We are IntechOpen, the world’s leading publisher of Open Access books
Built by scientists, for scientists

5,600
Open access books available

138,000
International authors and editors

170M
Downloads

154
Countries delivered to

TOP 1%
Our authors are among the most cited scientists

12.2%
Contributors from top 500 universities

WEB OF SCIENCE™
Selection of our books indexed in the Book Citation Index in Web of Science™ Core Collection (BKCI)

Interested in publishing with us?
Contact book.department@intechopen.com

Numbers displayed above are based on latest data collected.
For more information visit www.intechopen.com
Chapter

Insecticide’s Disappearance after Field Treatment and during Processing into Byproducts

Alberto Angioni and Nicola Arru

Abstract

Insecticide’s disappearance after field treatments could be ascribed to different factors such as sunlight photodegradation, dilution effect due to fruit growth, co-distillation during fruit respiration and evaporation. Moreover, the epicuticular waxes could speed or slow down the degradation rate, and the cultivation in an open field or greenhouses could affect the residues dramatically. After harvest, the processing techniques to produce byproducts deeply influence insecticide residues. For example, fruit drying, winemaking, the industrial processing of tomatoes to produce purée, triple-concentrated paste, fine pulp, diced, olive processing to obtain table olive and olive oil, and other industrial applications on fruits affect residues and their half-life time. The scope of this chapter is to highlight the major factors responsible for the disappearance of insecticides after treatment. Moreover, the chapter intends to review the influence of the industrial processes on insecticide behaviour when the raw material is transformed into its byproducts.

Keywords: insecticide disappearance, photodegradation, fruit growth, food processing

1. Introduction

Insecticides are plant protection products, namely pesticides, intended to prevent, destroy, repel, or mitigate pests, regulated in the EU by Regulation (EC) No 1107/2009 and Regulation (EC) No 396/2005 [1, 2]. Their toxicological and legal limits on food (MRL), human and environmental risk assessment are defined, set and continuously revised.

Before an active substance can be used within a plant protection product, the European Commission must approve it. Active substances undergo an intensive evaluation process before a decision can be made on approval.

Insects represent the most abundant group of animals on the Earth; the number of species is more than any other group with an estimated number of living species of insects of 30 million and is the major competitors with humans for agriculture resources [3].

Insecticides act in different modes, disrupting the nervous system, impacting the development of the exoskeleton, or have a repelling activity. In addition, insecticides can be applied in various formulations such as sprays, dust, gels and baits, showing a different level of risk to non-target insects, people, pets and the environment [4].
In natural environments, insects live in a complex relationship with mutual limitations and constrictions, whereas in defined agroecosystems, the natural regulations are limited, and insect pest outbreaks can occur [5]. The factors influencing insecticide disappearance after treatment and during processing are primary to evaluate the possible dangerous effect of insecticides on human health and environmental safety.

2. Materials and methods

Photodegradation studies have been carried out under sunlight in field and in model systems; moreover, trials on model systems under artificial lights have been widely used. Sunlight experiments in the field have studied the disappearance rate of insecticides comparing open field treatments versus greenhouse treatments, and the degradation compounds in the greenhouse have been investigated simulating with petry dishes the effect of the covering glasses [6]. Other model systems built up trials with catalystator to investigate photocatalytic degradation with TiO₂ or oxidating compounds such as H₂O₂ and O₃ [7–14], and the different effects of soil thin layers or epicuticular waxes extracted from different commodities [15–17]. Model systems in laboratories trials employed different light sources, and the most common are represented by the xenon arc lamp and mercury lamps [12, 15, 18]. Trials were performed in water or methanol solutions in Pyrex (adsorb length < 290 nm) and quartz glass filter photochemical reactors.

Drying experiments have been conducted following traditional processes under sunlight exposure or the industrial process in an oven with controlled temperature and humidity [19–28].

The effect of fruit growing was assessed in field and greenhouses trials, correlating fruit growing with insecticide disappearance rate [29].

The effect of the technological process has been studied at industrial to avoid laboratory mystification of the results. Vinification, olive oil production and tomatoes processing have been carried out in real conditions allowing a real risk assessment [30–52].

Analytical measures of the insecticides and their metabolites have been made mainly using liquid chromatographic apparatus with UV–VIS or mass spectrometry detectors (MS).

3. Factors affecting insecticide’s depletion

3.1 Photodegradation

Insecticides released in the environment are actively photodegraded by sunlight radiation, representing one of the most destructive pathways [5]; this is because most pesticides absorb UV–VIS bands at medium-short wavelengths. However, the sunlight reaching the Earth is mainly composed of UV-A and variable amounts of UV-B with only small amounts of short wavelengths of UV radiation; therefore, the effect on pesticides should be only of limited importance [7].

Photodegradation of insecticides could lead to non-toxic metabolites or more toxic compounds, such as systemic insecticides that are converted into more water-soluble compounds. For example, 95% of the nicotinoid imidacloprid is degraded into olefine, and 4-5-dihydroxy when applied as a drench or granule. These two metabolites are active against insect pests such as aphids. Thiamethoxam is converted to clothianidin, whereas acetamiprid is converted into five active metabolites [53].
The possible toxic effect of insecticides metabolites has led to the development of environmental monitoring studies to evaluate the presence of the parent compound and its metabolite in water and soil.

The mechanisms involved in the photodegradation process could be direct photodegradation, photosensitized degradation, photocatalytic degradation and degradation mediated by hydroxyl radicals [54].

When dealing with food and the environment, UV radiation comes from the sunlight, and direct photodegradation represents the primary mechanism, while other mechanisms are involved when remediation studies occur [7].

Plant surfaces, especially leaf surfaces, are the first reaction environment for a pesticide molecule after application, and spray drift would indirectly present a similar situation. Photolysis on soil surfaces becomes essential when a pesticide is directly applied to soil or not significantly intercepted by plants, providing that the leaf cover does not shade the ground from sunlight. Because the foliar interception of pesticides depends on plant species and usually increases with their growth stage [55], the importance of soil photolysis is considered to be lessened when plants become mature. Spray drift after pesticide application or wash off from plants by rain is the indirect route by which a pesticide reaches the soil [5].

Photodegradation of insecticides in typical environmental conditions did not lead to individual responses (homolysis, heterolysis, or photoionization). Therefore, trials in model systems have been carried out to define the effect of direct irradiation [56, 57]. These trials investigate photodegradation in water solutions in the presence of catalysts or OH donors.

Photodegradation experiments showed a higher rate in aqueous solution than in dry film; therefore, the results of model systems should be correct accordingly when dealing with fruit and vegetables in the field.

Amidinohydrazone insecticides led to three products in an aqueous medium within 10 hours and were only slightly affected by pH [9]; on the other hand, carbaryl and propoxur photodegradation increased with the pH, and the main photochemical products were derived from the ester bond cleavage [54].

Carbamate insecticide photodegradation has been widely studied, and different UV irradiation lengths and mediums have been used in model systems to reproduce the natural condition. Apolar solvent (hexane, cyclohexane, isopropanol) was used to simulate plant surface, and water at different pH was used to evaluate the influence of acidity; in addition, additional studies added O₃ or other oxidants (H₂O₂, TiO₂) to verify the enhanced oxidant effect of UV irradiation at selected wavelengths [7, 9–14]. Dry film photodegradation trials in the presence of epicuticular waxes extracted from fruits and vegetable commodities or soil with humic substances led to different results in the half-life time of insecticides [12, 13].

The epicuticular waxes from different vegetables and fruits did not show univocal results, decreasing or enhancing photodegradation (Table 1) [15].

The photochemical degradation of carbaryl and carbofuran under sunlight and UV (λ 290 nm) exposure in the natural waters of Northern Greece has been investigated. The major photoproducts observed were carbofuran–phenol from carbofuran and naphthol from carbaryl [54].

The analysis of the degradation pathways of aldicarb and carbaryl in water showed as major photodegradation products aldicarb sulfoxide and 1-naphthol, respectively. In addition, the study highlighted the influence of the UV source on the rate of photodegradation [28].

Organophosphorus insecticides in water solutions showed first-grade rate constants with an observed half-life in the range of hours [58, 59].

Neonicotinoid pesticides have shown a high degree rate of photodegradation on tomato leaves after treatment in water solutions [60, 61].
Insecticides

| Compound          | K\textsuperscript{a}/K\textsuperscript{b} | Wax\textsuperscript{a} ± SD | Blank ± SD | Wax\textsuperscript{a} | Blank | r\textsuperscript{2} |
|-------------------|-----------------|-----------------|-------------|-----------------|-------|-----------------|
| Methiocarb        | 1.0             | 2.5 (0.06)      | 2.5 (0.08)  | 436             | 438   | 0.9976          |
| Methiocarb sulfone | 0.9             | 0.35 (0.08)     | 0.39 (0.11) | 3351            | 2964  | 0.9955          |
| Fenthion          | 2.9             | 5.6 (0.4)       | 1.9 (0.5)   | 204             | 593   | 0.9889          |
| Aminocarb         | 0.3             | 5.2 (0.2)       | 19.2 (1.8)  | 222             | 60    | 0.9921          |
| Pirimicarb        | 3.0             | 19.4 (1.2)      | 6.4 (1.5)   | 59              | 181   | 0.9959          |

\textsuperscript{a} 70ug cm\textsuperscript{-2} \\
\textsuperscript{b} blank \\
\textsuperscript{w} waxes

Table 1. Photolysis rates of some insecticides in the presence of epicuticular waxes of Persica laevis [15].

3.2 Fruit and vegetable growing and shape

Insecticide amount on fruit and vegetable is related to the moment of treatment, the shape and cultivar. Fruits and vegetable sizes increase during development depending on the species and the agricultural practice adopted, modifying the rate surface/weight (s/w) and influencing the residue amount profoundly. The maximum residue limit (MRL) is the highest level of pesticide residue acceptable in food or feed when pesticides are applied following Good Agricultural Practice (GAP) [62] and is expressed as mg/Kg or mg/L of active ingredients (a.i.). therefore, the rate surface/weight (s/w) represents the discriminant leading to the residue amount.

The first treatment is made after the fruit set; when no other factors are involved in the residue decrease, the amount of the insecticides in the harvested commodities at commercial ripening is reduced by the growth factor and the residues are lower when the treatment is done much in advance of the harvest.

Therefore, when insecticides are applied to fruit and vegetable before harvest when the development is concluded, the growth dilution could not more influence the residue amount.

On the other hand, the shape and final size of the commodities have great importance. For example, tomatoes have different dimensions and shapes depending on the cultivar ranging from 12 to 200 g from cherry to beef heart. The surface/weight ratio for 1 Kg is notably higher for cherry; therefore, the same treatment applied on the cultivar would lead to entirely different results with higher residue expressed in mg/Kg in the cherry tomatoes. The cultivar (CV) Koreniki has small olives (1–2 g), whereas Yacouti has big olives (5–6 g), accounting for a lower s/w ratio and minor final residues (Table 2).

In iceberg and romana lettuce CV, the edible parts have different shapes: an open calyx in romana and ball-shaped in the iceberg; similar consideration can be made for artichoke when comparing meda or masedu cv (calyx shape) to spinoso sardo and romanescocv (close shape). The calyx shape allows the deposition of treatment solution among the fruit leaf, with prolonged contact and final higher residue concentration, whereas the ball and close shape let the solution slide down, allowing only a short contact (Figure 1). Moreover, the outer leaves in both cases are removed before eating [29].

3.3 Drying

Drying is one of the oldest and most common preservation methods; water removal minimizes many moisture-driven deterioration reactions. However, drying fruit to obtain raisins, prunes and apricots could increase insecticide levels in the
Insecticide's Disappearance after Field Treatment and during Processing into Byproducts
DOI: http://dx.doi.org/10.5772/intechopen.100802

final product due to the concentration factor (4, 3 and 6, respectively) [19]. In addition, sunlight or oven drying processes lead to different results [20].

In raisins, insecticides decrease has been ascribed to the temperature of oven drying and lesser effect to sunlight, correlating the decrease to the degradation of the pesticides [21]. However, trials in model systems evaluating the process of disappearance during oven drying showed that insecticide co-distillation with water could be as important as heat degradation [22, 23].

Apricots, plums and prunes showed lower residues in the dried product; however, results were not the same for the different pesticides; moreover, the effect of sunlight in apricot was more efficacious (Table 3) [24–26].

Chilli pepper subjected to oven drying showed a concentration factor of almost 5, and the insecticides tested had different behaviour some were more concentrated in the final product while other decreased [27]. A similar experiment on orange slices showed a general decrease in the pesticide investigated even if the mechanism was not explained [28].

3.4 Technological processes

3.4.1 Wine, beer and byproducts

The fate of insecticides residues on grapes during winemaking has been widely studied [30–37]. Depending on the technology adopted, two categories of wine

| Commodities | Cultivar | s/w ratio |
|-------------|---------|----------|
| Olive       | Yacouti | 0.7      |
|             | Koroneiki | 1.3     |
| Tomatoes    | Shiren  | 1.8      |
|             | Caramba | 0.8      |

Table 2. Surface/weight ratio of different cultivars and after development.

| Commodities | Cultivar | Weight (diluting factor/day) |
|-------------|---------|----------------------------|
| Peaches     | Flavorcrest | 45 (1.07/1) 135 (3.21/15) |

Figure 1. Different shapes of lettuce and artichoke cultivars.
Insecticides are obtained, white wines and red wines. The former are wines produced in the absence of skins, whereas red wines are produced with maceration in the presence of the skins. During fermentation, two main waste products are generated, lees and grapes. These fractions adsorb insecticides due to the affinities for the solid residues during alcoholic fermentation and, therefore, sequestered them from the must, which results free from residues or with reduced amounts with respect to the grapes. Moreover, active degradation by the yeast could be encountered, and these results were also confirmed during beer preparation [31, 32]. In the second stage, the malolactic fermentation by bacteria can actively decrease pesticide levels, which would encounter an added decrease with the clarification step using fining agents such as activated carbon, bentonite, polyvinylpolypyrrolidone (PVPP), gelatin, egg albumin, isinglass-fish glue, and casein [31, 38–41].

The spirit drink industry can use grapes and lees to produce alcohol, and distilled beverage spirits and insecticides could concentrate in the distillate of a factor between one (cake) and six hundred (lees) (Garoglio 1973). When wines are used to produce distillate, the concentration factor would be 10 times.

Literature data showed that only small amounts of fenthion (2%) and quinalphos (1%), and other organophosphate insecticides passed during the distillation process from artificially contaminated lees [42–44], indicating that insecticides hardly migrate to the distilled spirits.

### 3.4.2 Olive oil

The transfer to virgin olive oil is related to the active ingredients’ octanol/water partition coefficient during the production step. Since no MRL is set in olive oil, the values for olive are adapted to the oil relating to the partition coefficient. In 2015, EU differentiated between fat-soluble and fat insoluble compounds, setting processing factors of 5 and 1, respectively [45]. On the other hand, highly polar insecticides showed negligible transfer rates in the oil being concentrated in the aqueous phase [46].

Insecticides with Kow > 0 increase their concentration in the oil while decreasing their polarity. For example, organophosphorus insecticides concentrate 7 times in the oil following the concentration factor from olive to oil (7 kg olives for 1 l of oil) [47]. Although, on the other hand, triazoles and neonicotinoids displayed different behaviour, so that an increase of hydrophobicity did not cause such an increase of pesticide transfer efficiency for these two classes, water addition during the extraction step caused a decrease of the insecticides with lower Kow [46–48].

| Commodities | Insecticides | Fruit weight (g) | mg/kg ± SD | Conc. factor | Reference |
|-------------|--------------|------------------|------------|-------------|-----------|
| **Apricots** |              |                  |            |             | [25]      |
| Diazinon    | Fresh fruit  | 43.3 ± 3.3       | 0.50 ± 0.13|             |           |
|             | Dried fruit  | 6.6 ± 0.6        | 0.63 ± 0.20| 6.56        |           |
| Phosalone   | Fresh fruit  | 42.5 ± 2.0       | 0.48 ± 0.14|             |           |
|             | Dried fruit  | 7.6 ± 1.1        | 1.56 ± 0.37| 5.59        |           |
| **Prunes**  |              |                  |            |             | [24]      |
| Phosalone   | Fresh fruit  | 38.7 ± 1.3       | 0.21 ± 0.06|             |           |
|             | Dried fruit  | 12.5 ± 1.2       | 0.62 ± 0.16| 3.09        |           |

*Table 3. Insecticides level after drying process.*
3.4.3 Tomatoes processing

Europe is the most important producer of tomatoes, and integrated pest management strategies (IPM) are applied widely. For example, insecticides applied in the field could be transferred and concentrate into processing products such as purée, triple concentrated paste, fine pulp, and diced tomatoes [49].

Washing and peeling led to a decrease in insecticide residues, even if washing affected only the pesticide adsorbed on the dust adhering to the surface [50, 51].

Different batches of tomatoes from different fields subjected to different agriculture procedures and pesticide treatments are processed jointly during the industrial process. Therefore, a dilution effect would occur during the various production steps. The main effect related to the decrease of insecticides during tomatoes processing are represented by peeling and the dilution effect [52].

4. Conclusions

The disappearance of insecticides after treatment could be related to many different paths. The main effects in the field are related to sunlight photodegradation and the development of the fruits during fruit growing leading to a decrease of the residues below the legal limit and sometimes the analytical detectable levels. Run-off and washing could affect only the residues adsorbed in the adhering dust on fruits and vegetable surfaces not influencing the residues adsorbed in the epicuticular waxes. Drying causes a reduction in weight, theoretically the residue could increase giving a value that is a function of the concentration factor, however the results showed a decrease in insecticide residues in foodstuffs. The different processing steps affect insecticides residues involving partition, microbiological and chemical degradation, and adsorption on the waste such as lees, marc, vegetation water and pomace.

Acknowledgements

The chapter has been written with the active help of researchers from the Italian Society of FOO Chemistry (ItaChemFood).

Conflict of interest

The authors declare no conflict of interest.
References

[1] Regulation (EC.) No 1107/2009 of the European parliament and of the council of 21 October 2009. Official Journal of the European Union; L 309: 1-50

[2] Regulation (EC.) No 396/2005 of the European Parliament and of the Council of 23 February 2005 on maximum residue levels of pesticides in or on food and feed of plant and animal origin and amending Council Directive 91/414/EEC. Available from: http://data.europa.eu/eli/reg/2005/396/oj

[3] Sharma S, Kooner R, Arora R. Insect Pests and Crop Losses. In: Arora R, Sandhu S, editors. Breeding Insect Resistant Crops for Sustainable Agriculture. Singapore: Springer Nature Singapore Pte Ltd.; 2017. DOI: 10.1007/978-981-10-6056-4_2

[4] EPA Insecticides. 2021. Available from: https://www.epa.gov/caddis-vol2/insecticides

[5] Gill HK, Garg H, editors. Pesticides: Environmental Impacts and Management Strategies, Pesticides - Toxic Aspects. Rijeka: IntechOpen. DOI: 10.5772/57399. Available from: https://www.intechopen.com/chapters/46083

[6] Garau V, Angioni A, Real AAD, Russo M, Cabras P. Disappearance of azoxystrobin, pyrimethanil, cyprodinil and fludioxinil on tomatoes in a greenhouse. Journal of Agricultural and Food Chemistry. 2002; 50:1929-1932

[7] Katagi T. Photodegradation of Pesticides on Plant and Soil Surfaces. In: Ware GW, editor. Reviews of Environmental Contamination and Toxicology. Continuation of Residue Reviews. Vol. 182. New York, NY: Springer; 2004. DOI: 10.1007/978-1-4419-9098-3_1

[8] Assalin MR, Ferracini VL, Nascimento Queiroz SC, Jonsson CM, Clemente Z, Silva SRCM. Photocatalytic degradation of an organophosphorus pesticide from agricultural waste by immobilized TiO₂ under solar radiation. Revista Ambiente & Água. 2016;11(4). DOI: 10.4136/ambi-agua.1824

[9] Adityachaudhury N, Chowdhury A, Das AK, Bhattacharyya A, Pal S. Transformation of some selected pesticides. Journal of the Indian Chemical Society. 1994; 71:425-433

[10] Kanan M. A study of the photodegradation of carbaryl: The influence of natural organic matter and the use of silver zeolite Y as a catalyst. Electronic Theses and Dissertations. 2002:211

[11] Benitez FJ, Acero JL, Real FJ, Roldan G, Rodriguez E. Modeling the photodegradation of emerging contaminants in waters by UV radiation and UV/H₂O₂ system. Journal of Environmental Science and Health, Part A, Toxic/Hazardous Substances and Environmental Engineering. 2013; 48(1):120-8. doi: 10.1080/10934529.2012.707864

[12] Pirisi F, Cabras P, Garau VL, Melis M, Angioni A, Bullita D. Photodegradation of pesticides. 1. Photolysis rates and half-life of acylanilides and their major metabolites in water. Toxicological and Environmental Chemistry. 1996; 55:199-214. DOI: 10.1080/02772249609358336

[13] Mansour SA, Tony MA, Tayeb AM. Photocatalytic performance and photodegradation kinetics of Fenton-like process based on haematite nanocrystals for basic dye removal. SN Applied Science. 2019; 1:265. DOI: 10.1007/s42452-019-0286-x

[14] Tanaka K, Reddy KSN. Photodegradation of phenoxyacetic acid
Insecticides and carbamate pesticides on TiO₂, Applied Catalysis B: Environmental. 2002;39(4):305-310

[15] Pirisi FM, Angioni A, Cabizza M, Cabras P, Falqui CC. Photolysis of pesticides: influence of epicuticular waxes from Persica laevis DC on the photodegradation in the solid phase of aminocarb, methiocarb and fenithion. Pest Managment Science. 2001;57:522-526. DOI: 10.1002/ps.329

[16] Pirisi FM, Angioni A, Cabizza M, Cabras P, Maccioni E. Influence of epicuticular waxes on the photolysis of pirimicarb in the solid phase. Journal of Agricultural and Food Chemistry. 1998;46:762-765

[17] Graebing P, Frank M, Chib JS. Soil photolysis of herbicides in a moisture- and temperature-controlled environment. Journal of Agricultural and Food Chemistry. 2003;51:4331-4337

[18] de Bertrand N, Barceló D. Photodegradation of the carbamate pesticides aldicarb, carbaryl and carbofuran in water. Analytica Chimica Acta. 1991;254:1-2 235-244

[19] Zhao X, Kong W, Wei J, Yang M. Gas chromatography with flame photometric detection of 31 organophosphorus pesticide residues in Alpinia oxyphylla dried fruits. Food Chemistry. 2014;162:270-276

[20] Alasalvar C, Shahidi F. Composition, phytochemicals, and beneficial health effects of dried fruits: An overview. In: Alasalvar C, Shahidi F, editors. Dried fruits: Phytochemicals and health effects. Oxford: Wiley-Blackwell; 2013. pp. 1-18

[21] Ayşe O, Şeyda K, Ali C. Effect of drying process on pesticide residues in grapes. GIDA/The Journal of Food. 2017;42:204-209. DOI: 10.15237/gida.GD16098

[22] Cabras P, Angioni A. Pesticide residues in grapes, wine, and their processing products. Journal of Agricultural and Food Chemistry. 2000;48(4):967-973. DOI: 10.1021/jf990727a

[23] Athanasopoulos PE, Pappas C, Kyriakidis NV, Thanos A. Degradation of methamidophos on soulantina grapes on the vines and during refrigerated storage. Food Chemistry. 2005;91(2):235-240

[24] Cabras P, Angioni A, Garau VL, Pirisi FM, Brandolini V, Cabitza F, et al. Pesticide residues in prune processing. Journal of Agricultural and Food Chemistry. 1998;46:3772-3774

[25] Cabras P, Angioni A, Garau VL, Melis M, Pirisi FM, Cabitza F, et al. Pesticide Residues on Field-Sprayed Apricots and in Apricot Drying Processes. Journal of Agricultural and Food Chemistry. 1998;46:2306-2308

[26] Cabras P, Angioni A, Garau VL, Minelli EV, Cabitza F, Cubeddu M. Pesticide residues in plums from field treatment to the drying process. Italian Journal of Food Science. 1998;10(1):81-85

[27] Noh HH, Kim DK, Lee EY, Chang MI, Im MH, Lee YD. K KS. Effects of oven drying on pesticide residues in field-grown chili peppers. Journal of Korean Society for Applied Biological Chemistry. 2015;58:97-104. DOI: 10.1007/s13765-015-0016-z

[28] Acoglu B, Omeroglu PY. The effect of drying processes on pesticide residues in orange (Citrus sinensis). Drying Technology. An International Journal. 2021;39(13). DOI: 10.1080/07373937.2021.1946078

[29] Cabras P. Part II. Anthropogenic contaminants Pesticides: toxicology and residues in food. In D’Mello JPF, editor Food safety: contaminants and toxins.
Insecticide's Disappearance after Field Treatment and during Processing into Byproducts
DOI: http://dx.doi.org/10.5772/intechopen.100802

2003; CABI Publishing, UK. 91-124. 10.1079/9780851996073.0000

[30] Flori P, Frabboni B, Cesari A. Pesticide decay models in the winemaking process and wine storage. Italian Journal of Food Science. 2001;12(1):279-289

[31] Cabras P, Angioni A. Pesticide Residues in Grapes, Wine, and Their Processing Products. Journal of Agricultural and Food Chemistry. 2000;48(4):967-973

[32] Navarro S, Pérez G, Navarro G, Mená L, Vela N. Variability in the fermentation rate and color of young lager beer as influenced by insecticide and herbicide residues. Food Chemistry. 2007a;105:1495-1503. DOI: 10.1016/j.foodchem.2007.05.035

[33] Cabras P, Angioni A, Garau VL, Pirisi FM, Brandolini V. Gas Chromatographic Determination of Azoxytrobin, Fluazinam, Kresoxim-Methyl, Mepanipyrim, and Tetraconazole in Grapes, Must, and Wine. Journal of AOAC International. 1998;81(6):1185-1189

[34] Navarro S, Barba A, Oliva J, Navarro G, Pardo F. Evolution of residual levels of six pesticides during elaboration of red wines. Effect of winemaking procedures in their disappearance. Journal of Agricultural and Food Chemistry. 1999;47:264-270. DOI: 10.1021/jf980801

[35] Dumitriu (Gabur) GD, Teodosiu C, Valeriu V. Management of Pesticides From Vineyard to Wines: Focus on Wine Safety and Pesticides Removal By Emerging Technologies. 2021. DOI: 10.5772/intechopen.98991

[36] Cus F, Cesnik HB, Bolta SV, Gregoric A. Pesticide residues in grapes and during vinification process. Food Control. 2010;21:1512-1518. DOI: 10.1016/j.foodcont.2010.04.024

[37] Navarro S, Barba A, Oliva J, Navarro G, Pardo F. Evolution of residual levels of six pesticides during elaboration of red wines. Effect of winemaking procedures in their disappearance. Journal of Agricultural and Food Chemistry. 1999;47:264-270. DOI: 10.1021/jf980801

[38] Doulia DS, Anagnos EK, Liapis KS, Klimentzos DA. Effect of clarification process on the removal of pesticide residues in red wine and comparison with white wine. Journal of Environmental Science and Health. Part. B. 2018;53(8):534-545. DOI: 10.1080/03601234.2018.1462937

[39] Marangon M, Vincenzi S, Curioni A. Wine fining with plant proteins. Molecules. 2019;24(11):2186. DOI: 10.3390/molecules24112186

[40] Sen K, Cabaroglu T, Yilmaz H. The influence of fining agents on the removal of some pesticides from white wine of Vitis vinifera L. cv. Emir. Food and Chemical Toxicology. 2012;50(11):3990-3995. DOI: 10.1016/j.fct.2012.08.016

[41] Oliva J, Payá P, Cámara MA, Barba A. Removal of pesticides from white wine by the use of fining agents and filtration. Communications in Agricultural and Applied Biological Sciences. 2007;72(2):171-180 PMID: 18399438

[42] He NX, Bayen S. An overview of chemical contaminants and other undesirable chemicals in alcoholic beverages and strategies for analysis. Comprehensive Reviews in Food Science and Food Safety. 2020:3916-3950. DOI: 10.1111/1541-4337.12649

[43] Shin JA, Cho H, Seo DW, Jeong HG, Kim SC, Lee JH, et al. Approach Study for Mass Balance of Pesticide Residues in Distillers’ Stillage along with Distillate and Absence Verification of Pesticides in Distilled Spirits from Pilot-Scale of
Insecticides

Distillation Column. Molecules. 2019;24(14):2572. DOI: 10.3390/molecules24142572

[44] Cabras P, Angioni A, Garau VL, Minelli EV, Melis M, Pirisi FM. Pesticides in the distilled spirits of wine and its byproducts. Journal of Agricultural and Food Chemistry. 1997;45:2248-2251. DOI: 10.1021/jf9604571

[45] European Commission. Commission Implementing Regulation (EU) 2015/595 of 15 April 2015 concerning a coordinated multiannual control programme of the Union for 2016, 2017 and 2018 to ensure compliance with maximum residue levels of pesticides and to assess the consumer exposure to pesticide residues in and on food of plant and animal origin. The Official Journal of the European Union. 2015;L99:7-20

[46] López-Blanco R, Moreno-González D, Nortes-Méndez R, García-Reyes JF, Molina-Díaz A, Gilbert-López B. Experimental and theoretical determination of pesticide processing factors to model their behavior during virgin olive oil production. Food Chemistry. 2018;239:9-16

[47] Cabras P, Angioni A, Melis M, Minelli EV, Pirisi FM. Simplified multiresidue method for the determination of organophosphorus insecticides in olive oil. Journal of Chromatography A. 1997;761(1-2):327-331

[48] Amvrazi EG, Alabanis TA. 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. 2008;56:5700-5709

[49] Silva-Rodríguez A, Acedo-Valenzuela MI, Diez NMM, de la Peña AM, Galeano-Díaz T. Multiresidue method for the control of pesticide residues in tomatoes and derived products. Analytical Methods. 2012;4:2543-2549

[50] Kwon H, Kim TK, Hong SM, Se EK, Cho NJ, Kyung KS. Effect of household processing on pesticide residues in field-sprayed tomatoes. Food Science and Biotechnology. 2015;24:1-6

[51] Al-Taher F, Chen Y, Wylie P, Cappozzo J. Reduction of pesticide residues in tomatoes and other produce. Journal of Food Protection. 2013;76:510-515

[52] Corrias F, Atzei A, Lai C, Dedola F, Ibba E, Zedda G, et al. Effects of industrial processing on pesticide multiresidues transfer from raw tomatoes to processed products. Food. 2020;9:1497. DOI: 10.3390/foods9101497

[53] McKenzie R, Madronich S, Ultraviolet surface, In Encyclopedia of Atmospheric Sciences 1st edition, Holton JR edt., London, UK: Academic Press; 2003. pp 2474

[54] Burrows HD, Canle M, Steenken S. Reaction pathways and mechanisms of photodegradation of pesticides. Journal of Photochemistry and Photobiology B: Biology. 2002;67(2):71-108

[55] Cloyd RA. Pesticide Metabolites. Manhattan, KS: Kansas State University; 2012

[56] Linders J, Mensink H, Stephenson G, Wauchope D, Racke K. Pure and Applied Chemistry. 2000;72:2199-2218

[57] Bustosa N, Cruz-Alcalde A, Iriela A, Cirellia AF, Sans C. Sunlight and UVC-254 irradiation induced photodegradation of organophosphorus pesticide dichlorvos in aqueous matrices. The Science of the Total
Environment. 2019;649:592-600. DOI: 10.1016/j.scitotenv.2018.08.2540048-9697

[58] Hebert JVR, Hoonhout C, Miller GC. Use of stable tracer studies to evaluate pesticide photolysis at elevated temperatures. Journal of Agricultural and Food Chemistry. 2000;48(5):1916-1921. DOI: 10.1021/jf990699w

[59] Doong RA, Chang WH. Photoassisted titanium dioxide mediated degradation of organophosphorous pesticides by hydrogen oxidation of herbicides using natural sunlight. Journal of Photochemistry and Photobiology A. 1997;107:239-244

[60] Kole RK, Banerjee H, Bhattacharyya A, Chowdhury A, Adityachaudhury N. Photo transformation of some pesticides. Journal of the Indian Chemical Society. 1999;76:595-600

[61] Scholz K, Reinhard F. Photolysis of imidaclorpid (NTN 33893) on the leaf surface of tomato plants. Pesticide Science. 1999;55:633-675

[62] Codex Alimentarius, International Food Standards. Maximum residue limits (MRLs) and risk management recommendations (RMRs) for residues of veterinary drugs in foods CX/MRL 2-2018. FAO;