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Effects of washing treatments on pesticide residues in agricultural products

Tarımsal ürünlerde yıkama işlemlerinin pestisit kalıntıları üzerine etkileri

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Abstract

Objective: In recent years, besides the analysis of pesticide residues in fresh fruit and vegetables, researches have also been carried out on residue removal or reduction rates on different agricultural commodities. Farmers prefer various food-processing methods when they experience problems in marketing or when they wish to have value-added. In this sense, it is important to know the fate of pesticides after processing. Washing, peeling, drying and processing into fruit juice are the most common processing methods applied to fruits. In this study, it is aimed to compile information about the effects of various washing methods on pesticide residue removal or reduction rates and the factors (pesticide water solubility and mode of action, preharvest intervals, type, and duration of washing) affecting such removal or reduction rates.

Conclusion: There are various washing processes for the removal of pesticides from agricultural commodities. Washing usually reduces pesticide residues. Washing with non-toxic acidic solutions, ozonated water, and ultrasonic cleaning have been found to be more effective than washing with tap water. The most important factors affecting washing processes were identified as pesticide water solubility and mode of action. Since field-spraying allows the pesticides to penetrate into biologically active plant parts, field-sprayed samples should be used in washing processes. In this review study, the necessity of washing fruits and vegetables before consumption was pointed out once again.

Keywords: residue; washing process; processing factor (PF); pesticide mode of action

Öz

Amaç: Son yıllarda yaş meyve sebzelerde pestisit kalıntılarının analizine ilave olarak işlenmiş tarımsal ürünlerde de kalıntıların belirlenmesi üzerine araştırmalar yapılmaktadır. Üreticiler, ürünü pazarlamada problem olduğunda veya ürününe katma değer kazandırmak istediğinde, ürününü çeşitli şekillerde işlemeyi tercih etmektedir. Bu anlamda da işlemeden sonra ürünlerde pestisitlerin akıbetinin bilinmesi önemlidir. Bu ürün işlemelerinin en fazla kullanılanları, yıkama, kabuk soyma, kurutma ve meyve suyu işlemedir. Bu çalışmada, çeşitli yıkama tekniklerinin pestisit kalıntılarının giderilmesi üzerine etkisi ve buna etkili olan çeşitli faktörlerin (pestisitin suda çözünürlüğü, etki mekanizması, hasat ile son ilaçlama arasında geçen süre ve yıkamanın süresi) derlenmesi amaçlanmıştır.

Sonuç: Pestisitlerin ürünlerden uzaklaştırılması için çeşitli yıkama işlemleri vardır. Yıkama genellikle pestisit kalıntılarını azaltır. Toksik olmayan asidik çözeltiler, ozonlu su, ultrasonik temizleme ile yıkamanın çoğu çalışmada musluk suyu ile yıkamaya göre daha etkili olduğu bulunmuştur. Yıkama işlemini etkileyen en önemli faktörler pestisitin suda çözünürlüğü ve etki şeklidir. Tarlada ilaçlama, pestisitlerin biyolojik olarak aktif bitki kısımlarına nüfuz etmesine izin verdiği için, yıkama işleminde tarlada ilaçlanmış numuneler kullanılmalıdır. Bu derleme çalışmasında meyve ve sebzelerin tüketilmeden önce yıkanması gerekliliği bir kez daha vurgulanmıştır.

Anahtar kelimeler: kalıntı; yıkama işlemi; işleme faktörü (PF); pestisit etki mekanizması

1. Introduction

Pesticides are essential components of agronomic practices in some cases to minimize pests and disease-induced yield and quality losses (Tiryaki & Temur, 2010). Despite several advantages of pesticide in the agricultural fields, limit-exceeding residues pose a serious risk to human health (Randhawa et al., 2014a). Pesticide residues are a major concern for consumers and create important problems also in international trade. Therefore, there is a great interest in the reduction of residues on agricultural products and decreasing human exposure to these chemicals (Ghani et al., 2010; Gonzalez-Rodriguez et al., 2011). Residues exceeding MRL (maximum residue levels) specified for each pesticide on raw or processed commodities can be an important source of exposure (Acoğlu et al., 2018; Lozowicka et al., 2011; Lozowicka et al., 2013).

There is a limited number of food processing methods to reduce pesticide residues in fruits and vegetables. Effective methods include washing, cooking, ozone treatment, refrigeration, and ultrasonic cleaning (Lozowicka et al., 2016). Method efficiencies are largely dependent on physicochemical characteristics of the pesticide, type of processing, process duration, climate parameters throughout the growing season, and agricultural commodity produced (Holland et al., 1994; Kong et al., 2012; Polat & Tiryaki, 2020; Zhao et al., 2020**)**.

Washing is the first process used to reduce pesticide residues over the surface of commodity (Hassan et al., 2019). Effectiveness of washing process depends on chemical characteristics, mode of action, pesticide water solubility, and harvest times. Contact pesticides do not penetrate into the commodities (Heshmati et al., 2020; Gonzalez-Rodriguez et al., 2011; Lozowicka et al., 2016; Polat, 2021). Therefore, these residues could easily be reduced through washing process. On the other hand, systemic pesticides may penetrate into the other sections of the plant, thus it is highly difficult to remove systemic pesticides from different sections of the plants (Acoğlu et al., 2018; Lozowicka et al., 2013). Water solubility plays an important role in reducing pesticide residues on fruits and vegetables. With the exceptions of some pesticides, removal of higher soluble pesticides is readily possible (Krol et al., 2000; Lozowicka et al., 2016; Randhawa et al., 2014b).

Field-sprayed samples should be used in washing processes. The “field-sprayed" method differs from laboratory fortification. In field-spraying pesticides may penetrate into different sections of the plants. Absorption and translocation of the pesticide and weathering may affect the washing process. Spraying pesticides on any fruits and vegetables in laboratory and then processing them does not reflect real processing effects (Krol et al., 2000; Polat & Tiryaki, 2018).

In this review article, the effects of washing process on pesticide residue levels were reviewed. Factors affecting washing treatments, such as action mode of pesticide, residue age, types of washing and solubility in water were assessed one by one.

2. Reduction rate of pesticides and processing factor

Reduction rate (Eq. 1) and processing factors (Eq. 2) are calculated to assess the effects of washing process on pesticide residue concentrations (Bian et al., 2020; González-Rodríguez et al., 2011; Kong et al., 2012; OECD, 2008).

$$\text{Reduction rate, \%} = \frac{\text{Residue in the raw product} - \text{Residue in the processed product}}{\text{Residue in the raw product}} x100 \qquad (1)$$

$$\text{Processing factor, PF} = \frac{\text{Residue level in the processed product, mg/kg}}{\text{Residue level in the raw product, mg/kg}} \qquad (2)$$

A PF of less than 1 represents a decrease in pesticide residues on the processed product; a PF of bigger than 1 represents an increase in pesticide residues on the processed product. If PF equal to 1, there was no change in pesticide residues on the processed product.

3. Factors affecting washing treatments

Washing treatments usually reduce pesticide residue levels on commodity. Pesticide residue levels may be reduced by 9-99% through washing treatments. However, reduction levels achieved by washing treatments differs depending on residue location, mode of action, residue age, water solubility of pesticide, washing type (method and solutions), PHI (preharvest interval, the time between the harvest and pesticide application), temperature and duration of washing. Removal of pesticide on commodity by washing is also influenced by food type, physicochemical characteristics of pesticide, vapour pressure and octanol/water partition coefficient (K_{ow}/log K_{ow}). In previous studies, pesticide residue reductions of between 22-60% were reported with various washing processes (Acoglu & Yolci Omeroğlu, 2021; Chen et al., 2020; Dong, 2012; Gonzalez-Rodriguez et al., 2011; Rodrigues et al., 2017;). Pesticide residue reduction rates achieved through different washing process are provided in Table 1 for several pesticides and various commodities.

Table 1. Effects of different washing treatments on pesticide residues.

Commodity	Washing treatments	Pesticides	Range of reduction rate, %	Reference
Apple	Water, sodium hypochlorite, peroxyacetic acid, tween 20	Thiabendazole	50.97	Al-Taher et al. 2013
		Diphenylamine	88.8	
		Pyrimethanil	40.36	
		Thiabendazole	49.04	
		Diphenylamine	46.9	
Beans	Tap water, acetic acid, sodium bicarbonate, potassium permanganate, malic acid, oxalic acid, aqueous solution	Fenitrothion	39-63	Satpathy et al. 2012
		Formothion	27-90.7	
		Chlorpyriphos	31-87.6	
		Malathion	43-88.9	
		Methyl parathion	35-92.6	
		Parathion	33-88.1	
Brinjal		Endosulfan	15.42	Randhawa et al. 2014b
Capsicum	Tap water, acetic acid, sodium bicarbonate, potassium permanganate, malic acid, oxalic acid, aqueous solution	Fenitrothion	34-65	Satpathy et al. 2012
		Formothion	27-97.6	
		Chlorpyriphos	31-87.7	
		Malathion	40-95.3	
		Methyl parathion	36-92.6	
		Parathion	37-88.1	
Cabbage	Tap water, detergent solution, sodium hypochlorite	Chlorpyrifos	0.23-56.6	Ling et al. 2011
Cauliflower	Tap water	Endosulfan	27.27	Randhawa et al. 2014b
	Tap water, acetic acid, sodium bicarbonate, potassium permanganate, malic acid, oxalic acid, aqueous solution	Fenitrothion	36-86.8	Satpathy et al. 2012
		Formothion	29-90.7	
		Chlorpyriphos	35-87.7	
		Malathion	39-95.3	
		Methyl parathion	34-92.6	
		Parathion	32-88.1	
Carrots	Tap water	Chlorpyrifos	49-60	Bonnechère et al. 2012b
		Difenoconazole	86-89	
		Dimethoate	27-33	
		Tebuconazole	58-68	
Cucumber	Tap water, detergent solution, sodium hypochlorite	Chlorpyrifos	2.04-11	Ling et al. 2011
	Tap water, acetic acid, citric acid	Imidacloprid	48.43-93.75	Randhawa et al. 2014a
Garlic	Tap water, acidic solution, alkaline solution	Iprodione	4-90	Bian et al. 2020
Garlic sprouts	Tap water, detergent solution, sodium hypochlorite	Chlorpyrifos	3.65-25.6	Ling et al. 2011
Grape	Tap water, acetic acid, citric acid, ultrasonic cleaning	Chlorpyrifos-methyl	13.9-71.1	Polat, 2021
		Lambda-cyhalothrin	15.3-68	
		Tebuconazole	22.11-74.45	Duman et al. 2020
Eggplant	Tap water, detergent solution, sodium hypochlorite	Chlorpyrifos	36.2-50.7	Ling et al. 2011
	Tap water, acetic acid, sodium bicarbonate, potassium permanganate, malic acid, oxalic acid, aqueous solution	Fenitrothion	37-89	Satpathy et al. 2012
		Formothion	34-90.3	
		Chlorpyriphos	42-84.8	
		Malathion	38-95.3	
		Methyl parathion	22-83.8	
		Parathion	23-88.1	
Kumquat	Tap water, electrolysed water	Chlorpyrifos, Bifenthrin, Tebuconazole, Pyridaben, Buprofezin, Spirotetramat, Azoxystrobin, Imidacloprid, Difenoconazole, Nitenpyram	16.1-91.7	Yang et al. 2020
Lemon	Tap water, sodium hypochlorite, peroxyacetic acid, tween 20	Imazalil	41.68	Al-Taher et al. 2013
Mushroom	Glacial acetic acid, tap water, sodium bicarbonate	Diazinon	65.90-77.32	Heshmati et al. 2019
		Fenpropathrin	17.11-36.03	
		Malathion	72.77-72.77	
		Permethrin	38.76-66.46	
		Propargite	27.56-68.27	
Okra	Tap water	Endosulfan	22.27	Randhawa et al. 2014b
	Tap water, acetic acid, sodium bicarbonate, potassium permanganate, malic acid, oxalic acid, aqueous solution	Fenitrothion	35-66	Satpathy et al. 2012
		Formothion	20-90.7	
		Chlorpyriphos	31-87.7	
		Malathion	36-42	
		Methyl parathion	29-92.6	
		Parathion	29-78.7	

Table 1. Effects of different washing treatments on pesticide residues (continued).

Commodity	Washing treatments	Pesticides	Range of reduction rate, %	Reference
Orange	Tap water, sodium hypochlorite, peroxyacetic acid, tween 20	Imazalil	64.71	Al-Taher et al. 2013
		Thiabendazole	78.05	
	Tap water, sodium carbonate, sodium chloride, acetic acid, apple vinegar-water, grape vinegar-water	Abamectin	2.-38	Acoglu & Yolci Omeroglu, 2021
		Buprofezin	24-59	
		Etoxazole	5-46	Acoglu & Yolci Omeroglu, 2021
		Imazalil	5-61	
		Thiophanate-methyl	39-82	
Potato	Tap water	Endosulfan	22.22	Randhawa et al. 2014b
	Tap water, acetic acid, sodium chloride	Hexachlorobenzene	23.7-59.7	Soliman, 2001
		Lindane	18.8-65.3	
		p,p'-DDT	18.1-63.4	
		Dimethoate	12.4-95.6	
		Primiphos-methyl	18.1-96.5	
		Malathion	11.2-97.8	
Peach	Water, sodium hypochlorite, peroxyacetic acid, tween 20	Fludioxonil	71.63	Al-Taher et al. 2013
Pepper	Tap water, acetic acid, citric acid, ultrasonic cleaning	Acetamiprid	3.21-77.16	
		Chlorpyrifos	8.43-82.30	Polat & Tiryaki, 2020
		Formetanate hydrochloride	30.44-88.50	
		Pirimiphos-methyl	4.57-87.16	Çatak et al. 2020
	Tap water, sodium carbonate, sodium hypochlorite, glycerol, acetic acid	Boscalid	45.44-65.47	
		Fenhexamid	19.87-53.76	Ghani et al. 2010
		Myclobutanil	17.30-35.75	
	Tap water, acetic acid, citric acid	Imidacloprid	48.43-93.75	Randhawa et al. 2014a
	Water, sodium hypochlorite, peroxyacetic acid, tween 20	Imidacloprid	71.2	Al-Taher et al. 2013
		Chlorpyrifos	43.14	
Rape	Tap water, ozonated water	Diazinon	10.9-53.4	Wu et al. 2007
		Cypermethrin	25.5-61.1	
		Methyl parathion	16.4-47.9	
		Parathion	19.2-55.3	
Spinach	Tap water, acetic acid, citric acid, sodium chloride, sodium carbonate, ginger extract, garlic extract, radish extract, lemon extract	Chlorpyrifos	22.95-94.21	Amir et al. 2019
		Cypermethrin	22.60-89.99	
		Deltamethrin	10.21-79.68	
		Endosulfan	11.24-70.32	
	Tap water	Iprodione	43-48	Bonnechère et al. 2012a
		Mancozeb	43-48	
		Boscalid	29-57	
		Propamocarb	11.0-13	
		Endosulfan	27.1	Randhawa et al. 2014b
		Boscalid	33-68	Lozowicka et al. 2016
Strawberries	Tap water, ozone eater, ultrasonic cleaning	Bupirimate	6-57	Lozowicka et al. 2016
		Cyprodinil	15-54	
		Fenhexamid	16-57	
		Fludioxonil	12-60	
		Folpet	10-66	
		Iprodione	19-65	
		Pyraclostrobin	20-89	
		Tetraconazole	2-85	
		Trifloxystrobin	11-52	
		Acetamiprid	24-63	
		Alpha-cypermethrin	35-81	
		Chlorpyrifos	42-79	
		Deltamethrin	14-72	
		Lambda-cyhalothrin	6-58	
		Pirimicarb	14-65	
Soybeans	Tap water	Clomazone	18-95	Zhang et al. 2020
		Fomesafen	16-90	
		Quizalofop-p-ethyl	38-87	
	Tap water, sodium carbonate, sodium hypochlorite, glycerol, acetic acid	Boscalid	41.25-52.43	Ghani et al.2010
Tomato	Tap water, sodium carbonate, sodium hypochlorite, glycerol, acetic acid, detergent solution	Fenhexamid	28.10-53.44	Ghani et al. 2010
		Myclobutanil	13.33-30.04	
	tap water, detergent solution, sodium hypochlorite	Chlorpyrifos	37.2-51.0	Liang et al. 2011
	Tap water	Endosulfan	26.92	Randhawa et al. 2014b
	Tap water, acetic acid, sodium bicarbonate, potassium permanganate, malic acid, oxalic acid, aqueous solution	Fenitrothion	34-81	Satpathy et al. 2012
		Formothion	27-90.7	
		Chlorpyriphos	39-89.7	
		Malathion	41-88.9	
		Methyl parathion	32-92.6	
		Parathion	37-88.1	

3.1. Location of the residue

With washing treatments, it is too easy to remove surface residues, but it is not for systemic residues.

Washing was reported to reduce pesticide residues loosely attached to commodity surfaces (Bonnechère et al., 2012a). Location of pesticide residues on product surfaces depends on pesticide molecules, environmental parameters, type, and sections of the commodities (Bajwa & Sandhu, 2014).

3.2. Pesticide mode of action

Mode of action describes how a pesticide kills the pests. It plays an important role in residue removal from the products through washing processes. Pesticides are classified into two categories based on mode of action: contact and systemic. Contact pesticides are usually applied to commodity surfaces, and they usually do not penetrate into the product, thus easily be removed through washing processes. On the other hand, systemic pesticides penetrate into the commodity. Pesticide sprays are absorbed by leaves and stems, then translocated into different sections of the plant through vascular system. Therefore, it is highly difficult, even impossible to remove systemic pesticides through washing processes (Acoğlu et al., 2018; Çatak et al., 2020; Lozowicka et al., 2013; Polat & Tiryaki, 2020; Polat, 2021). It was reported that reduction rate of contact pesticides like diazinon was greater than that of systemic ones (Heshmati et al., 2020).

In a previous study, Polat & Tiryaki (2020) indicated that contact pesticides were more efficiently removed or reduced through washing processes. Researchers reported almost twice as much reduction for contact insecticides (chlorpyrifos, formetanate hydrochloride) as compared to systemic insecticides (acetamiprid). Rather than washing, ultrasonic cleaning treatments were found to be more effective in removal or reduction of systemic pesticides. Pesticide residue removals or reductions are thus largely designated by mode of actions (contact or systemic) of pesticides (Acoglu & Yolci Omeroğlu, 2021; Bonnechère et al., 2012c; Çatak et al., 2020).

3.3. Residue age

Residue age is defined as duration of stay of pesticide on commodity. It is an important factor affecting residue removals through washing processes. In washing treatments, pesticide residue removal or reduction rates generally decrease with the increasing age of residues (Dong, 2012; Holland et al., 1994; Levya et al., 1998)

3.4. Water solubility of pesticides and Kow (octanol–water partition coefficient)

Water solubility and Kow values significantly affects residue removal rates through washing processes. It was indicated in previous washing studies that higher pesticide removal efficiencies were achieved with higher water solubility and lower partition coefficients. It was also indicated that highly polar water-soluble pesticides were better removed that low-polarity materials (Holland, 1994; Lozowicka et al., 2016; Randhawa et al., 2014a; Saranjampour at al., 2017). However, several studies concluded that water solubility did not play a significant role in reduction of pesticide residues from agricultural commodities. Majority of pesticide residues appeared to reside on product surfaces and could be reduced by mechanical rinsing (Cabras et al., 1997 & 1998; Krol et al., 2000). Water solubility was reported as 3.4 mg/L for vinclozolin and as 3.3 mg/L for captan. Although vinclozolin was not removed with rinsing, captan was readily removed with rinsing.

Water solubility of methoxychlor and bifenthrin was reported as 0.1 mg/L, yet bifenthrin was not removed through rinsing and methoxychlor was removed easily with rinsing. Although chlorpyrifos had greater water solubility than endosulfan and permethrin, it was not easily removed through rinsing (Krol et al., 2000).

A larger removal is expected with highly water-soluble pesticides. Since deltamethrin has low water solubility (0.0002 mg/L at 20°C) and log-Kow (4.6), the reduction of residues was very low in washing trials of spinach. Whereas iprodione has an average 56% reduction with a high-water solubility (12.2 mg/L) and low log- Kow (3.1) (Bonnechère et al., 2012a).

3.5. Temperature and duration of washing

Hot washing is usually more effective than cold one. Pesticide cleaning efficiency of ultrasonic cleaning treatments depends on temperature of water (Saeedi Saravi & Shokrzadeh, 2016). Ultrasonic cleaning at 25°C and 10 min washing duration was the most effective treatment for removal of pesticides (Buakham et al., 2012)

Duration of washing treatments (the contact time with the washing solution) is also important. Longer washing durations generally yield greater pesticide removal efficiencies or reduction rates. It was reported in previous studies that increased washing durations increased efficiency of washing treatments (Acoglu & Yolci Omeroğlu, 2021; Buakham et al., 2012; Çatak et al., 2020; Lozowicka et al., 2016; Polat & Tiryaki, 2020; Polat, 2021). Similarly, 30 min washing duration was found to be more effective than 10 and 5 min for removal of both acephate and methamidophos residues in rice (Kong et al., 2012). Performance of washing process increased with prolonged washing durations. Washing duration of 5 min was the most effective one to reduce acetamiprid, chlorpyrifos-ethyl and formetanate hydrochloride residues on capia pepper (Polat & Tiryaki, 2020) and chlorpyrifos-ethyl, lambda cyhalothrin residues on Sultana grape (Polat, 2021). Similarly, pirimiphos-methyl and tebuconazole residue levels decreased with increasing washing durations in grapes and peppers, respectively (Çatak et al., 2020; Duman et al., 2021).

3.6. PHI (Preharvest interval)

The time between the harvest and last pesticide application (PHI-Preharvest Interval) plays also an important role in pesticide residue removal from commodity surfaces (Hassanzadeh et al., 2010; Polat & Tiryaki, 2020). The rate of reductions decreased with prolonged PHI values (Duman et al., 2021). Since the pesticides penetrate into the commodity, the more the PHI, the less the removal of pesticide (Polat, 2021). Özel and Tiryaki (2019) reported increasing reduction rates with decreasing PHI values. PHI significantly influenced efficiency of washing processes in removal of pesticide residues (Hassanzadeh et al., 2010; Özel & Tiryaki, 2019). Similarly, a gradual reduction of chlorpyrifos- ethyl, pirimiphos-methyl, acetamiprid and formetanate hydrochloride in pepper and tebuconazole, chlorpyrifos, lambda cyhalothrin in grape were determined with the increasing PHIs (Çatak et al., 2020; Duman et al., 2021; Polat & Tiryaki, 2020; Polat, 2021).

Romeh et al. (2009) applied tap-water washing treatments to tomato samples harvested 1, 3, 7 and 14 days after spraying and reported reduction rates of penconazole as 15.00, 11.76, 7.69 and 6.25%, respectively. Harvests should be practiced in accordance with the recommended PHI ranges (Çatak et al., 2020; Polat & Tiryaki, 2020; Duman et al., 2021).

4. Washing type (method and agents)

Washing type and washing agents also affect performance of processes in pesticide removal from agricultural commodities. Tap-water washing process was experimented in previous studies to reduce residue levels on commodity surfaces (Duman et al., 2021; Lozowicka et al., 2016). In some other studies, acid-washing and ultrasonic cleaning treatments were experimented (Kentish, 2014; Khadre et al., 2001; Polat & Tiryaki, 2020). Various chemical agents such as acetic acid, sodium carbonate and sodium chloride could be used in washing treatments. Performance of these washing solutions in removal of pesticide residues on different agricultural commodities were investigated in several works (Acoğlu & Yolci Omeroğlu, 2021; Kim et al., 2000; Randhawa et al., 2014b; Polat & Tiryaki, 2020; Ruengprapavut et al., 2020).

Concentration of non-toxic chemical solutions are also another factor affecting pesticide residue removal. Randhawa et al. (2014a) used tap-water, different concentrations (1.5%, 3%, 6% and 9%) of acetic and citric acid solutions and their combinations in washing processes of pepper and cucumber samples. The greatest reduction rates were obtained with 9% of acetic acid and citric acid treatments for both cucumber (82.29% and 93.75%) and pepper (68.48% and 72.48%). Similarly, washing with 0.1% Na_2CO_3 was more effective than 0.9% NaCl and tap-water washing for removal of both acephate and methamidophos residues on rice (Kong et al., 2012).

Washing type also affects reduction rate of residues (Lozowicka et al., 2016). Ozonated water washing treatments and ultrasonic cleaning treatments were reported as the most efficient processes to reduce pesticide residues on strawberries (Lozowicka et al., 2016).

Ultrasonic cleaning is a new process applied to wash agricultural commodity. Ultrasonic waves cause cavitation reaction which can reduce the pesticide residue more than the other processes. Cavitation reactions result in formation and collapse of micron-sized bubbles in a liquid medium, then in tiny implosions that provide cleaning power. The cavitation bubbles produce several air bubbles, these bubbles then grow, expand and break out simultaneously and produce shockwaves and mechanical energy. These shockwaves and resultant mechanical energy improve heat and mass transfer within quite small pores of the solid surface and ultimately reduce pesticide residues on agricultural commodities (Buakham et al., 2012; Lozowicka et al., 2016; Polat & Tiryaki, 2020).

In a few works, efficiency of different washing solutions on pesticide residue removal was compared and citric acid (9%) washing and ultrasonic cleaning were reported to be more efficient than the tap-water and acetic acid treatments (Polat & Tiryaki, 2020; Polat, 2021). Findings of these two studies were illustrated for sultana grapes and capia peppers in Figure 1 and Figure 2, respectively.

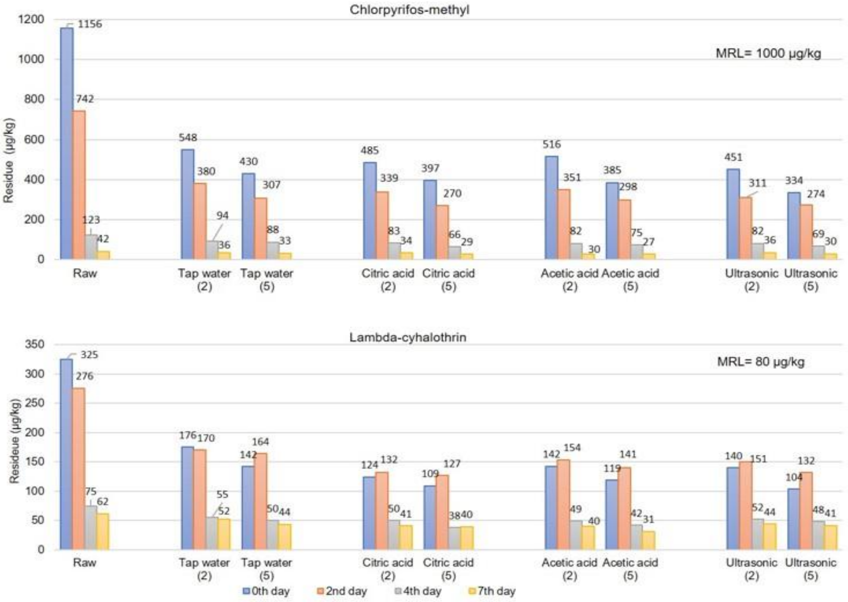

Figure 1. Pesticide residues in washed sultana grapes (Polat, 2021)

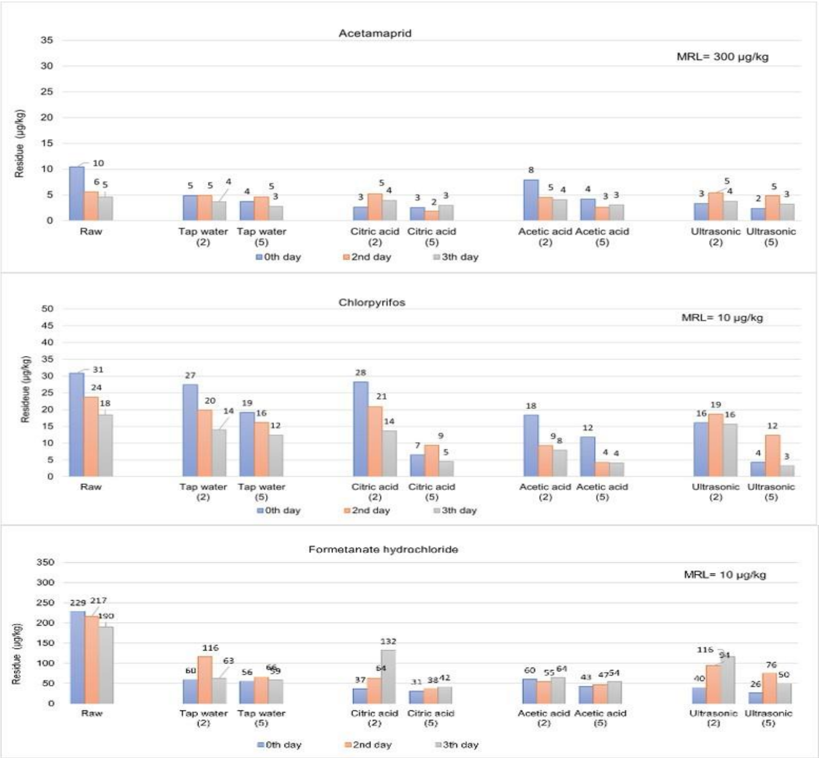

Figure 2. Pesticide residues in washed capia peppers (Polat & Tiryaki, 2020)

One of the other washing processes is ozonated washing. Ozone (O_3) is a natural component of atmospheric air (Lozowicka et al., 2016). O_3 is considered to be the most suitable process to remove pesticide residues from fruits and vegetables (Wu et al., 2007). With a 5-min ozonated washing, residues on strawberry were removed by between 75.1% (PF=0.25) for chlorpyrifos and 36.1% (PF=0.64) for tetraconazole (Lozowicka et al. ,2016).

Aslansoy (2012) investigated the effects of ozone treatments on pesticide residues of lemons. Ozonated water (with 2, 4, 8 mg/l concentrations and 3, 6 and 9 min washing durations) reduced chlorothalonil residues at the range of 28-92% and 70-89% in peeled and unpeeled lemons, respectively. These reduction ranges were 15-82% and 7-89% for chlorpyriphos ethyl and 16-95% and 14-100% for tetradifon.

Baltacı (2015) sprayed imidacloprid, phenazaquin and lambda cyhalothrin pesticides to tomatoes grown under field conditions and investigated the effects of ozone treatments on pesticide removal of harvested tomatoes. Washing with ozonated water yielded 57.8% reduction in phenazaquin, 40.9% in imidacloprid and 20.4% in lambda cyhalothrin.

5. Conclusion

Effects of various washing treatments on pesticide residue removal or reduction rates vary based on several factors, such as pesticide physicochemical characteristics, type of washing, pesticide water solubility and mode of action and preharvest intervals. Tap-water washing is the easiest way to reduce pesticide residues on agricultural commodities. Pesticide residues can be reduced by 22-60% with various washing processes. With washing processes, it is easier to reduce the residues of contact highly water-soluble pesticides below the MRL. However, systemic ones are difficult to remove because they penetrate into plant tissues. Field-sprayed samples should be used in washing processes. The “field-sprayed" method differs from laboratory fortification. Field-spraying allows the pesticides to penetrate into different sections of the plant. The longer the time after spraying (PHI), the more difficult to remove the residue. In addition, prolonged washing durations increase the efficiency of washing processes. Processing factor (PF) is another important criterion for food-processing. PF is expressed as the ratio of the residue on the processed product to the residue on the original product. A PF of less than 1 indicates a decrease in pesticide residues and a PF of more than 1 indicates an increase in pesticide residues on processed product. In this review article, the necessity of washing fruits and vegetables before consumption was pointed out once again.

6. References

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