Jordan Journal of Agricultural Sciences, Volume **19**, No.1 **2023**
DOI :https://doi.org/10.35516/jjas.v19i1.1236

Review Article
Olive Fruit Fly Bacterocera Oleae Infestation of Olives: Effect on Quality and Detection in Olive Oil

Amr,A[1]., Sader, M.[1], Sakarneh,N.[2]

[1]Professors, Departments of Nutrition and Food Technology and Horticulture and Agronomy respectively, College of Agriculture, University of Jordan, Amman, Jordan11942.

[2] Graduate Student, Departments of Nutrition and Food Technology, College of Agriculture, University of Jordan, Amman, Jordan11942

Received on 13/12/2021 and Accepted for Publication on 4/4/2022.

ABSTRACT

Bacterocera oleae is the most common olive fruit pest in Jordan. The high incidence of olive fruit infestation with fruit fly in its stages of larvae and pupa is a common problem in olive oil production. Although not detected by simple means, it is believed to impart a "Grubby" taste that is detected only by experts and results in lowering the value of the oil from infested fruits. The effect of damage caused by B. oleae depends on the degree of infestation which is manifested in the presence of exit holes (EH) produced by the full-grown larvae which destroy the fruit skin and expose it to oxygen and other destructive factors like fungi. This results in the acceleration of hydrolytic and oxidative types of rancidity which can be estimated by measuring oil acidity (FFA) and peroxide value (PV). This review covers the literature related to the effect of olive fruit fly infestation on the quality of olive fruits and oil and the methods used in its control and detection.

Keywords: Olive fruit fly, olive oil quality, insect residues in oil, olive fruit fly control.

INTRODUCTION

Olive oil is the juice extracted from olive fruit. In order to be classified as a virgin, olive oil must be extracted from sound fruits with no defects. One of these defects is *B.oleae* infestation which causes a rise in the extracted oil's acidity and peroxide value, consequently lowering its organoleptic properties by imparting a grubby taste. In addition, infested olives produce oil with low phenolic content with low antioxidant effects (Tamendjari *et al.*, 2004; Tamendjari *et al.*, 2009).

Jordan is considered one of the world's oldest habitats of olive trees which is treated as a national Jordanian legacy. Olive growing is spread in the west and north-east regions of the kingdom, with about 11 million olive trees of which 9 million produced about 215 thousand tons in 2019, thus putting Jordan among the ten largest olive-producing countries of the world (Freihat *et al.*, 2021; IOC, 2021). This helped the country achieve self-sufficiency (about 102.4% of local demand) in olives

* Corresponding author.E-mail: ayedamer@ju.edu.jo

(Department of Static of Jordan (DOS), 2021). The area planted to olive trees covers about 24% of Jordan's total arable surface area and 74% of the surface planted with fruit trees (Jordan Ministry of Planning, 2002). The objectives of this work are to review the most recent literature, from a food scientist's point of view, related to the biology of *B. oleae* and the various methods used for its control. The effect of infestation with the fly on olive oil sensory and chemical quality as well as available and potential methods for the detection of its residues in the extracted oil is also covered.

Methodology

Official scientific publications from 1978 to 2021 and internet browsing from different databases were used to retrieve and download review and research articles linked to the terms *Bacterocera oleae*, olive oil quality, acidity, peroxide value, organoleptic properties, olive oil adulteration, *Bacterocera oleae* detection in olive oil. Emphasis was placed on the effect of infestation on the sensory and chemical properties of olive oil. Furthermore, the research papers linked to the key terms *B. oleae* olive fruit fly infestation and methods of its detection with the various methods were given priority for this scientific review. Reference lists of identified studies were also searched to find additional articles and reviews. Any other potential methods used for the detection *of B. oleae* residues in olive oil were also reviewed and taken into consideration including molecular biology ones.

Olive fruit fly pest.

Development stages.

Multiple pests can affect the olive tree, olive fly, olive moth, thrips, cochineal, and leopard moth. The olive fruit fly (*B. oleae,* Rossi) is the main pest that affects olive trees causing a reduction in olive production due to fall of olive fruits on the ground. It is estimated that the annual cost of controlling this pest in European countries, amounts to about 100 million Euros 50% of which is on pesticides (Sagri *et al*., 2014).

B. oleae is known as olive fruit fly or olive fly. Figure 1 shows the adult fly which is a monophagous frugivorous pest that feeds mainly on Oleae species. Adult females lay their eggs beneath the epicarp, giving direct access to larvae for food. A single olive fruit fly whether in nature or under laboratory conditions can lay from 10 to 40 eggs in one day and from 200 to 500 during its lifecycle (Mavragani-Tsipidou, 2002; Yokoyama, 2015).

The temperature conditions for olive fruit fly eggs to develop is between 10°C to 30 °C, and under optimal conditions, the egg develops in one day into larvae which feed on 45 to 150 mg olive fruit mesocarp before developing into pupae after eight days. These pupae develop into olive fruit fly and exit from the fruit through the exit hole (figure 2) (Neuenschwander and Michelakis, 1978; Torrini *et al*.,2020).

Figure (1) Adult olive fruit fly B. oleae.

Figure (2) Exit holes caused by B. oleae infestation.

The number of generations of olive fruit fly per season depends on many factors, geographical, climatic and agronomical conditions. In the Middle East from 3 to 5 generations while in Europe from 2 to 5 generations per season were recorded (Da Silva Malheiro, 2015).

Effect of infestation on olive oil quality

When *B. olea* attacks the fruit and lays its eggs where they grow eating the fruit flesh to give pupae which decreases both fruit and olive oil quality (Tamendjari et al., 2004).

Effect on acidity:

Acidity is one of the most important parameters used to classify or evaluate olive oil quality (Mariotti and Mascini, 2001). As shown in table 1, based on its acidity, expressed as oleic acid, olive oil is classified (ECC,1991; JSMO,2012) into eight grades (categories). It appears that the Jordanian standard (table 1) adopts the same categories and limits set up by the ECC standard, with an additional category appearing in number nine (ordinary olive oil) with acidity not exceeding 3.30%. Also, the Jordanian standard defines Lampante acidity as exceeding 3.30% compared to the 2.0% set by the ECC standard.

It was found that olive fruits infested with olive fruit fly give olive oil with low-quality parameters due to high acidity levels (Pereira *et al*., 2004). However, a study conducted on olives grown in Turkey in five orchards, found no significant effect of *B. oleae* on acidity when olives were harvested before November (Topuz *et al*., 2008). On the other hand, a positive correlation was found between *B. oleae* infestation and acidity in olive oil in the Algerian Chemlal cultivar at all levels of *B. oleae* attack regardless of the harvest date (Mraicha *et al.*, 2010).

The larval development in olive pulp leads to the destruction of olive fruit tissues, thus increasing the lipolytic hydrolysis of triglycerides into glycerol and free fatty acids thus declassifying olive oil. On the other hand, acidity increases due to the long and improper storage of olive fruits causing interaction between lipases and their substrate (Pereira *et al.*, 2002). Exposure to lipases increases in insect-infested fruits due to the decompartmentization of lipases and their contact with their triglyceride substrates. The acidity of olive oil is accelerated with olive fruit fly infestation especially when stored under improper conditions, due to fermentation by microbes and enzymatic action (Torres-Vila *et al.*, 2003).

Table (1) Acidity* and peroxide value comparison of olive oil categories according to the Jordanian JS3/2012(JSMO, 2012) and ECC reg.no.2568/91 (ECC, 1991) .**

	Acidity (%)	Acidity (%) ECC	Peroxide Value JS3/2012	Peroxide Value ECC
Extra virgin olive oil	≤ 0.8	≤ 0.8	≤ 20.0	≤ 20.0
Virgin olive oil	>0.8 - 2.0	≤ 2.0	≤ 20.0	≤ 20.0
Lampante olive oil	> 3.30	> 2.0	-	-
Refined olive oil	≤ 0.3	≤ 0.3	≤ 5.0	≤ 5.0

Olive oil is composed of refined and virgin olive oil	≤ 1.0	≤ 1.0	≤ 15.0	≤ 15.0
Crude olive - pomace oil	-	-	-	-
Refined olive- pomace	≤ 0.3	≤ 0.30	≤ 5.0	≤ 5.0
Olive-pomace oil	≤ 1.0	≤ 1.0	≤ 15.0	≤ 15.0
Ordinary virgin olive oil	2.0- ≤ 3.3	-	≤ 15.0	-

* Expressed as % oleic acid.

** Expressed as meq. peroxide oxygen/ Kg. oil.

Effect on peroxide value:

Peroxide value (PV) is another parameter used to classify and evaluate olive oil quality. The peroxide value is the quantity of those substances in the sample expressed as milliequivalents of peroxide oxygen species per kilogram oil. These species oxidize potassium iodide under the operating conditions described according to ECC regulation no. 2568 (ECC, 1991) which sets the peroxide value for extra virgin (EVOO) and virgin (VOO) olive oil at ≤ 20 meq O2/kg. Table 1 shows the comparison between the Jordanian olive oil standard and that of the ECC. Jordanian standard has the same limits set by the ECC for the first eight categories but set up a new ordinary virgin (number 9) olive oil category with a peroxide value not exceeding 15meq. O2/ Kg.

It was reported that olive oil peroxide value increased in oils extracted from infested olive fruits and correlated positively with the number of exit holes. Also, it was reported that storage time and exposure to light resulted in a fivefold increase in PV over that of the properly stored control oil (Gucci *et al.*, 2012). Both factors are known to accelerate the oxidation of oils and fats. The exit holes also allow oxygen to enter the fruits and cause lipid oxidizing enzymes to be freed out of their compartments in the sound tissue. In a study by Pereira *et al*.(2004) olive fruits were collected and divided into five groups depending on infestation level by olive fruit fly attack, they found that peroxide value and acidity increased while phenol content decreased when infestation level increased.

Table 1a summarizes the findings of the research papers cited in the preceding paragraphs on the effect of olive fruit infestation on both FFA and PV. The table shows clearly that infestation results in higher FFA and PV in almost all of the olive oil samples regardless of the cultivar. Only one value reported by Pereira et al. (2004) had higher FFA in the oil from Cobrançosa sound olives (0.33%) compared to that from the infested (0.32%) olives from the same cultivar. Although the difference is minute, it is most likely due to experimental error and does not affect the grade of the oils involved as both oils (from infested and sound olives) meet the Extra Virgin Olive Oil grade. The effect of infestation, however, is more apparent in the PV than the FFA parameter in all oils reported in the table which could be due to the more pronounced effect of oxygen penetration through the infestation holes and the activation of the oxidoreductases including peroxidases. The process of peroxidation is more deleterious to the oil quality than the lipolysis as all olive standards tolerate much lower levels of FFA than PV in the grading of olive oil(table 1).

Table (1a): Summary of the influence of *B. oleae* infestation on quality parameters (acidity and peroxide value) of olive oil from different cultivars as reported by different authors.

Reference	**Olive cultivar**	**Infestation level (%)**	**Acidity (as % oleic acid)**	**PV (meq. peroxide O2 / Kg oil)**
Pereira *et al*. (2004)	Cobrançosa	0 100	0.33 0.32	11.4 16.6
	Madural	0 100	0.23 0.31	14.7 14.9
	Verdeal Transmontana	0 100	0.28 0.53	19.1 35.1
Mraicha *et al*. (2010)	Chemlali	0 100	0.52 3.41	- -
Gucci *et al*. (2012)	Frantoio	0 100	0.1 0.3	2.3 5.2
Tamendjari, (2009)	Chemlal	0 100	0.22 0.92	10.9 16.8
Topz *et al*, (2008)	Ayvalik	44	0.40	-

Effect on organoleptic properties:

A complex mixture of volatile compounds is responsible for EVOO aromas like aldehydes, alcohols, esters, ketones, hydrocarbons, acids, furans, terpenes, and other minor compounds (Cherfaoui *et al.,* 2018). The pleasant aroma of olive oil is due to volatiles produced by the action of enzymes on linoleic and linolenic acids during in vivo synthesis (García-Vico *et al*., 2017). Cherfaoui *et al*. (2018) reported about twenty volatile compounds in theChemlal cultivar of Algerian olive oils. They found that genetic makeup and the ripening stage of harvesting are responsible for the unique flavor of EVOO produced from this cultivar.

The sensory analysis is the official method for olive oil organoleptic assessment by a trained and certified test panel. The test is based on the International Olive Council (IOC) Doc.No15/Rev.9 (IOC, 2017) and the ECC regulation no. 640 (ECC, 2008). Based on these references, olive oil is classified into EVOO, VOO, and Lampante olive oil (LOO) according to the positive attributes of fruitiness, pungency, and bitterness which are well appreciated by consumers. In addition to the extraction conditions, these attributes depend on the cultivar, chemical composition, maturation, and condition of olives including bruising and insect infestation which causes a decrease in the assigned scores (Tamendjari *et al*., 2009) by panelists. The most common defects detected by panelists are fustiness, mustiness, winey, grubbiness and in some cases rancidity. The flavor of oil from heavily attacked olives by larvae of the olive fly *B. oleae* is characterized by the easily- recognized grubby taste (Bendini *et al*., 2008).

The quantity of phenolic compounds depends on many factors including cultivar, genetic makeup, ripening stage, and degree of *B. oleae* infestation. Several workers (Pereira *et al*., 2004; Tamendjari *et al*., 2004) reported a decrease in phenolic compounds as a result of *B. oleae* infestation. In addition to imparting a grubby taste, *B. oleae* infestation causes a decrease in volatile and phenolic compounds (have polar phenol groups that act as antioxidants) thus decreasing oil stability during storage (Tamendjari *et al*., 2009).

The simultaneous attack of *B. oleae* and maturation of olive fruits and its effect on phenolic compounds with other parameters were studied by Zelasco *et al*.(2021); they reported that early harvesting of olive fruits could decrease the effect of *B. oleae* infestation.

Olive fruit fly control

The Mediterranean basin has 98% of cultivated olive trees in the world. Losses due to insect damage by olive fruit fly are estimated at about thirty percent of crops leading to great economic losses. Therefore, controlling this pest is of paramount economic importance (Bueno and Jones, 2002).

Strategies followed for controlling olive fruit fly:

The most effective strategy followed for controlling the olive fruit fly is Integrated Pest Management (IPM). This strategy depends on the coordination of multiple complementary methods to inhibit pest growth (Parsa *et al*., 2014). IPM uses information in biology for pest control and its possible interaction with the surrounding environment (Ofuoku *et al*., 2009). IPM systems are widely used as the safe and best policy to have sustainable agriculture. Other useful techniques used in IPM include the use of resistant plant varieties, cultural practices, the use of predators and parasites, microbial pesticides, botanical insecticides, insect growth regulators, and semi-chemicals (Bueno and Jones, 2002).

Control methods-

A number of methods are used for the control of the fly, some are traditional while others are more environmentally friendly.

Baits and trapping methods:

The fruit fly is attracted to several compounds which are used as bait to kill it. The earliest trap was made of molasses with insecticides (Dominiak and Ekman, 2013). Later, protein hydrolysates (Solbait) were added to these traps along with yeast and ammonia-releasing salts (ammonium sulfate) (Haniotakis *et al*., 1986; Thomas and Mangan, 2005).

Yellow color is used in designing traps like McPhail's which are used to capture Tephritidae flies, a family of true fruit flies similar to but slightly different from the known Drosophilidae (Uchôa, 2012). Sticky traps utilize yellow color in combination with an odor source such as *Torula* yeast to attract olive fruit fly (Díaz-Fleischer *et al*., 2014). Other studies showed that this fly is attracted to red-colored sticky spheres, especially in adult females. This property was utilized in designing another type of trap (Katsoyannos and Kouloussis, 2001).

Semi-chemical methods:

Semi-chemical based products like sex-pheromones and food attractants in IPM were successful in controlling the fly on olive trees in some countries such as Spain, Italy, and Greece to be later used in the whole world (Kokkari *et al*., 2021). Sex-pheromones released by adult virgin females as part of the fly mating behavior is used to catch adult males in traps (Baker *et al*., 1980).In autumn, olive fruits mature, and sexual activity starts again. Here the yellow traps baited with sex pheromones are used to catch a bigger number of the fly males than traps not having sex pheromones (Amvrazi and Albanis, 2008)

Chemical methods (Insecticides):

During the last forty years, insecticides were used to manage the spread of olive fruit fly. One group of pesticides are the organophosphates used as a cover spray or in combination with baits in traps. Other types of pesticides used are pyrethroids and the naturally-synthesized bacteria Spinosad (Thomas and Mangan, 2005). Studies conducted on the resistance of the fly to these pesticides showed various levels of resistance to them. (Nardi *et al.*, 2006 ; Hsu *et al.,* 2006).

Effect of pesticides on olive oil quality:

Pesticides are used to control olive fruit pests and increase olive tree production. However, due to their high lipophilicity, they pose a high risk to consumer health if their residues remain in the olives or olive oil (Farré and Barceló, 2013). Improper exposure above Maximum Residual Limits (MRL) can cause adverse effects on human and animal health, causing nervous system damage, diseases of the immune system, reproductive and developmental disorders, and even cancers (Tahoun *et al.*, 2019).

Regulations for pesticide control:

Pesticides are bioactive compounds used in agriculture. They spread freely in the environment and their residues present a big problem (Glare *et al*., 2012)**.** According to European Union ECC regulation no.1107 (ECC, 2009), pesticides should pass rigorous risk assessment testing to ensure their safety and define their maximum tolerable level in food before being licensed for use (Marchand, 2017).

Since food safety has become a priority in all food processing aspects, a great deal of research efforts has focused on the development of optimum extraction and analytical methods for pesticide residue analysis. Gas chromatography and liquid chromatography coupled with mass spectrometry GC/ MS are generally the most suitable methods for multi-residue analysis. This task is not easy due to the complexity of oil matrices and the validation of the analytical methods as stated in the European pesticides' regulation ECC no. 1107(ECC, 2009) (Tahoun *et al.*, 2019).

The maximum residue limits (MRLs) of pesticides are set not only for olives, sunflower seeds, and soybeans but also for their processed oils by considering the processing factors (time, temperature …) (Hakme *et al.,* 2018). Codex Alimentarius Commission (CAC, 2021) developed harmonized international food standards for virgin olive oil whereby MRLs were set for a group of pesticides shown in table 2.

Table (2) MRL maximum residue limits of pesticides in olive oil according to Codex Alimentarius*.

Pesticide	MRL mg. Kg^{-1}
carbaryl	25 $mg.kg^{-1}$
cypermethrin	0.5 $mg.kg^{-1}$
fenthion	1 $mg.kg^{-1}$
kresoxym-methyl	0.7 $mg.kg^{-1}$
trifloxystrobin	0.9 $mg.kg^{-1}$
cypermethrin	0.5 $mg.kg^{-1}$
trifloxystrobin	1.2 $mg.kg^{-1}$

* Pesticide levels 1-5 apply to virgin olive oil while 6-7 apply to refined olive oil (according to CAC, 2021). The Japan Food Chemical Research Foundation has established a list of agricultural chemical residues in foods that includes MRLs for only three pesticides in edible virgin olive oil: carbaryl (25 $mg.kg^{-1}$), fenthion (1 $mg.kg^{-1}$), and methidathion (2 mg.kg-1) (Hakme *et al.*, 2018).

The MRLs set by the European Union (EU) according to ECC regulation no.396 (ECC, 2005) are more stringent as they cover a much broader spectrum of pesticides (472 pesticides) in olive oil with MRLs ranging from 0.01 to 0.05 $mg.kg^{-1}$.It is to be noted that some pesticides are authorized in some countries and banned in others, a situation that creates problems in international trade. Having the right information and MRLs requirements across the global market is the first step to overcoming this problem. For instance, to export to the EU, the residues levels in agricultural products must comply with ECC regulation no. 396(ECC, 2005) (Hakme *et al.*, 2018).

Biological control methods:

Biological control methods are used to suppress the pest by its natural enemies (Daane and Johnson, 2010). They are alternatives for chemical methods (pesticides), attract and kill methods, mass trapping methods (Bueno and Jones, 2002), and male sterile insect methods (Deutscher *et al.*, 2019). One form of biological control is symbiotic control which is the control of pests by disrupting insect symbiosis (Sinno *et al*., 2020). During the insect lifecycle, complex microbiota affects pests which can be manipulated to suppress insect growth (Gonella *et al.,* 2020). This can be achieved by a number of techniques including the vertical disruption of the transmission of an obligate needed for nutrition, from mother to offspring (Klepzig *et al*., 2009). *Candidatus erwinia dacicola* is the most common endosymbiont bacterium in all lifecycle stages of *B. oleae* (Dimou *et al.*, 2010).

Detection of fruit fly and its stages in olive fruits and oil.

Detection methods of insect infestation in fruits and their products are divided into the following methods:

Physical methods:

This group of methods includes some simple and some sophisticated methods as follows:

visual inspection

which is applicable to whole fruits (Dogan and Subramanyam, 2017) is simple but requires experience and is time-consuming. Such a method is used traditionally for the visual detection of infestation of olive fruits for pickling at home and small industrial levels, but cannot be used to judge whether the given olive oil was pressed from sound or infested olives.

-The X-ray technique is an effective method for the detection of adult, but not eggs and larval stages of the fly in olive fruits (Jackson and Haff, 2006).

- Near-Infrared spectroscopy (NIR):

This method is based on detecting the changes in the spectral properties of damaged tissues caused by insects. By using the proper wavelength, a good image of infested fruits can be obtained using NIR spectra as it penetrates more than 9 mm through the skin of the fruits (Ekramirad *et al*., 2016). NIR spectroscopy was shown to be an effective detection method for insects or insect damage in fruits like cherries and figs (Xing *et al*., 2008; Burks *et al.,* 2000). In a study conducted on the use of NIR spectroscopy for the detection or removal of olive fruits infested with *B*. *oleae*, Moscetti *et al.* (2015) reported that the use of NIR spectroscopy in the long-wavelength region (1100–2300 nm) for detection of larvae - attacked olives were feasible with an accuracy of 94%. The method also has the advantage of being automated, non-destructive, and rapid.

-Computer Vision:

This method was used by Beyaz *et al.* (2019) to detect sting and other bruises caused by olive fly for the purpose of classifying fruits by defects. The method had a success rate of 93% in detecting defective areas. This method can be used at the beginning of olive processing to produce extra virgin olive oil avoiding olive fruit fly destructive effect.

Chemical methods:

Uric acid is an insect excretion that can be used as an indicator of insect infestation in stored foods including fruits. Uric acid quantity varies depending on the insect species and life stage. Uric acid can be determined by colorimetric (TLC Thin Layer Chromatography) or enzymatic (Uricase enzyme) methods (Brown *et al.,* 1982). However, this method has not been used for the detection of insect residues in olive oil.

Organoleptic (taste) methods of olive oil:

While visual evaluation is used for the detection of insect stages in fruits, it cannot be used for the detection of insect effects in olive oil. Therefore, taste panels have been used for the detection of the flavor of olive oil produced from fruits infested with fruit fly. Oil from heavily infested fruits is characterized by a distinctive grubby taste that can be detected by expert tasters trained in olive oil evaluation. Grubbiness is classed among the negative attributes of olive oil; if available at high levels the oil becomes unfit for human consumption due to its repugnant taste. Despite using trained and certified panelists, this method, however, is highly subjective and effective only if the oil is obtained from highly infested olives. A more reliable and accurate method is needed for the detection of the infestation effect in olive oil.

Other potential and promising methods for olive oil:

Molecular biology methods such as Polymerase Chain Reaction (PCR) a molecular diagnostic method of in vitro enzymatic synthesis and amplification of specific DNA fragments (Green and Sambrook., 2021). This rapid method has been used in many fields, like COVID-19 viral detection, microbial detection, aquaculture, and so on (Younes *et al*., 2020). The wide use of this technique is due to its strong accuracy, sensitivity, and specificity

(Kadri, 2019). PCR technology is based on the amplification of known DNA sequences with synthetic DNA(Bhat and Rao, 2020). Multiplex PCR technique was used to study the relationship between infested guava and star fruit with *Bacterocera* species and braconid parasite. The resulting information is considered very important in the biological control of *Bacterocera* species (Shariff *et al*., 2014). Using PCR for the detection of the *B*. *oleae* effect in olive oil is a promising method that can be used in the future for determining whether the olive oil was extracted from infested olives and the degree of their infestation, which can add to the already available criteria of olive oil quality.

Conclusions and Recommendations

The high incidence of olive fruit infestation with the different stages of olive fruit fly *B. oleae* , mainly larvae and the pupa is a common problem in olive tree growing and olive oil production. In addition to the economic loss due to the dropping of fruits on the ground, damaged fruits produce low-quality olive oil with downgraded scores or even rejection by consumers.

This review covers, from a food science point of view and by referring to the most possible up-to-date scientific references, the effect of olive fruit fly infestation on the quality of olive fruits and oil, as well as the methods used for its detection in the fruits and oil as well as the methods used in its control.

In view of the present available practical and theoretical information on the detection of the effect of *B. oleae* inolive to use the chemical **recommended** oil, it is indicators of peroxide value and fat acidity as practical and simple indicators of this effect,with PV isa better

indicator thanFFA as evidenced from the available literature. These methods are simple and can be used with the minimum training and resources that can be afforded by all olive mills. Organoleptic testing methods also can be used for research and arbitration purposes, but since they are subjective and require a group of panelists, which is hard to secure in olive mills, their use as a quality control tool at the industrial level remains limited. Based on this review, it is recommended to continue researching for more accurate techniques including molecular biology ones, which although quantitative and reliable are expensive and require highly equipped laboratories. Research also should continue on developing other chemical methods like the uric acid content of the oil.

Acknowledgments

The authors thank the deanship of scientific research at the University of Jordan for supporting this work.

Declaration of Conflict of interest:

The authors declare no conflict of interest in the preparation of this work.

REFERENCES

Amvrazi, E and Albanis, T. (2008). Multiclass pesticide determination in olives and their processing factors in olive oil: comparison of different olive oil extraction systems. *Journal of agricultural and food chemistry*, 56(14), 5700-5709.

Baker, R., Herbert, R., Howse, P., Jones, O., Francke, W., and Reith, W. (1980). Identification and synthesis of the major sex pheromone of the olive fly (Dacus oleae). Journal of the Chemical Society, *Chemical Communications*, (2), 52-53.

Bendini, A., Cerretani, L., Cichelli, A. and Lercker, G. (2008). Come l'infestazione da Bactrocera oleae può causare variazioni nel profilo aromatico di oli vergini da olive. *Rivista Italiana di Sostanze Grasse*, 86, 167-177.

Beyaz, A., Gila, D. M. M., Ortega, J. G.,and García, J. G. (2019). Olive fly sting detection based on computer vision. *Postharvest Biology and Technology*, 150, 129-136.

Bhat, A. and Rao, G. (2020). *Polymerase chain reaction. In Characterization of Plant Viruses* (pp. 323-345). Humana, New York, NY.

Brown, S. M., Abbott, S., and Guarino, P. A. (1982). Screening procedure for uric acid as an indicator of infestation in spices. *Journal of the Association of Official Analytical Chemists*, 65(2), 270-272.

Bueno, A. and Jones, O. (2002). Alternative methods for controlling the olive fly, Bactrocera oleae, involve semiochemicals. *Foods***,** 25 (9), 147-156.

Burks, C. S., Dowell, F. and Xie, F. (2000). Measuring fig quality using near-infrared spectroscopy. *Journal of stored products Research*, 36(3), 289-296.

Cherfaoui, M., Cecchi, T., Keciri, S., and Boudriche, L. (2018). Volatile compounds of Algerian extra-virgin olive oils: Effects of cultivar and ripening stage. *International Journal of Food Properties*, 21(1), 36-49.

Joint FAO/WHO Codex Alimentarius Commission. (2022). *Pesticide residues in food and feed*. (CAC) Food and Agriculture Organization of the United Nations. Rome, Italy. https://www.fao.org/fao-who-codexalimentarius/codex-home/es. Retrieved 11/2021.

Da Silva Malheiro, R. M. (2015). *Olive Fruit Fly (Bactrocera oleae Rossi): Olive Tree Interactions: Study of Physical and Chemical Aspects*. Unpuplished Master Dissertation, Universidade do Porto (Portugal).

Daane, K. M., and Johnson, M. W. (2010). Olive fruit fly: managing an ancient pest in modern times. *Annual review of entomology*, 55, 151-169.

Deutscher, A. T., Chapman, T. A., Shuttleworth, L. A., Riegler, M., and Reynolds, O. (2019). Tephritid-microbial interactions to enhance fruit fly performance in sterile insect technique programs. *BMC microbiology*, 19(1), 1-14.

Díaz-Fleischer, F., Pinero, J. C., and Shelly, T. E. (2014). *Interactions between tephritid fruit fly physiological state and stimuli from baits and traps: looking for the pied piper of Hamelin to lure pestiferous fruit flies*. In Trapping and the detection, control, and regulation of tephritid fruit flies (pp. 145-172). Springer, Dordrecht.

Dimou, I., Rempoulakis, P. and Economopoulos, A. .(2010).Olive fruit fly [Bactrocera (Dacus) oleae (Rossi)(Diptera: Tephritidae)] adult rearing diet without antibiotics. *Journal of Applied Entomology***,** 134 (1), 72-79.

Dogan, H., and Subramanyam, B. (2017). *Analysis for the extraneous matter*. In Food Analysis (pp. 599-614). Springer, Cham.

Dominiak, B. C., and Ekman, J. H. (2013). The rise and demise of control options for fruit fly in Australia. *Crop Protection*, 51, 57-67.

Jordan Department of Statistics (DOS).(2019). *Food balance sheets/self sufficiency ratio*. DOS, Amman/ Jordan. http://jorinfo.dos.gov.jo/Databank/pxweb/en/FoodBalanceSheet/FoodBalanceSheet__Self-Sufficiency-Ratio/L_Tab12-OliveProduct.px/table/tableViewLayout. Retrieved 2/11/2021.from

Ekramirad, N., Adedeji, A. A.,and Alimardani, R. (2016). *A review of non-destructive methods for detection of insect infestation in fruits and vegetables*.

European Commission. (1991). Regulation No. 2568/91/EEC, July 11. *Official Journal of the European Communities*, L248, 1–83.

European Commission. (2009). *EU*. Pesticides database, Regulation No 1107/2009.

Farré, M. and Barceló, D. (2013). Analysis of emerging contaminants in food. *TrAC Trends in Analytical Chemistry*, 43, 240-253.

Freihat, N. M., Shannag, H. K., and Alkelani, M. A. (2021). Effects of supplementary irrigation on the performance of 'Nabali'and 'Grossa de Spain'olives under semi-arid conditions in Jordan. *Scientia Horticulturae,* 275, 109696.

García-Vico, L., Belaj, A., Sánchez-Ortiz, A., Martínez-Rivas, J. M., Pérez, A. G. and Sanz, C. (2017). Volatile compound profiling by HS-SPME/GC-MS-FID of a core olive cultivar collection as a tool for aroma improvement of virgin olive oil. *Molecules*, 22 (1), 141.

Glare, T., Caradus, J., Gelernter, W., Jackson, T., Keyhani, N., Köhl, J., and Stewart, A. (2012). Have biopesticides come of age?. *Trends in biotechnology*, 30(5), 250-258.

Gonella, E., Orrù, B., Marasco, R., Daffonchio, D., and Alma, A. (2020). Disruption of Host-Symbiont Associations for the Symbiotic Control and Management of Pentatomid Agricultural Pests-A Review. *Frontiers in Microbiology*, 11.

Green, M. R., and Sambrook, J. (2021). *A guide to cloning the products of polymerase chain reactions*. Cold Spring Harbor Protocols, 2021(9), pdb-top101345.

Gucci, R., Caruso, G., Canale, A., Loni, A., Raspi, A., Urbani, S., Taticchi, A., Esposto, S. and Servili, M. (2012). Qualitative changes of olive oils obtained from fruits damaged by Bactrocera oleae (Rossi). *HortScience*, 47 (2), 301-306.

Hakme, E., Lozano, A., Ferrer, C., Díaz-Galiano, F. and Fernandez-Alba, A. (2018). Analysis of pesticide residues in olive oil and other vegetable oils. *TrAC Trends in Analytical Chemistry*, 100, 167-179.

Haniotakis, G., Kozyrakis, E. and Bonatsos, C. (1986). Control of the olive fruit fly, Dacus oleae Gmel.(Dipt., Tephritidae) by mass trapping: A pilot scale feasibility study. *Journal of Applied Entomology*, 101 (1-5), 343-352.

Hsu, J., Haymer, D., Wu, W., and Feng, H. (2006). Mutations in the acetylcholinesterase gene of Bactrocera dorsalis are associated with resistance to organophosphorus insecticides. *Insect Biochemistry and Molecular Biology*, 36 (5), 396-402.

IOOC. International Olive Council (IOC). (2021). *Jordan and IOC strengthen collaboration. IOC*. Madrid/ Spain. (https://www.internationaloliveoil.org/jordan-andiocstrengthen%E2%80%8E%E2%80%8E%E2%80%8Ecollaboration%E2%80%8E). Retrieved 20/11/ 2021 .

Jackson, E. S., and Haff, R. P. (2006). X-ray detection and sorting of olives damaged by fruit fly. In 2006 ASAE Annual Meeting (p. 1). *American Society of Agricultural and Biological Engineers*.

JSMO (Jordan Standards and Metrology Organisation). (2012).*Fats and oils-Olive oil and olive pomace oil*, Jordan, Amman.

Kadri, K. (2019).*Polymerase chain reaction (PCR): principles and application.* In Synthetic Biology-New Interdisciplinary Science.IntechOpen.

Katsoyannos, B. I. and Kouloussis, N. A. (2001). Captures of the olive fruit fly Bactrocera oleae on spheres of different colors. *Entomologia Experimentalis et Applicata*, 100 (2), 165-172.

Klepzig, K., Adams, A., Handelsman, J. and Raffa, K. (2009). Symbioses: a key driver of insect physiological processes, ecological interactions, evolutionary diversification, and impacts on humans. *Environmental Entomology*, 38 (1), 67-77.

Kokkari, A. I., Milonas, P. G., Anastasaki, E., Floros, G. D., Kouloussis, N. A., and Koveos, D. S. (2021). Determination of volatile substances in olives and their effect on reproduction of the olive fruit fly. *Journal of Applied Entomology.*

Marchand, P. A. (2017). Basic and low-risk substances under European Union pesticide regulations: a new choice for biorational portfolios of small and medium-sized enterprises. *Journal of Plant Protection Research*, 57(4).

Mariotti, E., and Mascini, M. (2001). Determination of extra virgin olive oil acidity by FIA-titration. *Food Chemistry,* 73(2), 235-238.

Mavragani-Tsipidou, P. (2002). Genetic and cytogenetic analysis of the olive fruit fly Bactrocera oleae (Diptera: Tephritidae). *Genetica*, 116(1), 45-57.

Ministry of Planning in Jordan (MOP). (2002). *Report on export strategies for Jordanian olive oil*, Jordan, Amman.

Moscetti, R., Haff, R. P., Stella, E., Contini, M., Monarca, D., Cecchini, M., and Massantini, R. (2015). Feasibility of NIR spectroscopy to detect olive fruit infested by

Bactrocera oleae. *Postharvest Biology and Technology*, 99, 58-62.

Mraicha, F., Ksantini, M., Zouch, O., Ayadi, M., Sayadi, S., and Bouaziz, M. (2010). Effect of olive fruit fly infestation on the quality of olive oil from Chemlali cultivar during ripening. *Food and Chemical Toxicology*, 48(11), 3235-3241.

Nardi, F., Carapelli, A., Vontas, J. G., Dallai, R., Roderick, G. K., and Frati, F. (2006). Geographical distribution and evolutionary history of organophosphate-resistant Ace alleles in the olive fly (Bactrocera oleae). *Insect biochemistry and molecular biology*, 36(7), 593-602.

Neuenschwander, P. and Michelakis, S. (1978).The infestation of Dacus oleae (Gmel.)(Diptera, Tephritidae) at harvest time and its influence on yield and quality of olive oil in Crete. *Zeitschrift für angewandte Entomologie*, 86 (1-4), 420-433.

Ofuoku, A., Egho, E. and Enujeke, E. (2009).Integrated pest management (IPM) adoption among farmers in Central Agro-ecological Zone of Delta State, Nigeria. *African Journal of Agricultural Research*, 3 (1-2), 29-33.

Parsa, S., Morse, S., Bonifacio, A., Chancellor, T. C., Condori, B., Crespo-Pérez, V., Hobbs, S. L., Kroschel, J., Ba, M. N. and Rebaudo, F. (2014). Obstacles to integrated pest management adoption in developing countries. *Proceedings of the National Academy of Sciences*, 111 (10) 3889-3894.

Pereira, J. A., Alves, M. R., Casal, S. and Oliveira, B. (2004). Effect of olive fruit fly infestation on the quality of olive oil from cultivars Cobrançosa, Madural, and Verdeal Transmontana. *Italian Journal of Food Science*. 16:3, p. 355-365.

Pereira, J. A., Casal, S., Bento, A., and Oliveira, M.. (2002). Influence of olive storage period on oil quality of three portuguese cultivars of Olea europea, cobrançosa, madural, and verdeal transmontana. *Journal of Agricultural and Food Chemistry*, 50 (22), 6335-6340.

Sagri, E., Reczko, M., Tsoumani, K. T., Gregoriou, M.-E., Harokopos, V., Mavridou, A.-M., Tastsoglou, S., Athanasiadis, K., Ragoussis, J. and Mathiopoulos, K. (2014). The molecular biology of the olive fly comes of age. *BMC Genetics*, 15 (2), 1-15.

Shariff, S., Ibrahim, N. J., Md-Zain, B. M., Idris, A. B., Suhana, Y., Roff, M. N., and Iatrou, K. (2014). Multiplex PCR in the determination of Opiinae parasitoids of fruit flies, Bactrocera sp., infesting star fruit and guava. *Journal of Insect Science*, *14*(1).

Sinno, M., Bézier, A., Vinale, F., Giron, D., Laudonia, S., Garonna, A. P., and Pennacchio, F. (2020). Symbiosis disruption in the olive fruit fly, Bactrocera oleae (Rossi), as a potential tool for sustainable control. *Pest Management Science*, 76(9), 3199-3207.

Tahoun, I. F., Yamani, R. N.,and Shehata, A. B. (2019). Preparation of matrix reference material for quality assurance and control of pesticide analysis in olive oil. *Accreditation and Quality Assurance*, 24 (4), 297-304.

Tamendjari, A., Angerosa, F. and Bellal, M. (2004). Influence of *Bacterocera Oleae* infestation on olive oil quality during ripping of chemical olives. *Italian Journal of Food Science*, 16 (3).

Tamendjari, A., Angerosa, F., Mettouchi, S. and Bellal, M. (2009). The effect of fly attack (*Bactrocera oleae*) on the quality and phenolic content of Chemlal olive oil. *Grasasy aceites*, 60 (5), 509-515.

Thomas, D. B. and Mangan, R. L. (2005). Nontarget impact of spinosad GF-120 bait sprays for control of the Mexican fruit fly (Diptera: Tephritidae) in Texas citrus. *Journal of economic entomology*, 98 (6), 1950-1956.

Topuz, H. and Durmusoglu, E . (2008). The effect of early harvest on infestation rate of Bactrocera oleae (Gmelin)(Diptera: Tephritidae) as well as yield, acidity, and fatty acid composition of olive oil. *Journal of Plant Diseases and Protection*, 115 (4), 186-191.

Torres-Vila, L., Rodriguez-Molina, M. and Martinez, J. (2003). Olive fly damage and olive storage effects on paste microflora and virgin olive oil acidity. *Grasas y aceites*, 54 (3), 285-294.

Torrini, G., Mazza, G., Benvenuti, C., Simoncini, S., Landi, S., Frosinini, R., and Roversi, P. F. (2020). Entomopathogenic nematodes as potential biocontrol agents against Bactrocera oleae (Diptera: Tephritidae). *Biocontrol Science and Technology*, *30*(9), 909-919.

Uchôa, M. A. (2012). Fruit flies (Diptera: Tephritoidea): biology, host plants, natural enemies, and the implications to their natural control. Integrated Pest Management and Pest Control: Current and Future Tactics. InTech, Rijeka, *Croatia*, 271-300.

Xing, J., Guyer, D., Ariana, D., and Lu, R. (2008). Determining optimal wavebands using genetic algorithm for detection of internal insect infestation in tart cherry. *Sensing and Instrumentation for Food Quality and Safety*, 2(3), 161-167.

Yokoyama, V. (2015). Olive fruit fly (Diptera: Tephritidae) in California table olives, USA: invasion, distribution, and management implications. *Journal of Integrated Pest Management*, 6 (1).

Younes, N., Al-Sadeq, D. W., Al-Jighefee, H., Younes, S., Al-Jamal, O., Daas, H. I., and Nasrallah, G. K. (2020). Challenges in laboratory diagnosis of the novel coronavirus SARS-CoV-2. *Viruses*, 12(6), 582.

Zelasco, S., Carbone, F., Lombardo, L., and Salimonti, A. (2021). *Olive tree genetics, genomics, and transcriptomics for the olive oil quality improvement*. In Olives and Olive Oil in Health and Disease Prevention (pp. 27-49). Academic Press.

مراجعه للأدبيات

إصابة ثمار الزيتون بذبابة Bacterocera Oleae وتأثيرها على جودة الزيت وتحريها فيه

عايد عمرو[1] ومنذر الصدر[1] ونوال السكارنه[2]

[1]أستاذ، قسم التغذية والتصنيع الغذائي وقسم البستنة والمحاصيل، كلية الزراعة، الجامعة الأردنية.
[2] طالبة دراسات عليا، قسم التغذية والتصنيع الغذائي، كلية الزراعة، الجامعة الأردنية

تاريخ استلام البحث: 2021/12/13 وتاريخ قبوله: 2022/4/4.

ملخص

تعتبر ذبابة ثمار الزيتون Bacterocera oleae أكثر آفات الزيتون شيوعاً في الاردن. ويعد ارتفاع معدل الاصابة بها بمراحل تطورها المختلفة، وخاصة اليرقات والعذارى، مشكلة شائعة في انتاج زيت الزيتون. على الرغم من عدم اكتشافها بالوسائل البسيطة، الا انه يعتقد ان الإصابة بها تضفي طعما "غريبا" Grubby لا يكتشفه الا الخبراء مما يؤدي الى خفض قيمة الزيت الناتج من الثمار المصابة. يعتمد تأثير الضرر الذي تسببه ذبابة ثمار الزيتون على درجة الإصابة التي تتجلى في وجود ثقوب تنتج عن خروج اليرقات التي تدمر أيضا قشور ثمار الزيتون وبالتالي تعريض الثمار لعوامل خارجية كالفطريات والاكسجين وما ينتج عنها من تسريع معدلات التزنخ التأكسدي والتحللي اللواتي تقدر بقيمة البيروكسيد وحموضة الزيت على التوالي. تتناول هذه المراجعة الأدبيات المتعلقة بتأثير الإصابة بذبابة ثمار الزيتون على جودة الزيت الناتج منها، والطرق المتبعة لمكافحتها والكشف عنها في ثمار الزيتون وزيتها.

الكلمات الدالة: ذبابة ثمار الزيتون، جودة زيت الزيتون، بقايا الحشرة في الزيت، مكافحة ذبابة ثمار الزيتون.