5	16.11	F,G,H,I,J	2	17.18

Asira Al-Shamaliya: A,B	1	18.31
D,E,F,G	2	17.25
B,C	3	17.98
C,D,E,F	4	17.51
Si'ir: I,J,K	1	16.38
G,H,I	2	16.91
N,O	3	15.25
I,J,K	4	16.38
Salfit : F,G,H	1	16.98
J,K,L	2	16.11
O	3	14.98
C,D,E	4	17.58
F,G,H	5	16.98
A,B	6	18.25
Surif : M,N,O	1	15.51
A,B	2	18.25
E,F,G,H	3	17.05

Al-Shuyukh: L,M,N	1	16.25
F,G,H,I,J	2	17.18
K,L,M	3	16.51
A	4	18.78
C,D,E,F,G	5	17.51
G,H,I,J,K	6	16.91
Surif: O,P	1	15.58
B,C,D	2	18.05
A,B	3	18.51
C,D,E,F	4	17.78
H,I,J,K,L	5	16.85
Asira Al-Qibliya:E,F,G,H,I	1	17.38
G,H,I,J,K	2	16.98
I,J,K,L	3	16.78
M,N,O	4	16.11
J,K,L,M	5	16.71
J,K,L,M	6	17.51



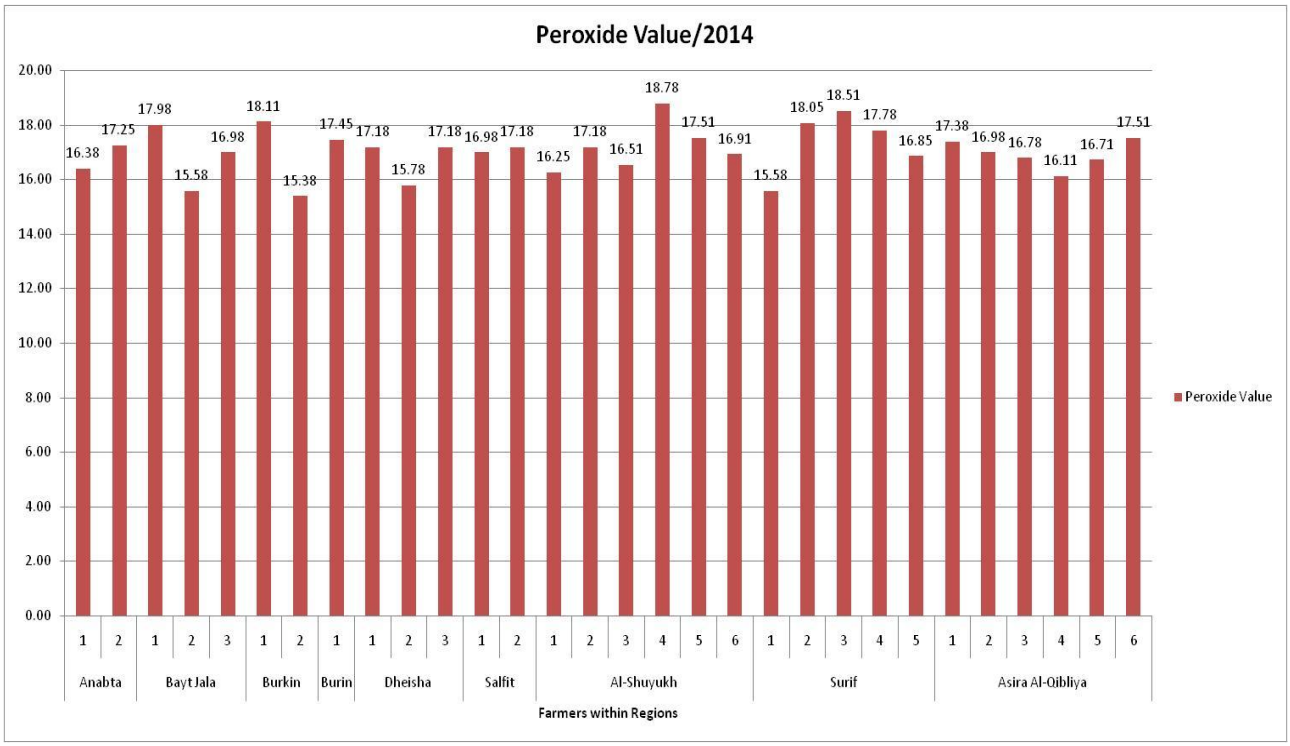


Figure 4.35: Average peroxied values (milliequivalents O_2 kg^{-1} oil) according to region, farmer code and year.

4.5.10. Average specific gravity values according to region, farmer code and year

In 2013 it was observed that in Anabta there were two farmers and their specific gravity values were 0.9173 and 0.9150 respectively, in Bayt Jala there were two farmers and their specific gravity values were 0.9156 and 0.9190 respectively, in Burkin there were four farmers and their specific gravity values were 0.9105, 0.9113, 0.9100 and 0.9186 respectively, in Dheisha there were five farmers and their specific gravity values were 0.9151, 0.9124, 0.9071, 0.9094 and 0.9117 respectively and in Asira Al-Shamaliya there were four farmers and their specific gravity values were 0.9106, 0.9118, 0.9135 and 0.9158 respectively, in Si'ir there were four farmers and their specific gravity values were 0.9190, 0.9120, 0.9199 and 0.9141 respectively, in Salfit there were six farmers and their specific gravity values were 0.9104, 0.9112, 0.9057, 0.9102, 0.9045 and 0.9192 respectively and in Surif there were three farmers and their specific gravity values were 0.9108, 0.9164 and 0.9093 respectively (Table 4.36).

In 2014 it was observed that in Anabta there were two farmers and their specific gravity values were 0.9122 and 0.9114 respectively, in Bayt Jala there were three farmers and their specific gravity values were 0.9090, 0.9118 and 0.9112 respectively, in Burkin there were two farmers and their specific gravity values were 0.9173 and 0.9100 respectively, in Burin there was one farmer and his specific gravity value was 0.9175, in Dheisha there were three farmers and their specific gravity values were 0.9128, 0.9094 and 0.9119 respectively, in Salfit there were two farmers and their specific gravity values were 0.9180 and 0.9129 respectively, in Al-Shuyukh there were six farmers and their specific gravity values were 0.9142, 0.9123, 0.9082, 0.9163, 0.9188 and 0.9152 respectively, in Surif there were five farmers and their specific gravity values were 0.9141, 0.9158, 0.9176, 0.9117 and 0.9106 respectively and in Asira Al-Qibliya there were six farmers and their specific gravity values were 0.9065, 0.9156, 0.9097, 0.9095, 0.9097 and 0.9125 respectively (Table 4.36).

The average specific gravity values of our study ranged from 0.9045-0.9199 (dimensionless quantity).

According to Codex Alimentarius Commission (2003) specific gravity (Relative density) for virgin olive oil (20°C/water at 20°C) range between 0.910-0.916, so our oil samples are in EVOO category. Zafar (2012) reported that average specific gravity value for olive oil

samples extracted from olives grown in Khyber pakhtunkhwa was 0.91. Fakhri & Qadir (2011) reported that in comparison between the specific gravity and iodine value, it was suggested that as the specific gravity is lower the iodine value is higher. Also the study shows that when the peroxide value is high and has abnormal range value, the iodine value is also high and has abnormal range but not vice versa and they showed that density and specific gravity may not seem an exciting physical property for evaluating edible oils.

Only oil percentage has a negative significant correlation with Specific gravity values since the correlation coefficient was equal to (-0.456) ($p < 0.05$).

In 2013, days of storage and green to black olive ratio were positively correlated with specific gravity values but the correlation was statistically not significant since pearson coefficient for days of storage (0.009) and pearson coefficient for green to black olive ratio (0.242).

Olive fly infection, dropped olive percentage and olive fruit percentage yield were negatively correlated with specific gravity values but the correlation was statistically not significant since pearson coefficient olive fly infection (-0.04), pearson coefficient dropped olive percentage (-0.152) and pearson coefficient for olive fruit percentage yield (-0.174).

Only oil percentage has a negative significant correlation with specific gravity values since the correlation coefficient was equal to (-0.456) ($p < 0.05$) (Table 4.40).

While a close look at the results in 2014 revealed that olive fly infection, days of storage and dropped olive percentage were positively correlated with specific gravity values but the correlation was statistically not significant since pearson coefficient for olive fly infection (0.176), pearson coefficient for days of storage (0.139) and pearson coefficient for dropped olive percentage (0.369).

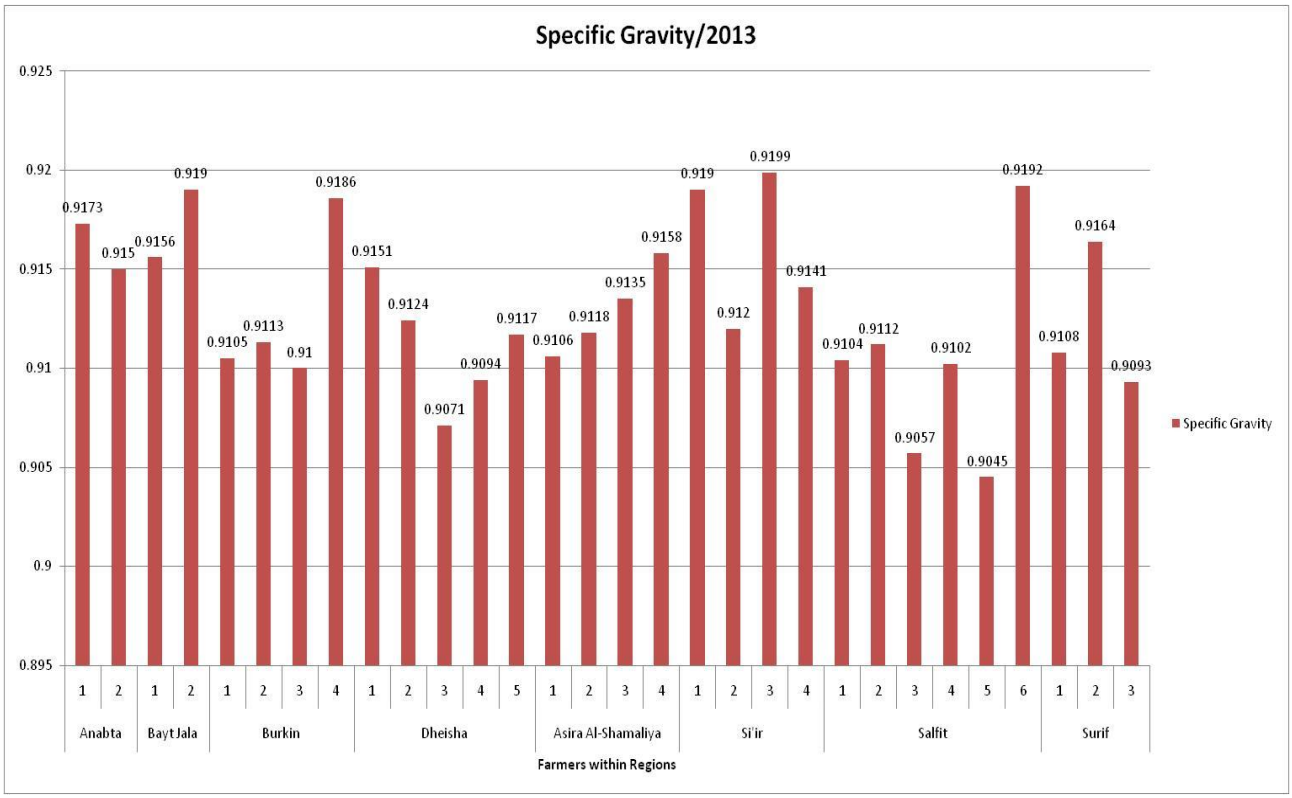
Green to black olive ratio, oil percentage and olive fruit percentage yield were negatively correlated with Specific gravity values but the correlation was statistically not significant since pearson coefficient for green to black olive ratio (-0.346), pearson coefficient for oil percentage (-0.282), and pearson coefficient for olive fruit percentage yield (-0.156) (Table 4.41).

Table 4.36: Average oil specific gravity values (dimensionless quantity) in different regions in Palestine according to region, farmer code and year; results are expressed as average only since farmers in 2013 in the same region are not themselves in 2014 in the same region.

2013			2014		
Region and significant symbols	**Farmer Code**	**Oil Specific gravity V**	**Region and significant symbols**	**Farmer Code**	**Oil Specific gravity V**
Anabta: F,G	1	0.9173	Anabta: C	1	0.9122
H	2	0.9150	J	2	0.9114
Bayt Jala: M	1	0.9156	Bayt Jala: A	1	0.9090
B	2	0.9190	C	2	0.9118
Burkin: I,J,K	1	0.9105	C	3	0.9112
I,J	2	0.9113	Burkin: D,E	1	0.9173
A	3	0.9100	G	2	0.9100
M	4	0.9186	Burin: H	1	0.9175
Dheisha: H	1	0.9151	Dheisha: B	1	0.9128
C	2	0.9124	G	2	0.9094
L	3	0.9071	B	3	0.9119
J,K	4	0.9094	Salfit: H	1	0.9180
I	5	0.9117	I	2	0.9129
Asira Al-Shamaliya: P	1	0.9106	Al-Shuyukh: F	1	0.9142

I	2	0.9118
D,E	3	0.9135
G,H	4	0.9158
Si'ir: E,F	1	0.9190
I	2	0.9120
E	3	0.9199
N	4	0.9141
Salfit : I,J,K	1	0.9104
P	2	0.9112
Q	3	0.9057
I,J,K	4	0.9102
Q	5	0.9045
O	6	0.9192
Surif: I,J,K	1	0.9108
C,D	2	0.9164
K	3	0.9093

J	2	0.9123
G	3	0.9082
B	4	0.9163
D	5	0.9188
H	6	0.9152
Surif: H	1	0.9141
E,F	2	0.9158
B	3	0.9176
I	4	0.9117
H	5	0.9106
Asira Al-Qibliya: K	1	0.9065
I	2	0.9156
G	3	0.9097
K	4	0.9095
G	5	0.9097
G	6	0.9125



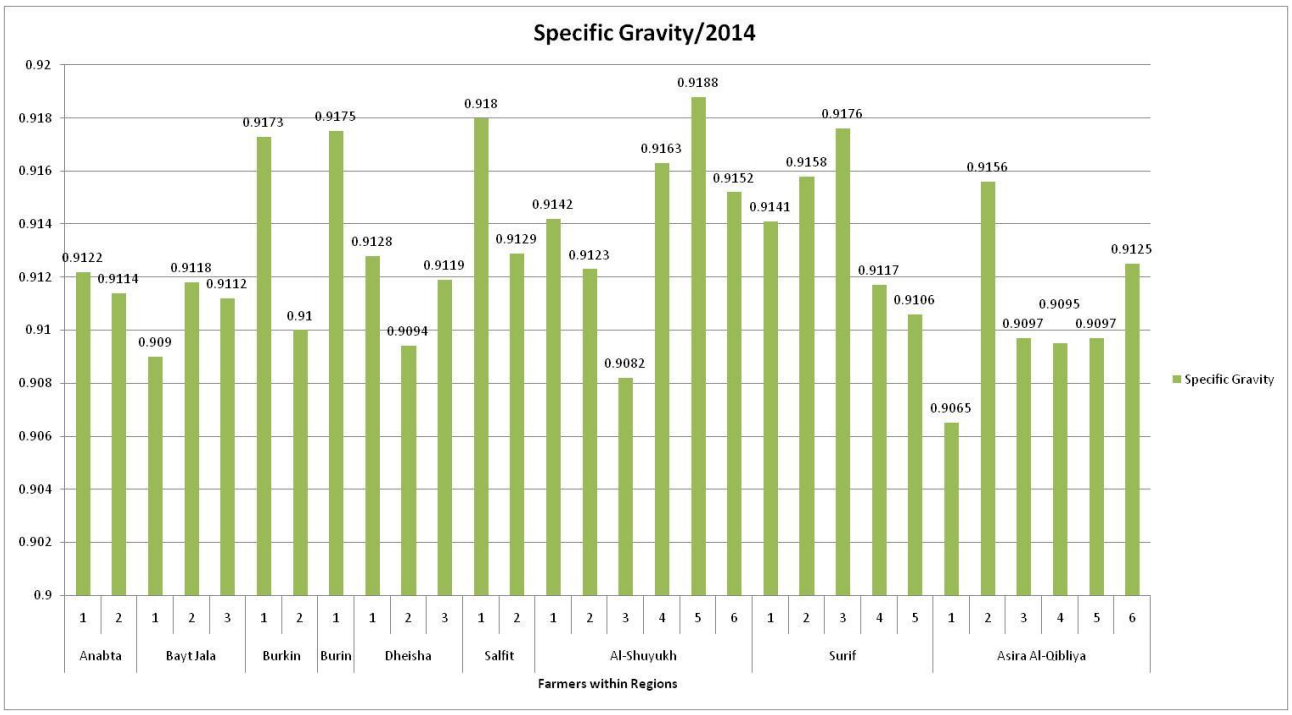


Figure 4.36: Average oil specific gravity values (dimensionless quantity) according to region, farmer code and year.

4.5.11. Average refractive index values according to region, farmer code and year

In 2013 it was observed that in Anabta there were two farmers and their refractive index values were 1.4647 and 1.4657 respectively, in Bayt Jala there were two farmers and their refractive index values were 1.4657 and 1.4657 respectively, in Burkin there were four farmers and their refractive index values were 1.4647, 1.4647, 1.4647 and 1.4647 respectively, in Dheisha there were five farmers and their refractive index values were 1.4647, 1.4657, 1.4657, 1.4657 and 1.4657 respectively and in Asira Al-Shamaliya there were four farmers and their refractive index values were 1.4657, 1.4647, 1.4647 and 1.4657 respectively, in Si'ir there were four farmers and their refractive index values were 1.4657, 1.4657, 1.4657 and 1.4667 respectively, in Salfit there were six farmers and their refractive index values were 1.4657, 1.4657, 1.4657, 1.4647, 1.4657 and 1.4647 respectively and in Surif there were three farmers and their refractive index values were 1.4657, 1.4657 and 1.4647 respectively (Table 4.37).

In 2014 it was observed that in Anabta there were two farmers and their refractive index values were 1.4657 and 1.4657 respectively, in Bayt Jala there were three farmers and their refractive index values were 1.4657, 1.4647 and 1.4657 respectively, in Burkin there were two farmers and their refractive index values were 1.4647 and 1.4657 respectively, in Burin there was one farmer and his refractive index value was 1.4667, in Dheisha there were three farmers and their refractive index values were 1.4657, 1.4657 and 1.4647 respectively, in Salfit there were two farmers and their refractive index values were 1.4657 and 1.4657 respectively, in Al-Shuyukh there were six farmers and their refractive index values were 1.4657, 1.4667, 1.4657, 1.4657, 1.4647 and 1.4657 respectively, in Surif there were five farmers and their refractive index values were 1.4647, 1.4657, 1.4657, 1.4657 and 1.4657 respectively and in Asira Al-Qibliya there were six farmers and their refractive index values were 1.4657, 1.4647, 1.4667, 1.4657, 1.4667 and 1.4657 respectively (Table 4.37).

The refractive index values of our study ranged from 1.4647-1.4667 (dimensionless quantity).

According to Codex Alimentarius Commission (2001) refractive index values range between 1.4677 - 1.4705 (dimensionless quantity), so our results were slightly lower than the range for

the temperature effect since Fakhri& Qadir (2011) showed that refractive index values decrease with increasing temperatures.

El Sohaimy et al (2016) reported that refractive index values of Manzanilla oil were between 1.4674-1.4677 and 1.4678-1.4683 for Kalamata oil, while Amarna et al (2011) showed that average refractive index of their oil samples was 1.4696, while Ali & El-Waseif (2015) and Ghanbari et al (2012) reported that average refractive index value at 25 ºC of olive oil extracted from Manzanillo olive fruits was1.4704 and that was in agreement with IOOC Standard for olive oils and olive pomace oils (2001), and from the otherhand Bahti (2014) showed that the refractive index of the olive oil samples studied against storage ages decreases as a function of storage age and reported that the average value of refractive index of all olive oil samples was 1.4708 and the range of refractive index of all samples extended from 1.4690 (16 years storage age) to 1.4718 (1 year storage age).

Only green to black olive ratio and oil percentage have a negative significant correlation with Refractive Index values in 2013 since the correlation coefficients were equal to (-0.4) ($p < 0.05$) for green to black olive ratio and equal to (-0.462) ($p < 0.05$) for oil percentage while in 2014 only green to black olive ratio has a negative significant correlation with Refractive Index values since the correlation coefficient was equal to (-0.452) ($p < 0.05$).

In 2013, dropped olive percentage and olive fruit percentage yield were positively correlated with Refractive Index values but the correlation was statistically not significant since pearson coefficient for dropped olive percentage (0.238) and pearson coefficient for olive fruit percentage yield (0.168).

Olive fly infection and days of storage were negatively correlated with Refractive Index values but the correlation was statistically not significant since pearson coefficient olive fly infection (-0.118) and pearson coefficient for days of storage (-0.268).

Only green to black olive ratio and oil percentage have a negative significant correlation with Refractive Index values since the correlation coefficients were equal to (-0.4) ($p < 0.05$) for green to black olive ratio and equal to (-0.462) ($p < 0.05$) for oil percentage (Table 4.40).

While a close look at the results in 2014 revealed that oil percentage was positively correlated with Refractive Index values but the correlation was statistically not significant since pearson coefficient for oil percentage (0.045).

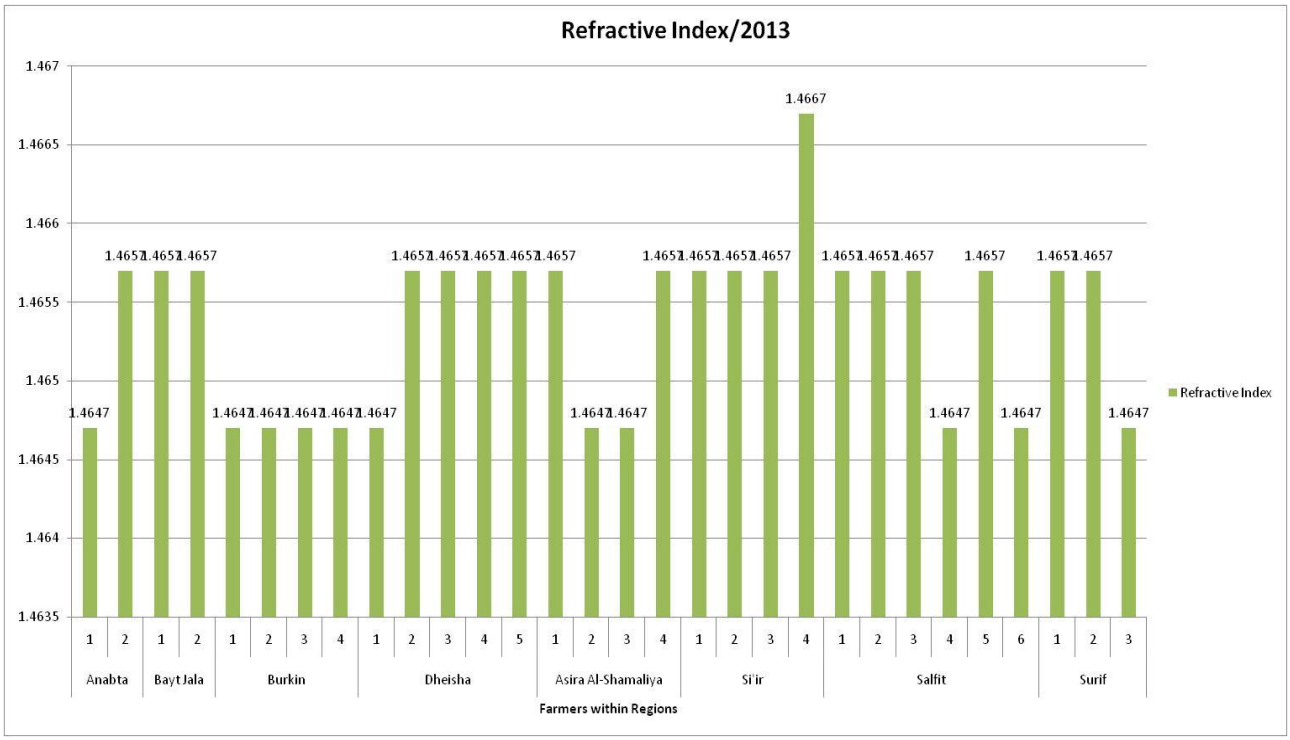
Olive fly infection, days of storage, dropped olive percentage and olive fruit percentage yield were negatively correlated with Refractive Index values but the correlation was statistically not significant since pearson coefficient for olive fly infection (-0.495), pearson coefficient for days of storage (-0.102), pearson coefficient for dropped olive percentage (-0.101) and pearson coefficient for olive fruit percentage yield (-0.062).

Only green to black olive ratio has a negative significant correlation with Refractive Index values since the correlation coefficient was equal to (-0.452) ($p < 0.05$) (Table 4.41).

Table 4.37: Average refractive index values (dimensionless quantity) in different regions in Palestine according to region, farmer code and year; results are expressed as average only since farmers in 2013 in the same region are not themselves in 2014 in the same region.

2013			2014		
Region and significant symbols	**Farmer Code**	**Refractive**	**Region and significant symbols**	**Farmer Code**	**Refractive**
Anabta: C	1	1.4647	Anabta:B	1	1.4657
B	2	1.4657		2	1.4657
Bayt Jala: B	1	1.4657	Bayt Jala:B	1	1.4657
B	2	1.4657	B	2	1.4647
Burkin: C	1	1.4647	B	3	1.4657
C	2	1.4647	Burkin:C	1	1.4647
C	3	1.4647	B	2	1.4657
C	4	1.4647	Burin:A	1	1.4667
Dheisha: C	1	1.4647	Dheisha:B	1	1.4657
B	2	1.4657	B	2	1.4657
B	3	1.4657	C	3	1.4647
B	4	1.4657	Salfit:B	1	1.4657
B	5	1.4657	B	2	1.4657
Asira Al-Shamaliya: B	1	1.4657	Al-Shuyukh: B	1	1.4657

C	2	1.4647	A	2	1.4667
C	3	1.4647	B	3	1.4657
B	4	1.4657	B	4	1.4657
Si'ir: B	1	1.4657	C	5	1.4647
B	2	1.4657	B	6	1.4657
B	3	1.4657	Surif: C	1	1.4647
A	4	1.4667	B	2	1.4657
Salfit: B	1	1.4657	B	3	1.4657
B	2	1.4657	B	4	1.4657
B	3	1.4657	B	5	1.4657
C	4	1.4647	Asira Al-Qibliya:B	1	1.4657
B	5	1.4657	C	2	1.4647
C	6	1.4647	A	3	1.4667
Surif: B	1	1.4657	B	4	1.4657
B	2	1.4657	A	5	1.4667
C	3	1.4647	A	6	1.4657



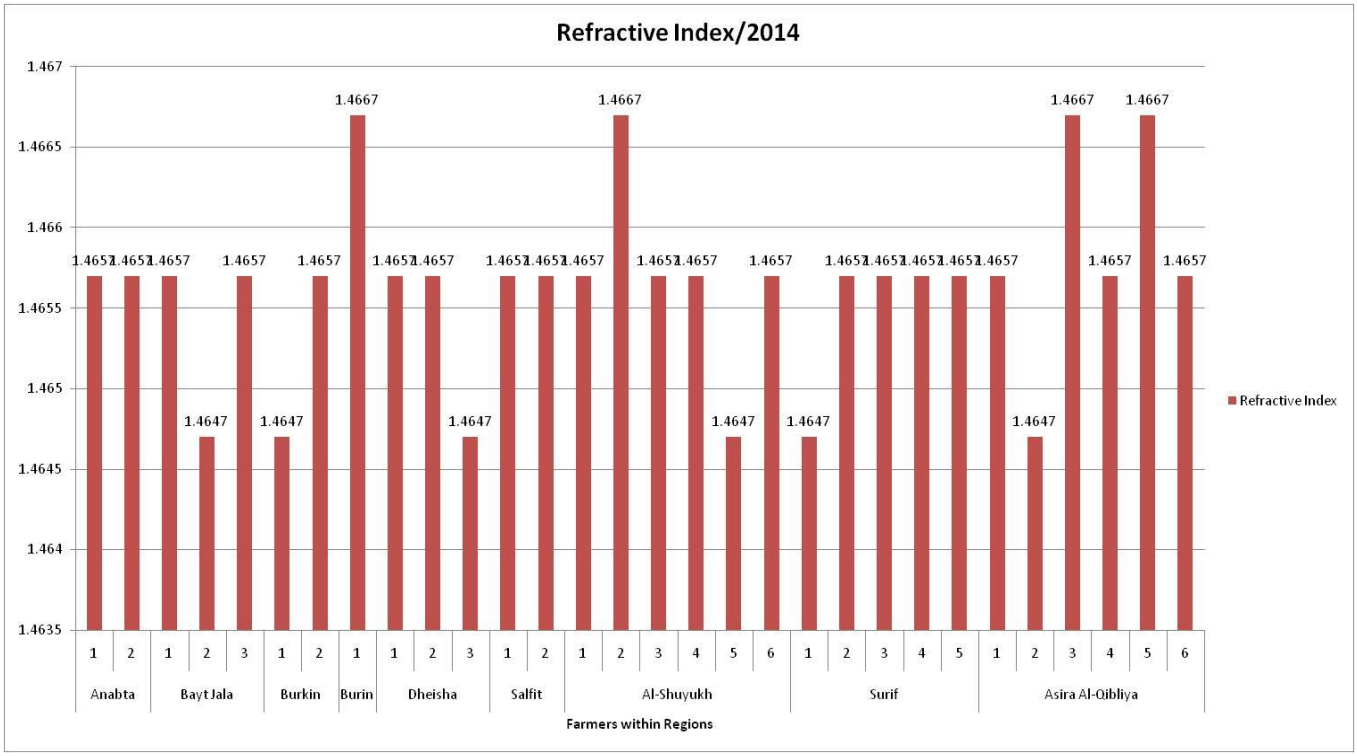


Figure 4.37: Average refractive index values (dimensionless quantity) according to region, farmer code and year.

4.5.12. Average K_{270} values according to region, farmer code and year

In 2013 it was observed that in Anabta there were two farmers and their K_{270} values were 0.2353 and 0.2277 respectively, in Bayt Jala there were two farmers and their K_{270} values were 0.2337 and 0.2263 respectively, in Burkin there were four farmers and their K_{270} values were 0.2333, 0.2203, 0.2237 and 0.2323 respectively, in Dheisha there were five farmers and their K_{270} values were 0.2127, 0.2337, 0.2273, 0.2317 and 0.2447 respectively and in Asira Al-Shamaliya there were four farmers and their K_{270} values were 0.2350, 0.2233, 0.2463 and 0.2377 respectively, in Si'ir there were four farmers and their K_{270} values were 0.2233, 0.2443, 0.2123 and 0.2150 respectively, in Salfit there were six farmers and their K_{270} values were 0.2167, 0.2207, 0.2157, 0.2143, 0.2477 and 0.2383 respectively and in Surif there were three farmers and their K_{270} values were 0.2317, 0.2413 and 0.2120 respectively (Table 4.38).

In 2014 it was observed that in Anabta there were two farmers and their K_{270} values were 0.2397 and 0.2227 respectively, in Bayt Jala there were three farmers and their K_{270} values were 0.2273, 0.2167 and 0.2123 respectively, in Burkin there were two farmers and their K_{270} values were 0.2147 and 0.2157 respectively, in Burin there was one farmer and his K_{270} value was 0.2307, in Dheisha there were three farmers and their K_{270} values were 0.2130, 0.2193 and 0.2193 respectively, in Salfit there were two farmers and their K_{270} values were 0.2127 and 0.2143 respectively, in Al-Shuyukh there were six farmers and their K_{270} values were 0.2153, 0.2213, 0.2123, 0.2170, 0.2157 and 0.2163 respectively, in Surif there were five farmers and their K_{270} values were 0.2227, 0.2247, 0.2433, 0.2477 and 0.2337 respectively and in Asira Al-Qibliya there were six farmers and their K_{270} values were 0.2137, 0.2187, 0.2173, 0.2167, 0.2213 and 0.2283 respectively (Table 4.38).

Our K_{270} values were between 0.2120-0.2477 ($K_{1\%}$/1cm).

According to Codex Alimentarius Commission (2003) the absorbency in ultraviolet at 270 nm for virgin olive oil ≤ 0.25, so our oil samples are in EVOO category.

Ranalli et al (1996) and Kiritsakis (1998) reported that geographical origin has no significant influence on K_{232} and K_{270} which are basically affected by factors that cause fruit damage such as attacks from olive fruit fly or damage from harvest equipment or during fruit transportation and storage and said that K values significantly decreased from Intense green stage to black

stage but still within standard limit and found that K_{270} was between 0.10 and 0.18 for Manzanilla oil ($p<0.005$). while K_{270} was varied from 0.116-0.140 for Kalamata oil ($p<0.005$), and the obtained results confirmed the high purity and freshness of the oil especially in reddish maturation stage but these findings disagreed with the study of Desouky et al (2009) who reported that the K_{232} or K_{270} values increased significantly from purple to black fruits.

In 2013, olive fly infection, green to black olive ratio, and dropped olive percentage were positively correlated with K_{270} values but the correlation was statistically not significant since pearson coefficient for olive fly infection (0.14), pearson coefficient for green to black olive ratio (0.109) and dropped olive percentage (0.314).

Days of storage, oil percentage and olive fruit percentage yield were negatively correlated with K_{270} values but the correlation was statistically not significant since pearson coefficient days of storage (-0.118), pearson coefficient oil percentage (-0.092) and pearson coefficient for olive fruit percentage yield (-0.265) (Table 4.40).

While a close look at the results in 2014 revealed that days of storage and olive fruit percentage yield were positively correlated with K_{270} values but the correlation was statistically not significant since pearson coefficient for days of storage (0.211) and pearson coefficient for olive fruit percentage yield (0.289).

Olive fly infection, green to black olive ratio, oil percentage and dropped olive percentage were negatively correlated with K_{270} values but the correlation was statistically not significant since pearson coefficient for olive fly infection (-0.129), pearson coefficient for green to black olive ratio (-0.121), pearson coefficient for oil percentage (-0.371), pearson coefficient for dropped olive percentage (-0.101) and pearson coefficient for dropped olive percentage (-0.148) (Table 4.41).

Table 4.38: Average K_{270} values ($K_{1\%}$/1cm) in different regions in Palestine according to region, farmer code and year; results are expressed as average only since farmers in 2013 in the same region are not themselves in 2014 in the same region.

2013			2014		
Region and significant symbols	**Farmer Code**	**K_{270}**	**Region and significant symbols**	**Farmer Code**	**K_{270}**
Anabta: D,E	1	0.2353	Anabta: B	1	0.2397
F,G	2	0.2277	E,F,G	2	0.2227
Bayt Jala D,E	1	0.2337	Bayt Jala:D,E	1	0.2273
G	2	0.2263	H,I,J,K,L	2	0.2167
Burkin: D,E	1	0.2333	L	3	0.2123
H,I	2	0.2203	Burkin: I,J,K,L	1	0.2147
G,H	3	0.2237	I,J,K,L	2	0.2157
E,F	4	0.2323	Burin: C,D	1	0.2307
Dheisha: J	1	0.2127	Dheisha: K,L	1	0.2130
D,E	2	0.2337	G,H,I	2	0.2193
F,G	3	0.2273	G,H,I	3	0.2193
E,F	4	0.2317	Salfit:K,L	1	0.2127
A,B	5	0.2447	J,K,L	2	0.2143
Asira Al-	1	0.2350	Al-Shuyukh:	1	0.2153

Shamaliya: D,E		
G,H	2	0.2233
A,B	3	0.2463
C,D	4	0.2377
Si'ir: G,H	1	0.2233
A,B	2	0.2443
J	3	0.2123
J	4	0.2150
Salfit: I,J	1	0.2167
H,I	2	0.2207
: I,J	3	0.2157
J	4	0.2143
A	5	0.2477
C,D	6	0.2383
Surif: E,F	1	0.2317
B,C	2	0.2413
J	3	0.2120

I,J,K,L		
F,G,H	2	0.2213
L	3	0.2123
H,I,J,K,L	4	0.2170
I,J,K,L	5	0.2157
I,J,K,L	6	0.2163
Surif: E,F,G	1	0.2227
E,F	2	0.2247
A,B	3	0.2433
A	4	0.2477
C	5	0.2337
Asira Al-Qibliya: E,F,G,H,I	1	0.2137
K,L	2	0.2187
H,I,J,K	3	0.2173
H,I,J,K,L	4	0.2167
F,G,H	5	0.2213
F,G,H	6	0.2283

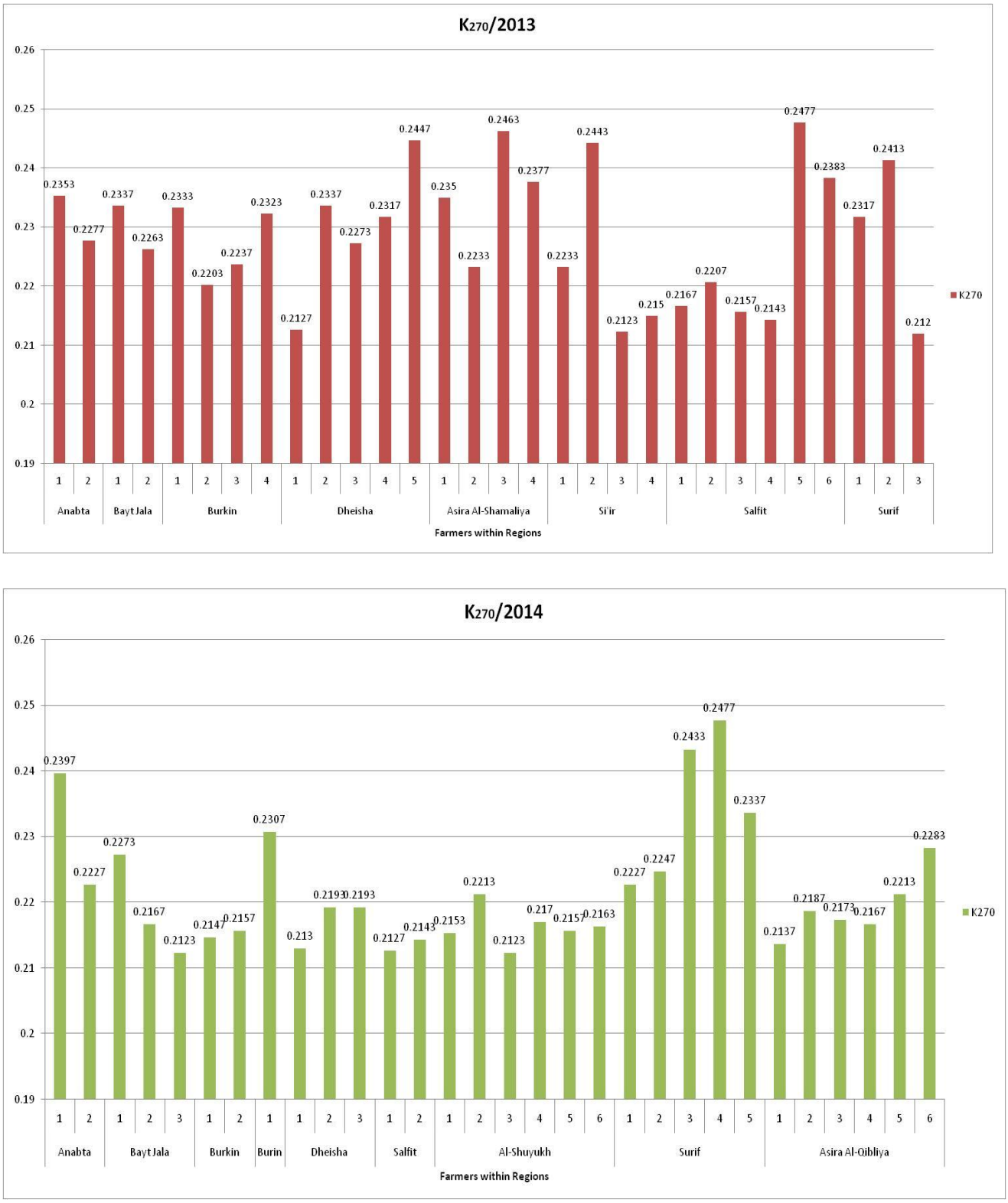


Figure 4.38: Average K_{270} values ($K_{1\%}$/1cm) according to region, farmer code and year.

4.5.13. Average K_{232} values according to region, farmer code and year

In 2013 it was observed that in Anabta there were two farmers and their K_{232} values were 1.63 and 1.66 respectively, in Bayt Jala there were two farmers and their K_{232} values were 1.64 and 1.62 respectively, in Burkin there were four farmers and their K_{232} values were 1.53, 1.53, 1.54 and 1.63 respectively, in Dheisha there were five farmers and their K_{232} values were 1.63, 1.68, 1.68, 1.68 and 1.67 respectively and in Asira Al-Shamaliya there were four farmers and their K_{232} values were 1.68, 1.63, 1.63 and 1.65 respectively, in Si'ir there were four farmers and their K_{232} values were 1.67, 1.67, 1.52 and 1.62 respectively, in Salfit there were six farmers and their K_{232} values were 1.45, 1.62, 1.65, 1.62, 1.63 and 1.45 respectively and in Surif there were three farmers and their K_{232} values were 1.67, 1.68 and 1.64 respectively (Table 4.39).

In 2014 it was observed that in Anabta there were two farmers and their K_{232} values were 1.58 and 1.58 respectively, in Bayt Jala there were three farmers and their K_{232} values were 1.45, 1.49 and 1.48 respectively, in Burkin there were two farmers and their K_{232} values were 1.62 and 1.43 respectively, in Burin there was one farmer and his K_{232} value was1.60, in Dheisha there were three farmers and their K_{232} values were 1.46, 1.48 and 1.50 respectively, in Salfit there were two farmers and their K_{232} values were 1.46 and 1.44 respectively, in Al-Shuyukh there were six farmers and their K_{232} values were 1.48, 1.46, 1.66, 1.43, 1.50 and 1.53 respectively, in Surif there were five farmers and their K_{232} values were 1.57, 1.59, 1.56, 1.62 and 1.65 respectively and in Asira Al-Qibliya there were six farmers and their K_{232} values were 1.46, 1.55, 1.44, 1.44, 1.54 and 1.47 respectively (Table 4.39).

Our K_{232} values were between 1.43-1.68 ($K_{1\%}$/1cm).

According to Codex Alimentarius Commission (2003) absorbency in ultraviolet at 232 nm for virgin olive oil ≤ 2.60, so our oil samples are in the EVOO category.

Ranalli et al (1996) and Kiritsakis (1998) reported that geographical origin has no significant influence on K_{232} and K_{270} which are basically affected by factors that cause fruit damage such as attacks from olive fruit fly or damage from harvest equipment or during fruit transportation and storage and said that K values significantly decreased from Intense green stage to black

stage but still within standard limit and found that K_{232} value was ranged between 1.65 and 2.41. K_{232} was 1.50 -2.17 for Kalamata oil ($p<0.005$).

The obtained results confirmed the high purity and freshness of the oil especially in reddish maturation stage but these findings disagreed with the study of Desouky et al (2009), who reported that the K_{232} or K_{270} values increased significantly from purple to black fruits.

In 2013, dropped olive percentage and olive fruit percentage yield were positively correlated with K_{232} values but the correlation was statistically not significant since pearson coefficient for dropped olive percentage (0.156) and olive fruit percentage yield (0.178).

Olive fly infection, days of storage, green to black olive ratio and oil percentage were negatively correlated with K_{232} values but the correlation was statistically not significant since pearson coefficient olive fly infection (-0.216), pearson coefficient for days of storage (-0.085), pearson coefficient for green to black olive ratio (-0.004) and pearson coefficient for oil percentage (-0.353) (Table 4.40).

While a close look at the results in 2014 revealed that green to black olive ratio and olive fruit percentage yield were positively correlated with K_{232} values but the correlation was statistically not significant since pearson coefficient for green to black olive ratio (0.077) and pearson coefficient for olive fruit percentage yield (0.186).

Olive fly infection, days of storage, oil percentage and dropped olive percentage were negatively correlated with K_{232} values but the correlation was statistically not significant since pearson coefficient for olive fly infection (-0.078), pearson coefficient for days of storage (-0.052), pearson coefficient for oil percentage (-0.026), pearson coefficient for dropped olive percentage (-0.166) and pearson coefficient for dropped olive percentage (-0.148) (Table 4.41).

Table 4.39: Average K_{232} values ($K_{1\%}$/1cm) in different regions in Palestine according to region, farmer code and year; results are expressed as average only since farmers in 2013 in the same region are not themselves in 2014 in the same region.

2013			2014		
Region and significant symbols	**Farmer Code**	**K_{232}**	**Region and significant symbols**	**Farmer Code**	**K_{232}**
Anabta: I	1	1.63	Anabta:E, F	1	1.58
F	2	1.66	F,G	2	1.58
Bayt Jala: H	1	1.64	Bayt Jala: Q	1	1.45
K,L	2	1.62	L,M	2	1.49
Burkin: O	1	1.53	M,N	3	1.48
O	2	1.53	Burkin:C	1	1.62
N	3	1.54	S	2	1.43
J,K,L	4	1.63	Burin: D	1	1.60
Dheisha: I,J	1	1.63	Dheisha: P	1	1.46
A	2	1.68	N,O	2	1.48
B,C	3	1.68	L	3	1.50
A,B	4	1.68	Salfit:Q	1	1.46
E,F	5	1.67	R	2	1.44
Asira Al-Shamaliya: C,D	1	1.68	Al-Shuyukh: O	1	1.48

I,J	2	1.63
I,J,K	3	1.63
G	4	1.65
Si'ir: D,E,F	1	1.67
C,D,E	2	1.67
P	3	1.52
M	4	1.62
Salfit: Q	1	1.45
L,M	2	1.62
G,H	3	1.65
L,M	4	1.62
I	5	1.63
Q	6	1.45
Surif: C,D,E	1	1.67
A	2	1.68
H	3	1.64

P	2	1.46
A	3	1.66
S	4	1.43
L	5	1.50
K	6	1.53
Surif: G,H	1	1.57
E	2	1.59
H	3	1.56
C	4	1.62
B	5	1.65
Asira Al-Qibliya: P,Q	1	1.46
I	2	1.55
R	3	1.44
R	4	1.44
J	5	1.54
J	6	1.47

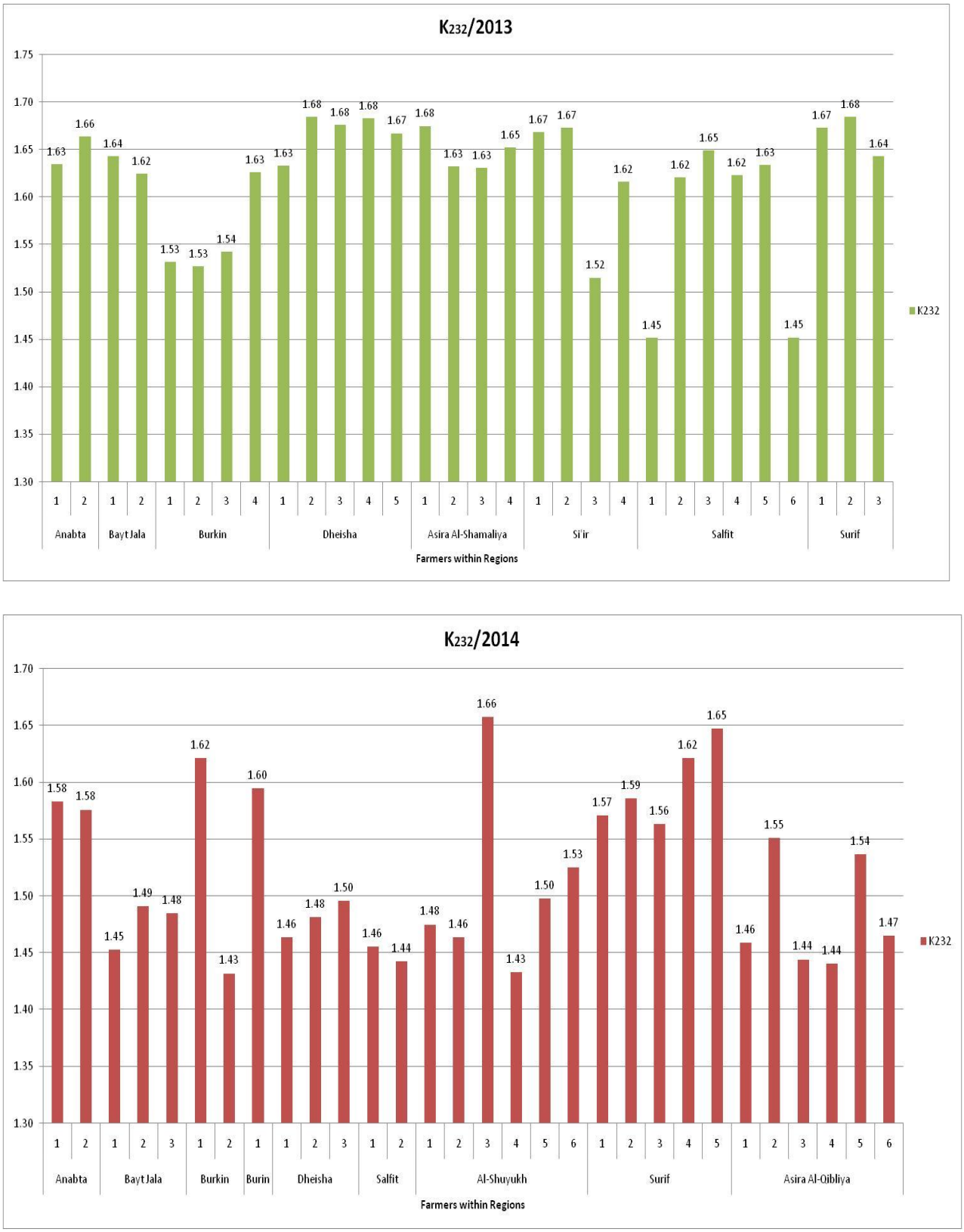


Figure 4.39: Average K_{232} values ($K_{1\%}$/1cm) according to region, farmer code and year.

4.6. Variations of the studied parameters (TPC, TFC, FRAP, CUPRAC, ABTS, DPPH, acidity%, peroxide value, K_{232}, K_{270}, iodine value, specific gravity and refractive index) among farmers

According to ANOVA test analysis and the Tukey HSD post hoc pair wise tests, the conclusions about farmers are as the following:

In 2013, there were significant differences at (α=0.05) between farmers in all scales in Jenin governorate except the refractive scale. There were significant differences at (α=0.05) between farmers in all scales in Nablus governorate. There were significant differences at (α=0.05) between farmers in all scales in Tulkarm governorate except in the peroxide value, DPPH and ABTS scales. Finally, there were significant differences at (α=0.05) between farmers in all scales in both Bethlehem and Hebron governorates.

In 2014, there were significant differences at (α=0.05) between farmers in all scales in Jenin governorate except in K_{270}, Acidity%, FRAP and TPC scales. There were significant differences at (α=0.05) between farmers in all scales in Nablus governorate. There were significant differences at (α=0.05) between farmers in all scales in Tulkarm governorate except in refractive, specific gravity, CUPRAC and TFC scales. There were significant differences at (α=0.05) between farmers in all scales in Bethlehem governorate except in specific gravity and FRAP scales. Finally, there were significant differences at (α=0.05) between farmers in all scales in Hebron governorates.

4.7.Pearson coefficients between studied quality indices (k_{232}, k_{270}, RI, Specific gravity, PV, Acidity%, IV, DPPH, ABTS, CUPRAC, FRAP, TFC, TPC) with some agronomic and olive fruits (olive fly infection, days of storage, green to black%, oil%, drop% and olive yield%) obtained from farmers and oil tests in 2013.

Table 4.40 shows the Pearson correlations between some agronomic and olive fruits treatments with studied quality indices studied in 2013. A close look at the results reveals that the degree of olive fruit infection with olive fly, days of storage before pressing, drop percentage and yield percentage were not significantly correlated with any of the studied olive oil quality parameters. The percentage of green to black olives, and oil percentage were significantly correlated with some oil quality parameters. The percentage of green to black

olives was significantly and negatively correlated with refractive index and total phenolic content while it was positively correlated with peroxide value. Oil percentage had signifact negative correlation with refractive index, oil density and total flavonoids contents, while the correlation with iodine value was significantly positive.

Table 4.40: Pearson coefficients between some agronomic and olive fruits with studied quality indices in 2013.

2013	**TPC**	TFC	FRAP	CUPRAC	ABTS	DPPH	IV	Acidity%	PV	Specific gravity	RI	k_{270}	k_{232}
OFI	0.147	0.093	0.064	0.01	0.194	0.047	0.133	0.04	0.133	-0.04	-0.118	0.14	-0.216
DOS	-0.216	-0.169	-0.164	-0.077	-0.093	0.067	0.095	0.021	-0.069	0.009	-0.268	-0.118	-0.085
GtoBper	**-0.4337 ***	-0.356	-0.202	0.027	-0.284	0.02	-0.091	0.097	**0.49 ****	0.242	**-0.4 ***	0.109	-0.004
Oilper	-0.0368	**-0.416 ***	-0.044	-0.331	-0.212	0.365	**0.48 ****	0.329	0.184	**-0.456 ***	**-0.462 ***	-0.092	-0.353
droper	-0.009	0.009	-0.023	0.007	0.019	-0.205	0.305	0.051	0.111	-0.152	0.238	0.314	0.156
Yieldper	0.282	0.044	0.009	0.138	0.33	0.485	-0.107	-0.194	-0.343	-0.174	0.168	-0.265	0.178

Significance indicated as * for $p < 0.05$, ** for $p < 0.01$, and *** for $p < 0.001$,n=60

4.8. Pearson coefficients between studied quality indices (k_{232}, k_{270}, RI, Specific gravity, PV, Acidity%, IV, DPPH, ABTS, CUPRAC, FRAP, TFC, TPC) with some agronomic and olive fruits (olive fly infection, days of storage, green to black%, oil%, drop% and olive yield%) obtained from farmers and oil tests in 2014.

Table 4.41 shows the Pearson correlations between some agronomic and olive fruits treatments with quality indices studied in 2014. A close look at the results reveals that the degree of olive fruit infection with olive fly, days of storage before pressing and drop percentage were not significantly correlated with any of the studied olive oil quality parameters. The percentage of green to black olives, oil percentage and yield percentage were significantly correlated with some oil quality parameters. The percentage of green to black olives was significantly and negatively correlated with refractive index. Oil percentage had significant positive correlation with DPPH and Acidity%.Yield percentage had significant positive correlation with TPC.

Table 4.41: Pearson coefficients between some agronomic and olive fruits with studied quality indices in 2014.

2014	**TPC**	TFC	FRAP	CUPRAC	ABTS	DPPH	IV	Acidity %	PV	Specific gravity	RI	k_{270}	k_{232}
OFI	0.116	-0.318	0.069	-0.104	-0.105	-0.01	0.027	-0.268	-0.129	0.176	-0.495	-0.129	-0.078
DOS	0.158	0.246	-0.045	0.054	0.307	-0.315	-0.135	-0.412	-0.105	0.139	-0.102	0.211	-0.052
GtoBper	-0.068	-0.227	-0.023	0.104	-0.129	-0.174	-0.157	-0.195	0.124	-0.346	**-0.452 ***	-0.121	0.077
Oilper	-0.102	-0.102	0.108	0.045	-0.191	**0.468 ***	0.139	**0.476 ***	-0.167	-0.282	0.045	-0.371	-0.026
droper	-0.202	-0.24	-0.104	-0.267	-0.169	-0.119	0.123	-0.009	-0.169	0.369	-0.101	-0.148	-0.166
yieldper	**0.449 ***	0.209	0.18	0.291	0.326	-0.291	-0.209	-0.191	-0.091	-0.156	-0.062	0.289	0.186

Significance indicated as * for $p < 0.05$, ** for $p < 0.01$, and *** for $p < 0.001$,n=60

4.9. Correlaions between the studied parameters

A correlation between all studied parameters of the olive oil samples collected in 2013 and 2014 was performed using SAS, see (Table 4.42). Table 4.42 showed that total phenolic content (TPC) is very highly and significantly correlated with TFC, FRAP, CUPRAC, Acidity% and ABTS. TPC is also highly and significantly correlated with Peroxide value and Acidity% and significantly correlated with K_{232}, Specific gravity, while it is not significantly correlated with DPPH, K_{270}, Refractive index, and Iodine value.TFC was found to be very highly and significantly correlated with TPC, ABTS, CUPRAC and FRAP, and highly and significantly correlated with K_{270}, Specific gravity and DPPH, and significantly correlated with K_{232}, Refractive index, Iodine value, while it is not significantly correlated with Peroxide value, and Acidity%.

FRAP was found to be very highly and significantly correlated with TPC, TFC, CUPRAC and ABTS, and significantly correlated with Refractive index, Iodine value, while it is not significantly correlated with K_{232}, K_{270}, Specific gravity, Peroxide value, Acidity% and DPPH. CUPRAC was found to be very highly and significantly correlated with TPC, TFC, FRAP, ABTS, and highly significantly correlated with Specific gravity, K_{232} and significantly correlated with Peroxide value, while it is not significantly correlated with K_{270}, Refractive index, Acidity%, Iodine value and DPPH. ABTS was found to be very highly and significantly correlated with TPC, TFC, FRAP, CUPRAC, and highly significantly correlated with K_{232} and Acidity%, while it is not significantly correlated with Iodine value, Peroxide value, Specific gravity, Refractive index, K_{270} and DPPH. DPPH was found to be very highly and significantly correlated with K_{232} and highly significantly correlated with TFC and significantly correlated with Specific gravity, while it is not correlated with the rest of oil parameters.

Iodine value was found to be very highly and significantly correlated with Acidity% and significantly correlated with K_{232}, specific gravity, FRAP, and TFC, while it is not correlated with the rest of oil parameters. Acidity% was found to be very highly and significantly correlated with Iodine value, and highly significantly correlated with ABTS and TPC, while it is not correlated with the rest of oil parameters. Peroxide value was found to be highly and

significantly correlated with TPC and significantly correlated with K_{232}, K_{270}, Refractive index, CUPRAC, while it is not correlated with the rest of oil parameters.

Specific gravity was found to be highly and significantly correlated with CUPRAC and TFC and significantly correlated with Refractive index, Iodine value, DPPH, TPC, while it is not correlated with the rest of oil parameters. Refractive index was found to be significantly correlated with Specific gravity, Peroxide value, FRAP and TFC, while it is not correlated with the rest of oil parameters.

K_{270} was found to be very highly and significantly correlated with K_{232} and highly significantly correlated with TFC and significantly correlated with Peroxide value, while it is not correlated with the rest of oil parameters. K_{232} was found to be very highly and significantly correlated with K_{270} and highly significantly correlated with TFC and significantly correlated with Peroxide value, while it is not correlated with the rest of oil parameters.

Table 4.42: Pearson coefficients between quality indices of oil samples (TPC, TFC, FRAP, CUPRAC, ABTS, DPPH, Acidity%, Peroxide value, K_{232}, K_{270}, Iodine value, Specific gravity and Refractive index) collected in 2013 and 2014.

	K_{232}	K_{270}	Refractive	Specific gravity	Peroxide value	Acidity %	Iodine value	DPPH	ABTS	CUPRIC	FRAP	TFC	TPC
K_{232}		<.0001***	0.3599	0.1533	0.0656*	0.7085	0.0256*	0.0002***	0.0015**	0.0040**	0.3938	0.0162*	0.0139*
K_{270}			0.8284	0.6388	0.0349*	0.9913	0.1708	0.2729	0.3581	0.2353	0.4081	0.0058**	0.6099
Refractive index				0.0588*	0.0934*	0.2918	0.9910	0.1450	0.9730	0.4074	0.0662*	0.0698*	0.8964
Specific gravity					0.6471	0.3036	0.0164*	0.0113*	0.1066	0.0027**	0.1074	0.0063**	0.0116*
Peroxide value						0.7770	0.6370	0.8760	0.1340	0.0591*	0.3235	0.4020	0.0021**
Acidity%							<.0001***	0.1139	0.0030**	0.5396	0.5191	0.7801	0.0036**
Iodine value								0.5572	0.1636	0.1778	0.0694*	0.0775*	0.3238
DPPH									0.1443	0.1416	0.8724	0.0085**	0.2302

	K_{232}	K_{270}	Refractive index	Specific gravity	Peroxide value	Acidity%	Iodine value	DPPH	ABTS	CUPRIC	FRAP	TFC	TPC
ABTS										<.0001***	<.0001***	<.0001***	<.0001***
CUPRIC											<.0001***	<.0001***	<.0001***
FRAP												<.0001***	<.0001***
TFC													<.0001***
TPC													

Significance indicated as * for $p < 0.05$ (significant correlation), ** for $p < 0.01$ (highly significant correlation), and *** for $p < 0.001$ (very highly significant).

CHAPTER FIVE
GENERAL CONCLUSION AND RECOMMENDATIONS

Conclusion

A set of quality tests and antioxidant activity tests were done on olive oil from different geographical regions in West Bank. Data results were analyzed statistically according to governorates, regions within governorates and farmers within regions.

There is no significant difference in the studied quality parameters of olive oil (TPC, TFC, FRAP, CUPRAC, ABTS, DPPH, acidity%, peroxide value, K_{232}, K_{270}, iodine value, specific gravity and refractive index) between governerates, and to some extent between regions too, while there is a significant difference between farmers.

The quality indices and antioxidant activities of olive oil can be influenced by different factors such as olive fly infection, days of storage between harvesting and oil extraction, green to black olive ratio percentage, oil percentage (percentage weight of extracted oil to weight of olive fruit before extraction), drop percentage (percentage of olive fruit found under the tree before harvesting to the total olive fruit weight) and olive yield percentage (percentage of olive fruit weight in comparison with maximum olive fruit weight ever seen), the growing climate, harvest maturity, olive cultivar, agronomic practices including irrigation or application of fertilizers, ripening hormones and the techniques employed to process and extract the oil and altitude.

Olive oil from West Bank is rich in antioxidants, phenolics and flavonoids when compared to results in other countries such as Turkey and Spain.

Recommendations:

Researchers are advised in such a research to deal with one olive cultivar, pick olive themselves from farmers and make good practices before pressing in the same day, use umber glass to put their oil in before tesing directly, try to choose trees that have the same conditions

such as irrigation, pruning, exposure to sunlight in addition to cultivar, to concentrate on two quality tests and two antioxidant tests and to take other important conditions into consideration.

However, it is very interesting to accomplish this study by other interventions to know more about the different compounds responsible for the antioxidant activity and also to investigate the mechanism of their action in vitro and in vivo.

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Appendices

Appendix A

Table 1: Absorbance of different concentration of Gallic acid

Concentration of Gallic acid (ppm)	Absorbance at λ= (765 nm)
100	0.132
200	0.426
350	0.830
450	1.070
500	1.199

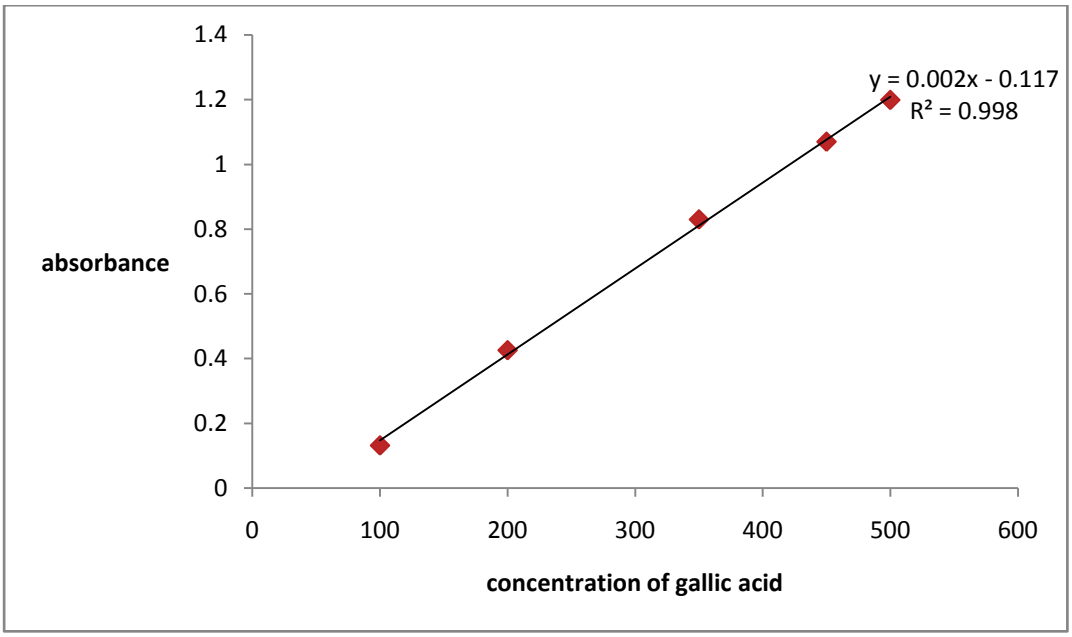

Figure 1: Calibration curve for total phenols content.

Appendix B:

Table 2: Absorbance for different concentration of Catechin.

Concentration of catechin (ppm)	Absorbance λ= (510 nm)
50	0.255
60	0.282
75	0.353
86	0.396
100	0.496

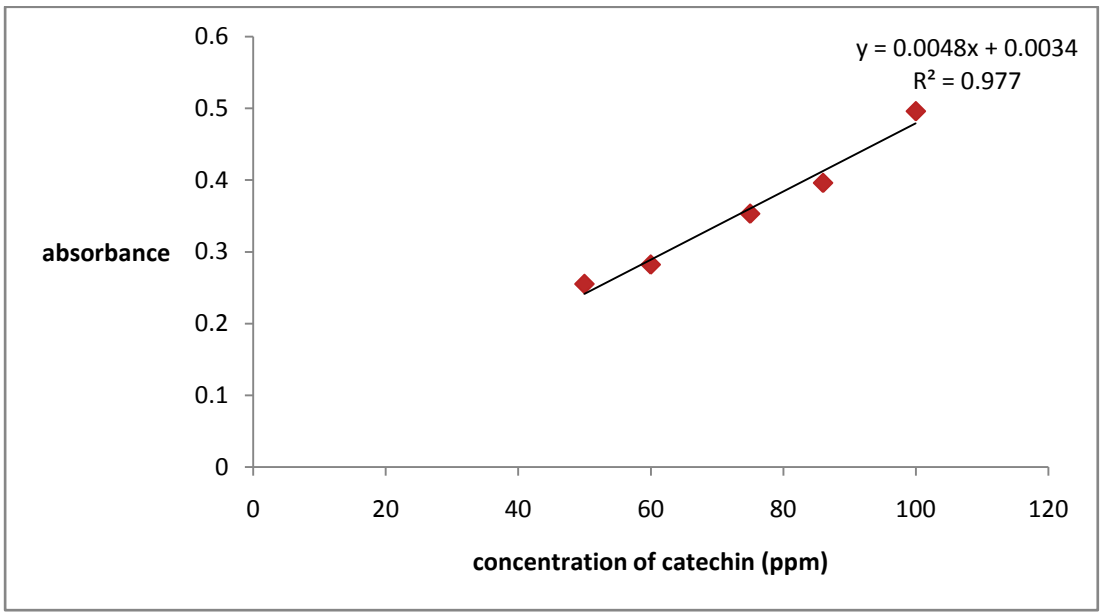

Figure 2: Calibration curve for total flavonoid content. From the calibration curve

Appendix C:

Table 3: Absorbance of different concentration of Ferric ion

Concentration of Fe^{+2} (mM)	Absorbance λ= (593 nm)
2	0.279
2.5	0.299
3	0.400
3.5	0.511
4	0.627
4.5	0.745
5	0.848

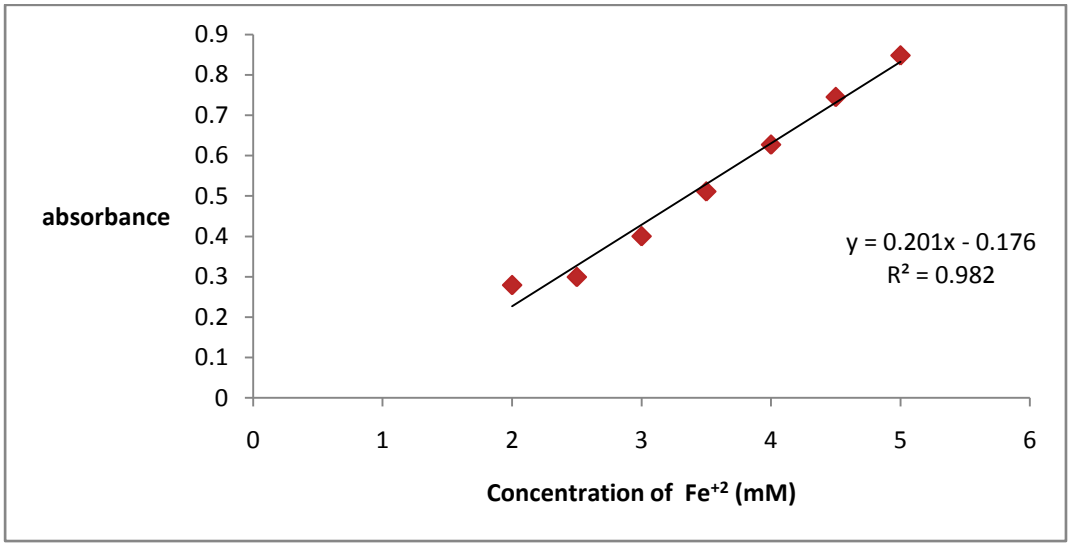

Figure 3: Calibration curve for FRAP antioxidant.

Appendix D:

Table 4: Absorbance for different concentration of trolox

concentration of trolox (ppm)	Absorbance at λ= (450nm)
20	0.032
40	0.059
60	0.077
80	0.098
100	0.118
120	0.142
140	0.168

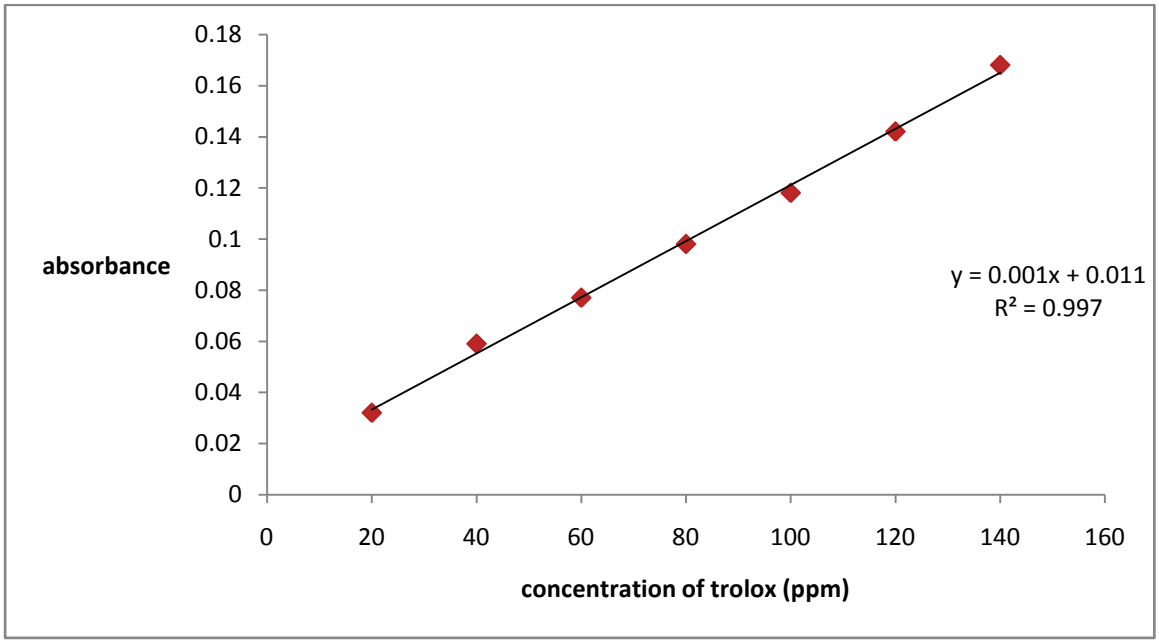

Figure 4: Calibration curve for CUPRAC antioxidant power

Appendix E:

Table 5: Absorbance for different concentration of Trolox

concentration of Trolox (ppm)	Absorbance at λ= (515 nm)
20	0.729
40	0.677
60	0.623
80	0.580
100	0.523
120	0.470

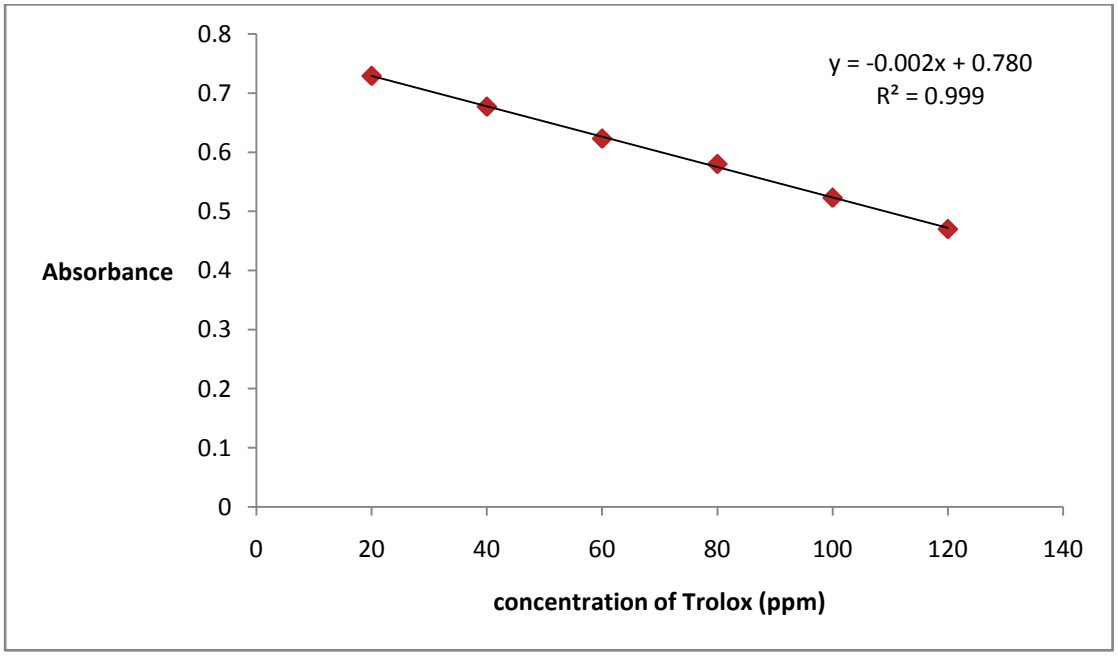

Figure 5: Calibration curve for DPPH

Appendix F

Table 6: Absorbance for different concentration of Trolox

concentration of Trolox (ppm)	Absorbance at λ=(734 nm)
5	0.571
10	0.500
15	0.426
20	0.361
25	0.289
30	0.199
35	0.120
40	0.027

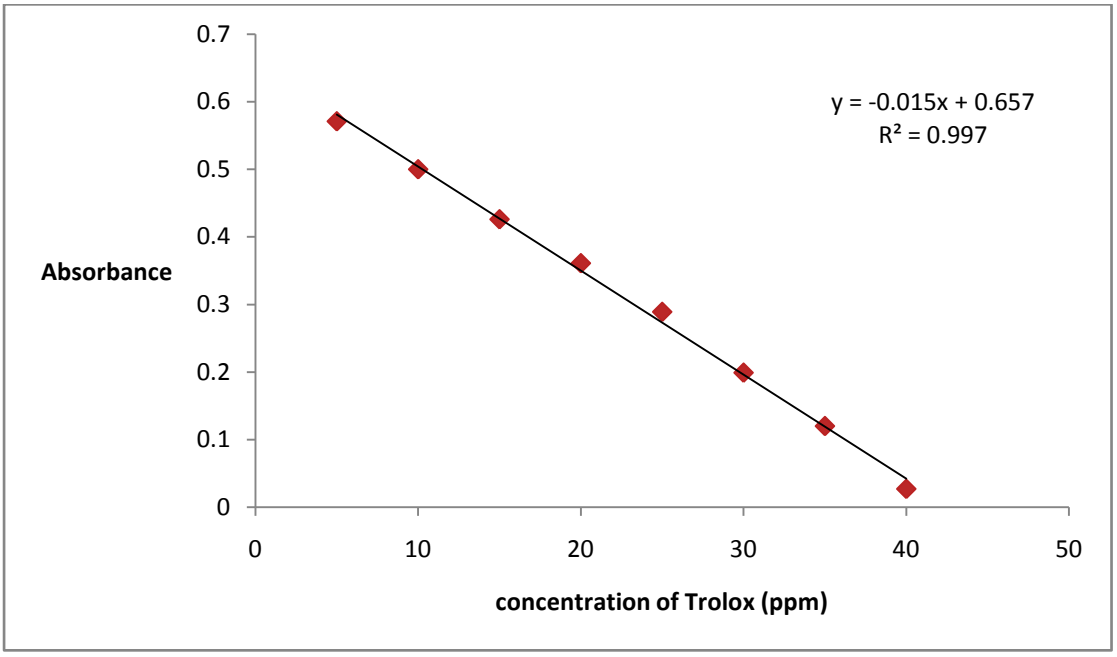

Figure 6: Calibration curve for ABTS.

تقييم المحتوى العام للمركبات الفينولية والنشاط المضاد للأكسدة لعينات زيت الزيتون البكر الممتاز التي تم جمعها من مناطق مختلفة في الضفة الغربية في فلسطين.

إعداد: وائل هاني علي دويك.

إشراف: د. فؤاد الريماوي.

ملخص:

هدفت الدراسة إلى تقييم النشاط المضاد للأكسدة والمحتوى الفينولي والمحتوى الفلافونويدي وبعض عوامل الجودة (النسبة المئوية للحموضة ورقم البيروكسيد و K_{232}, K_{270} والرقم اليودي) لزيت الزيتون من مناطق جغرافية مختلفة في الضفة الغربية (شمال ووسط وجنوب) وايضا لدراسة وجود فروق محتملة بين كل فحص والفحوصات الأخرى للمزارعين في نفس المنطقة الجغرافية ودراسة وجود علاقة بين كل فحص وبين بعض العوامل التي تم اختيارها في الاستبانة.

تم فحص مضادات الأكسدة لمستخلصات الزيت باستخدام فحوصات (FRAP, CUPRAC, ABTS DPPH) وتم حساب (TPC) بطريقة (Folin–Ciocalteu) و (TFC) بطريقة (Aluminium chloride method).

تم تحليل نتائج البيانات إحصائياً حسب المحافظات وحسب المناطق ضمن المحافظات وحسب المزارعين ضمن تلك المناطق ولوحظ بأنه لا توجد فروق ذات دلالة إحصائية ضمن المحافظات باستثناء عدد قليل

من الفروقات بينما وجد عدد أكبر من الفروق ذات الدلالة الإحصائية ضمن المناطق بينما لوحظ بشكل واضح وجود فروق ذات دلالة إحصائية بشكل كبير بين المزارعين.

تم عمل علاقات بين البيانات الموجودة في استبانة تم توزيعها على المزارعين وتحتوي على ستة أسئلة حول (الإصابة بذبابة الزيتون ونسبة الأخضر إلى الأسود ونسبة الزيت المئوية ونسبة الحمل ونسبة المتساقط تحت الشجر والفترة الزمنية بين القطاف والعصر) وبين الفحوصات حيث لوحظ أنه توجد بعض العلاقات القليلة بين المحافظات وتزداد قوة العلاقة بين المناطق ضمن المحافظات وتزداد بشكل أوضح وأكبر بين المزارعين.