Türk. entomol. derg., 2024, 48 (1): 89-101
DOI: http://dx.doi.org/10.16970/entoted.141875

ISSN 1010-6960
E-ISSN 2536-491X

Original article (Orijinal araştırma)

Effect of washing method on the reduction of insecticide residues and quality characteristics of sweet cherry fruits[1]

Yıkama yönteminin kiraz meyvelerindeki insektisit kalıntılarının azaltılmasına ve ürün kalitesi üzerine etkisi

Gülden HAZARHUN[2] **Nabi Alper KUMRAL[3]*** **Burcu GÜMÜL[2]**

Ayşenur KOLCU[2] **Simge ERTAŞ[4]**

Abstract

Sweet cherry trees were sprayed with 5 insecticides (acetamiprid, dimethoate, lambda-cyhalothrin, malathion, tau-fluvalinate) at the recommended field doses in this study. Fruits were harvested after the pre-harvested interval for each pesticide completed and then they were immersed into tap water and three different washing solutions (with three different concentrations) for 3 minutes (at 20ºC). Insecticide concentrations were detected with a multi-residual analysis method using LC-MS/MS in Bursa Uludağ University in 2022. Following the treatments, changes in the quality characteristics of fruits were also investigated by quality (colour, texture and fruit cracking rate, water-soluble dry matter) and sensory analysis (fruit and stem colour, firmness, appearance, general acceptability). The results revealed that washing method with tap water during 3 min decreased insecticide residue level by 7-45% depending on insecticide active compound. Higher reduction rates were observed by washing with citric acid (10%), sodium bicarbonate (2.5%) and sodium hydroxide (0.5%). But significant reductions were detected only in lambda-cyhalothrin and malathion residues when compared with the newly harvested fruit samples. Processing factors (PF) of all washing methods were generally lower than 1 except for three treatments. PF values showed variations depending on the type of washing solution and the active compound of insecticides. Although washing with citric acid (10%), sodium bicarbonate (2.5%) and sodium hydroxide (0.5%) solutions caused reduction in residue levels, their negative effects on the quality and sensory characteristics of the fruits cannot be ruled out.

Keywords: Cherry, insecticide, LC-MS/MS, pesticide residues, processing factor, washing method

Öz

Bu çalışmada, kiraz ağaçlarına 5 insektisit formülasyonu (acetamiprid, dimethoate, lambda-cyhalothrin, malathion, tau-fluvalinate) önerilen dozlarda meyvelere uygulanmıştır. Hasat öncesi bekleme süresinden sonra hasat edilen meyveler musluk suyu ve üç farklı yıkama solüsyonuyla (üç farklı konsantrasyonda) 3 dakika süreyle (20°C'de) yıkanmıştır. İnsektisit kalıntıları LC-MS/MS cihazı kullanılarak çoklu kalıntı analizi yöntemiyle Bursa Uludağ Üniversitesi'nde 2022 yılında tespit edilmiştir. Yıkama uygulamaların ardından meyvelerin kalite özelliklerinde meydana gelen değişiklikler (renk, doku ve meyve çatlama oranı, suda çözünür kuru madde) ve duyusal özellikleri (meyve ve gövde rengi, sertlik, görünüm, genel kabul edilebilirlik) ayrıca araştırılmıştır. Araştırma sonuçlarına göre, musluk suyuyla 3 dakika süreyle yıkama yöntemi, insektisit etken maddesine bağlı olarak kalıntı seviyesini %7-45 oranında azalttığı ortaya konulmuştur. Diğer taraftan, sitrik asit (%10), sodyum bikarbonat (%2.5) ve sodyum hidroksit (%0.5) ile yıkamada daha yüksek etkiler gözlemlenmiştir. Ancak hasat edilen meyve örnekleriyle karşılaştırıldığında sadece lambda-cyhalothrin ve malathion kalıntılarında istatistiki anlamda önemli azalmalar tespit edilmiştir. Tüm yıkama yöntemlerinin işleme faktörleri (PF), üç işlem dışında genellikle 1'den düşük bulunmuştur. PF değerleri yıkama solüsyonunun cinsine ve insektisitlerin aktif bileşiğine bağlı olarak değişiklik göstermiştir. Sitrik asit (%10), sodyum bikarbonat (%2.5) ve sodyum hidroksit (%0.5) solüsyonları ile yıkama, kalıntı düzeylerinde azalmaya neden olsa da meyvelerin kalitesi ve duyusal özellikleri üzerinde göz ardı edilemez olumsuz etkiler oluşturmuştur.

Anahtar sözcükler: Kiraz, insektisit, LC-MS/MS, pestisit kalıntısı, işleme faktörü, yıkama metodu

[1] This study was supported by Bursa Uludağ University, Scientific Research Unit, Bursa, Türkiye, Grant Project No: FKA-2021-320.
[2] Perla Fruit Private Food Control Laboratory, Bursa Uludağ University ULUTEK R&D Center, 16059, Bursa, Türkiye
[3] Bursa Uludağ University, Faculty of Agriculture, Department of Plant Protection, 16059, Bursa, Türkiye
[4] Department of Horticulture, Natural School of Natural and Applied Science, Bursa Uludağ University, 16059, Bursa, Türkiye
* Corresponding author (Sorumlu yazar) e-mail: akumral@uludag.edu.tr
Received (Alınış): 04.01.2024 Accepted (Kabul ediliş): 19.02.2024 Published Online (Çevrimiçi Yayın Tarihi): 20.02.2024

Introduction

Previous studies have shown that fruits have protective effects against the development of serious human diseases such as cardiovascular problems, diabetes, obesity and cancer (Ferretti et al., 2010). Their protective roles could be originated from the various nutrients such as dietary fiber, vitamins and phytonutrients. Several studies on phenols originated from fruits have demonstrated that they are bioavailable and have got a protective role against oxidative stress and free radical damages in human (Prior, 2003).

Cherries belonging to the subgenus *Cerasus*, *Prunus avium* L. of stone fruit family (Rosaceae) are known as "sweet cherry". Sweet cherries are characterized by high content of simple sugar, hydrosoluble (C) and liposoluble (A, E and K) vitamins, niacin, panthothenic acid, some carotenoids (beta carotene, lutein, zeaxanthin) and phenols. Some phenolic acids such as hydroxycinnamates, flavonols and flavan-3-ols and minerals like calcium, magnesium, phosphorous and potassium are also found in sweet cherry fruits (Gao & Mazza, 1995; Chaovanalikit & Wrolstad, 2004). Since sweet cherry fruits contain several antioxidants and particularly polyphenols, the fruits display many biological activities, such as antioxidant, anti-inflammatory and anticancer properties.

The geographic and climatic conditions in many regions of Türkiye are appropriate for sweet cherry production and Türkiye is an important sweet cherry producer with the production rate of 2.5 million tons (25.0%), followed by USA (12.0%), Uzbekistan (7.0%), Chile (6.0%), Iran (5.0%), and Italy and Spain (4.0%), respectively (TUİK, 2021; FAO, 2021). Dimethoate, tau-fluvalinate, lambda cyhalothrin and malathion are intensively used insecticides for the control of insect pests during sweet cherry growing (Hazarhun et al., 2022; BKUTARIM, 2023). The heavy use of these pesticides may end in environmental problems such as ecological imbalance, widespread pest resistance, environmental pollution, hazards to non-target organisms and wildlife (Simon, 2014). These pesticides may also cause some health problems like reproduction/ development effects, and act as endocrine disruptor, skin irritant, respiratory tract irritant, skin sensitizer, eye irritant, acetyl cholinesterase inhibitor and neurotoxicant (PPDB, 2023). Although synthetic pesticides have the significant role in crop productivity and food security, their residues in agricultural products exert serious risks for human health (Çatak & Tiryaki, 2020). Therefore, there is an increasing interest in reducing pesticide residues over the surfaces or within the tissues of vegetables and fruits using different washing methods. Success of washing treatments on residues is highly dependent on the physicochemical properties of pesticide, such as mode of action (systemic or residual), water solubility, pH sensitivity, volatility and persistence. So, due to the different mode of action of pesticides, their removal is possible only by multiple methods of decontamination depending on the effects of these methods on the quality characteristics of the target commodity. The effect of washing on pesticide residue levels of cherry fruits is still not known. Effect of washing on the concentration of pesticide residues of different commodities (Al-Taher et al., 2013; Lozowicka et al., 2016; Acoglu & Yolci Omeroglu, 2021; Duman et al., 2021; Polat, 2021; Tiryaki & Polat, 2023) were studied previously with tap water and/or solutions containing different salts such as citric acid (CA), sodium bicarbonate (SB), sodium hydroxide (SH), potassium permanganate (PP) and acetic acid (AA). Harinathareddy et al. (2014) reported 37.0-73.2% reduction in the dimethoate, chlorpyrifos, quinolphos, profenophos, phosalone, lamda-cyhalothrin, malathion and triazophos concentrations as a result of washing with tap water for 10 minutes (Harinathareddy et al., 2014). 24.0-97.41% reduction in the concentration of various pesticides were reported after washing with SB, PP, SH and CA solutions (Radwan, 2005; Harinathareddy et al., 2014; Polat & Tiryaki, 2020; Yalçın et al., 2023).

Industrial cherry packaging, involves a washing step (generally 3 minutes) for the removal of superficial dirt. For this purpose, fruits are washed with tap water during the sorting and classification processes by using automatic machines. Fresh sweet cherry fruits are very delicate, so for the protection of the fruit quality, they require painstaking processing and packaging precautions and also transportation conditions within the cold chain. Undesirable visible changes may easily occur on the fruit surface if these factors are not taken into consideration. The effects of pesticide removal applications on the quality characteristics of sweet

cherry fruits have not been studied yet. Previous studies have showed that chemical pre-treatments such as alkali solutions (sodium hydroxide) break down the wax on the cuticular surface of cherry and create microscopic cracks that increase moisture losses (Doymaz & İsmail, 2011). High amounts of dehydration (75%) were reported for sour cherry samples dipped in 1% (w/v) citric acid solution at room temperature in 50 h (Tarhan et al., 2006). The effect of SB solutions on postharvest decay of sweet cherry was investigated previously but how quality and sensory characteristics of fruits affected were not monitored concurrently (Karabulut et al., 2001). Presence of pesticide residues on agricultural commodities is an important food safety and public health issue and recently numerous studies were focused on their removal from the consumer products. The agents can safely take in low doses for human, but high concentrations could cause skin irritation or serious eye irritation (Merck, 2023). However, there is still a big gap about the reliability of these applications and how they affect the sensory and quality characteristics of the commodity. This study is conducted to fill the gap in this field by measuring the effectiveness of citric acid (CA), sodium bicarbonate (SB) and sodium hydroxide (SH) solutions for the removal of some pesticide residues and displaying their effects on the colour, texture and sensory characteristics of the sweet cherry fruits.

Materials and Methods

Pesticide applications

Unsprayed sweet cherry trees in an orchard in Bursa (Kestel) were used during 2022 season. Before insecticide spray, the samples collected from these trees were analysed to ensure there is no pesticide residue (Figure 1). Each plot size had four trees. The plots were with three replicates. Insecticides tested in current study were selected based on the results of our survey study during 2020–2021 seasons (Hazarhun et al. 2022). According to OECD (2008) guide, acetamiprid (Mospilan 20 SP), dimethoate (Poligor 40 EC), malathion (Malathion 65 EM), lambda-cyhalothrin (Sumosa 5 EC) and tau-fluvalinate (Mavrik 24 EW) were sprayed homogenously with an electric atomizer at the recommended field doses (Table 1). After pre-harvest interval (PHI) for each pesticide completed (7th and 14th days), 1 kg of sweet cherry sample were randomly collected and immediately transferred to laboratory in cold chain (Figure 1).

Table 1. Application dose, residue levels at the harvest day and maximum residue levels of the pesticides (BKUTARIM, 2023; EU, 2023)

Pesticides	Pesticide application dose (g /100 L water)	EU MRL (µg kg^{-1})	TR MRL (µg kg^{-1})	PHI (days)
Acetamiprid	5	1500	1500	7
Dimethoate	**	10	**	**
Lambda-cyhalothrin	2.5	300	300	14
Malathion	65	20	20	7
Tau-fluvalinate	7.2	400	400	14
Omethoate	*	10	**	**

* Not used due to the restrictions in Türkiye, but determined as dimethoate metabolite,

** No indicated; EU: European Union, MRL: Maximum residue limit, TR, Türkiye, PHI, Post Harvest Interval.

Experimental design

Tap water and three different washing solutions (with three different concentrations) were used during the experiments (Figure 1). 75 g portions of sweet cherry samples were immersed into 1.5 L washing solution (at 20ºC) for 3 min. Following washing, samples were air-dried and prepared for the pesticide residue analyses. For the simulation of transport conditions to markets, a part of the samples was stored under cold conditions (4°C) during 8 days. Then, a series of fruit quality tests were performed on them. All of the analyses were done in triplicate.

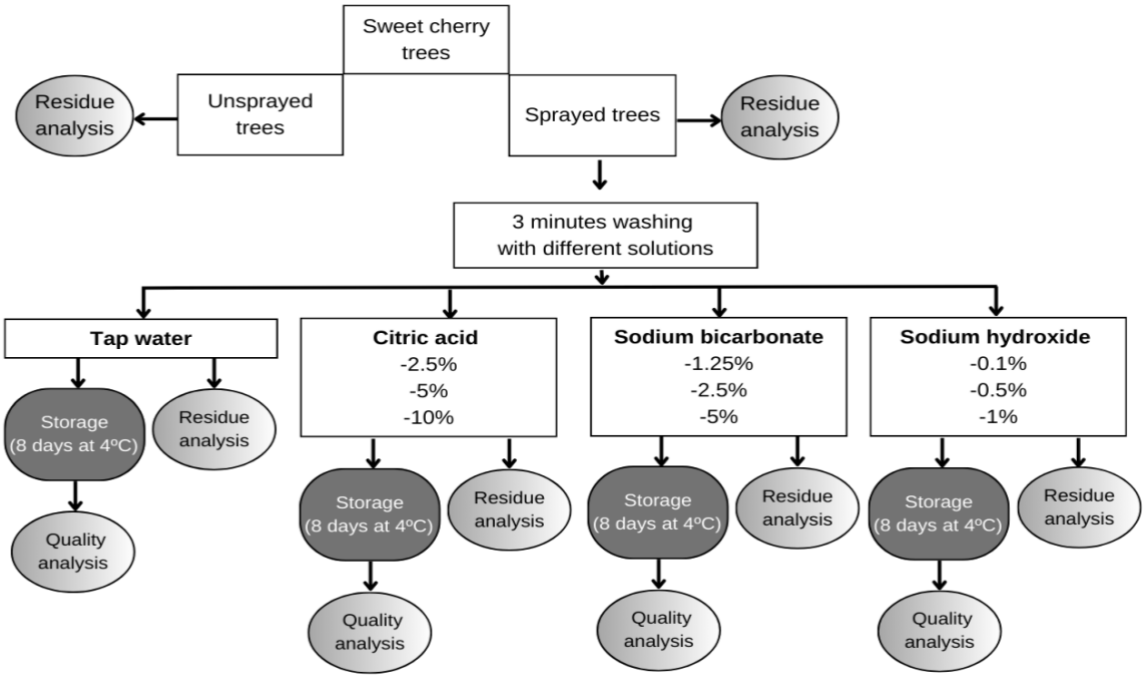

Figure 1. Processing steps and sampling details of different washing treatments.

Chemicals and reagents

The analytical standards used in validation studies were purchased from Dr. Ehrenstorfer GmbH (Germany), AccuStandard (USA) and CRM Labstandard (UK). The purity of all reference standards was higher than 96%. All other reagents, acetonitrile, ammonium format, formic acid and methanol were of analytical grade and obtained from different manufacturers. Quick, easy, cheap, effective, rugged, and safe (QuEChERS) extraction (Q16E15E092) and clean-up (Q2A23Z592) kits were supplied from QuE Lab (Italy) (AOAC 2007.01 method). Chemical and toxicological characteristics of each pesticide tested in this study are presented in Table S1.

Pesticide analysis

Pesticide analysis were performed using Agilent 6470 Triple Quad Liquid−Mass Spectrometry (Agilent Technologies, Santa Clara, CA, USA). Chromatographic separation was achieved using gradient elution with Agilent Poroshell SB-C18 analytical column (3 × 100 mm × 2.7 µm) at 40°C. The mobile phase consisted of an aqueous solution of 0.1% formic acid and 1 mM ammonium formate (A) and methanol (B). The mobile phase flow rate was 0.52 mL min^{-1}. The gradient elution programme was as follows: 0−0.5 min 70% A, 0.5−8 min 70% A, 8-12.5 min 5% A, 8-12.6 min 5% A and 12.6-15 %70 A. The detection by the mass spectrophotometer (MS) was conducted in multiple-reaction monitoring and electrospray ionization mode. Nitrogen gas (N_2) was used as nebulizing and drying gas and supplied by a nitrogen generator (Peak Scientific Scotland, UK). Gas flow, gas capillary voltage and source temperature were set at 10 psi, 3500 V and 100 °C rrespectively. Sample injection volume was 1 µL. Experimental parameters (precursor and product ions, collision energy) for LC−MS/MS analysis of pesticides were displayed at Table S2. Sweet cherry fruits for each treatment were homogenised and used for pesticide analysis. Extraction and partition of pesticides were done using QuEChERS kits according to the manufacturer's instructions (QuE Lab, Italy). Sample preparation steps for pesticide analysis were summarised in Figure 2 (Lehotay, 2007; Hazarhun et al., 2022).

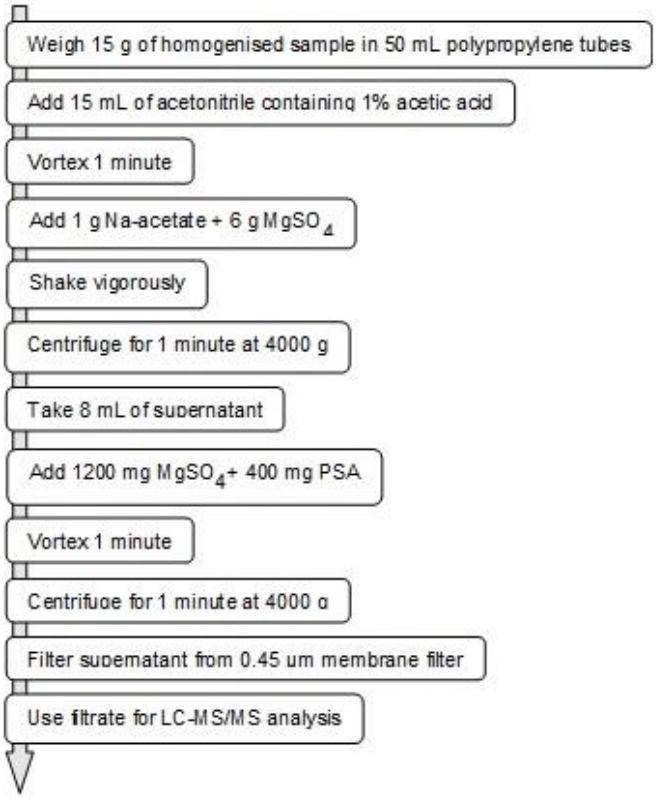

Figure 2. Sample preparation for LC-MS/MS analysis.

Method verification

The vertification of the analysis method was tested according to SANTE/12682/2021 guidelines (SANTE, 2021). Within the guideline`s context, selectivity, linearity, limit of detection (LOD), limit of quantification (LOQ), trueness (recovery %) and precision (intra-day and inter-day) parameters were tested. The selectivity was determined by analysing fortified and blank samples. The vertification studies were performed on pesticide-free sweet cherry fruit samples. Linearity was evaluated by six levels matrix-matched calibration ranging from 2.5 to 250 µg L^{-1}. Trueness (recovery) and precision (repeatability and reproductively) of the method calculated for five days using five replicates for two level (10 and 50 µg L^{-1}). The sensitivity of the method (LOD and LOQ) was calculated using the standard deviation (SD) of the analysis results of the lowest level (5 µg L^{-1}) spiked samples (Tiryaki, 2016; SANTE, 2021).

Calculation of processing factors

The effect of washing treatments was calculated (equation 1) similar to processing factor (PF) and obtained by the division of the residue concentration of washed fruits to the residue concentration of the unprocessed fruits (Chen et al., 2013, Đorđević et al., 2013).

$$PF = \frac{PRP}{PRR} \quad (1)$$

PF= Processing factor; PRP= Pesticide residue of processed material (mg kg^{-1}); PRR= Pesticide residue of raw material (mg kg^{-1})

The PF value may indicate reduction (PF<1), no change (PF=1) or concentration increase (PF>1) of the pesticide residues (Chen et al., 2013). When residues were below the limit of quantification (LOQ) after processing, the PF value was accepted as zero (Aguilera et al., 2012). Additionaly, the difference between

the initial pesticide concentration and the residue level of the final product was calculated by using the following formula (equation 2).

$$RR = \frac{PRR-PRP}{PRR} * 100 \quad (2)$$

RR= Residue reduction rate (%); PRR= Pesticide residue of raw material (mg kg-1); PRP= Pesticide residue of processed material (mg kg-1)

Determination of quality parameters

After performing different washing applications, the samples were divided into two equal parts. One group of samples were kept at +4ºC for 8 days for the simulation of transportation stage of sweet cherries to markets. At the end of this storage period, changes in colour, texture, water soluble dry content and cracking levels were analysed. Additionally, visual and textural characteristics of the fruits were evaluated by an untrained test panel in terms of appearance, stem colour, firmness, colour and overall acceptance. Panellists were asked to evaluate samples in a random order using a numbered hedonic scale changing from 9 to 1 representing different levels from excellent to non-consumable (Kappel et al., 1996; Martínez-Romero et al., 2006).

For the determination of cracking level, 20 fruits were checked by eye and the number of fruits with cracks were noted. The percentage of cracked fruits were calculated by dividing the number of cracked fruits to the total number of fruits (Bilginer et al., 1999; Yıldırım & Koyuncu, 2010; Ozturk et al., 2018; Akkaya, 2021).

The changes in the fruit colour characteristics were measured based on the L*, a*, and b* criteria determined by the International Lighting Commission (CIE). The L* coordinate represented the lightness of the colour, a* indicated the position between green and red, and b* was the extent of blueness/yellowness. Measurements were made on 20 fruits using Konica Minolta CR-400 colorimeter (Tokyo, Japan). Average of minimum 2 measurements taken from the 2 opposite poles of the equatorial part of each fruit under luminous conditions (McGuire, 1992).

For the determination of fruit flesh firmness, 20 fruits were analysed using TA XT Plus (Stable Micro Systems, Surrey, UK) texture analyser. For this purpose, HDP/BS probe of the device was used in compression mode, 2 mm/s speed and 20% deformation rate (Kumral et al., 2019).

Water-soluble dry matter content of the fruits was measured using refractometer (Kem RA500, Kyoto Electronics Manufacturing Co. Ltd.) after the pitted fruits were homogenised with a household blender (Sinbo, Türkiye) and strained through a cotton cloth (Kappel et al., 1996).

Statistical analysis

All analyses and trials were conducted in triplicate. The insecticide concentrations and fruit quality data obtained at each treatment were subjected to one-way variance analysis using JMP 7.0 Software (SAS, Cary, NC). For the detection of different groups, Tukey's multiple comparison test was performed with a significance level of 0.05 (α) after normality testing with the Shapiro-Wilk test.

Results and Discussion

Verification results

The results of linearity, limit of detection and quantification, trueness and precision for each pesticide were given at Table S3. Matrix matched calibration curves of the 6 insecticides were linear (R^2 = 0.997-0.999). The LOQ values (2.70 to 4.04 µg kg^{-1}) were quite lower than the MRLs of each insecticide (Table 1 & S3). The recovery rates of the insecticides for two spike levels were calculated between 101.391-113.74 and 100.91-112.16, respectively. For repeatability and reproducibility parameters, the highest RSDr and RSDwr did not exceed 20% for both spike levels. All verification parameters were compatible with SANTE 11312/2021 criteria (SANTE, 2021).

Changes in pesticide residues and processing factor

Pesticide residue levels in sweet cherries harvested at the end of PHI, the processing factors (PF) and the reduction rates (RR) are shown in Table 2. In all the washing methods, the diifferences are significant for lambda-cyhalothrin and malathion during washing with different solutions (lambda cyhalothrin: $F_{10,36}$=2.98, P=0.01; malathion: $F_{10,36}$=3.35, P=0.006). Whereas only washing with 2.5% sodium bicarbonate yielded significant reductions in residue levels of lambda-cyhalothrin. Similarly, significant declines in malathion residues were observed when washing with citric acid (10%), sodium bicarbonate (1.25%) and sodium hydroxide (0.5 and 1%) solutions compared with residue level in the raw material. Reductions in the concentrations of all active substances were detected during washing treatments, but majority of these were statistically insignificant (acetamiprid: $F_{10,36}$=1.09, P=0.41; dimethoate: $F_{10,36}$=0.94, P=0.52; fluvalinate: $F_{10,36}$=1.67, P=0.14; omethoate: $F_{10,36}$=2.12, P=0.06). Processing factors (PF) of all washing methods were generally lower than 1. PF values were showed variations depending on the washing solution and the insecticide active compound (Table 2). The lowest PFs were obtained with citric acid (10%), sodium bicarbonate (2.5%) and sodium hydroxide (0.5%) solutions complying with the previous studies reporting lower PFs for fruits washed with acid or basic solutions (Osman et al., 2014; Polat & Tiryaki, 2020).

Table 2. Insecticide residue levels, their removal rates and the processing factor after different washing treatments

Treatment			Pesticides					
			Acetamiprid (µgkg^{-1})	Dimethoate (µgkg^{-1})	Lambda-cyhalothrin (µgkg^{-1})	Malathion (µgkg^{-1})	Tau Fluvalinate (µgkg^{-1})	Omethoate (µgkg^{-1})
Initial residue level			37.67±4.05^{a*}	223.75±8.61^{a}	30.00±0.00^{a}	6.33±1.45^{a}	10.00±3.51^{a}	10.75±0.25^{a}
Tap water		PR (mg/kg)	32.00±1.00^{a}	186.50±4.50^{a}	25.00±2.88^{ab}	3.50±0.29^{ab}	6.00±1.16^{a}	10.00±0.00^{a}
		RR (%)	15.02	16.65	16.67	44.71	40.00	6.98
		PF	0.85	0.83	0.83	0.55	0.60	0.93
Citric acid solutions	2.5%	PR (mg/kg)	32.00±1.73^{a}	191.67±9.14^{a}	27.50±2.50^{ab}	3.25±0.75^{ab}	6.00±1.16^{a}	8.67±0.33^{a}
		RR (%)	15.02	14.34	8.33	48.66	40.00	19.35
		PF	0.85	0.86	0.92	0.51	0.60	0.81
	5%	PR (mg/kg)	36.33±0.88^{a}	212.50±6.76^{a}	30.00±0.00^{ab}	3.33±0.33^{ab}	7.00±0.41^{a}	9.25±0.25^{a}
		RR (%)	3.55	5.03	0	47.39	30.00	13.95
		PF	0.96	0.95	1.00	0.53	0.70	0.86
	10%	PR (mg/kg)	29.00±1.53^{a}	212.75±7.28^{a}	25.00±2.90^{ab}	2.67±0.33^{b}	4.25±0.63^{a}	10.00±0.41^{a}
		RR (%)	22.96	4.92	16.67	57.82	57.50	6.98
		PF	0.77	0.95	0.83	0.42	0.43	0.93
Sodium bicarbonate	1.25%	PR (mg/kg)	30.50±4.41^{a}	177.33±35.22^{a}	22.50±2.50^{ab}	2.25±0.63^{b}	4.67±0.33^{a}	8.33±0.88^{a}
		RR (%)	18.99	20.75	25.00	64.46	53.30	22.51
		PF	0.81	0.79	0.75	0.36	0.47	0.78
	2.5%	PR (mg/kg)	29.33±2.33^{a}	199.25±13.83^{a}	20.00±0.00^{b}	3.00±0.57^{ab}	5.00±0.58^{a}	8.25±0.63^{a}
		RR (%)	22.09	10.95	33.33	52.61	50.00	23.26
		PF	0.78	0.89	0.67	0.47	0.50	0.77
	5%	PR (mg/kg)	31.50±3.59^{a}	192.00±14.01^{a}	20.00±0.00^{ab}	3.67±0.88^{ab}	5.50±1.04^{a}	8.75±0.95^{a}
		RR (%)	16.34	14.19	33.33	42.02	45.00	18.60
		PF	0.84	0.86	0.67	0.58	0.55	0.81
Sodium hydroxide	0.1%	PR (mg/kg)	33.33±1.45^{a}	212.33±16.23^{a}	30.00±0.00^{ab}	4.00±0.00^{ab}	6.00±0.00^{a}	9.67±0.67^{a}
		RR (%)	11.49	5.10	0	36.81	40.00	10.05
		PF	0.89	0.95	1.00	0.63	0.60	0.89
	0.5%	PR (mg/kg)	28.00±1.00^{a}	202.67±16.25^{a}	22.50±2.50^{ab}	2.00±0.41^{b}	4.75±0.85^{a}	9.00±0.58^{a}
		RR (%)	25.61	9.42	25.00	68.40	52.50	16.28
		PF	0.74	0.91	0.75	0.32	0.48	0.84
	1%	PR (mg/kg)	29.67±1.76^{a}	212.33±1.45^{a}	26.67±3.33^{a}	2.00±0.41^{b}	5.50±0.50^{a}	10.00±0.41^{a}
		RR (%)	0	5.10	11.10	68.40	45.00	6.98
		PF	1.05	0.95	0.89	0.32	0.55	0.93

PR, pesticide residue; RR, reduction rate; PF, processing factor;

*Means with different letters are significantly different at p<0.05.

Similarly, PFs as low as 0.12-0.27 were reported for neonicotonid and organophosphate insecticides for fruits treated with 2-9% citric acid solutions (Osman et al., 2014; Randhawa, 2014; Polat & Tiryaki, 2020). Radwan et al. (2005) revealed that washing with 0.1% sodium hydroxide solution exhibited PFs of 0.08-0.35 for profenofos on pepper and eggplant. Moreover, Yang (2017) reported decrease in PF of phosmet during washing of apples with sodium bicarbonate solutions.

Water solubility and octanol-water partition coefficient (Log P) are the most significant environmental fate features for removing pesticide residues from agricultural commodities (Holland et al., 1994). Especially, highly soluble pesticides with a low octanol-water partition coefficient can easily be eliminated from these commodities (Randhawa et al., 2014; Lozowicka et al., 2016). In current study, malathion displayed high reduction rate (44.67%) in tap water with a low 2.75 Log P and a high water solubility (148 mgl^{-1}). On the contrary, acetamiprid, dimethoate and omethoate exhibited low reduction rates (15.02, 16.65, 6.98%, respectively), despite having high water solubility (2950, 25900 and 500000 mgl^{-1}, respectively) and low logP (0.80, 0.75 and -0.9 Log P, respectively). High solubility does not always have the same impact, mode of action also plays a significant role in the removal of pesticide residues from agricultural commodities. Since acetamiprid, dimethoate and its metabolite omethoate have xylem systemic mode of action, they displayed less reduction rates (0-25.61%, 4.92-20.75%, 6.98-23.26% respectively) during different washing treatments. On the other hand, higher reduction rates were observed for contact insecticides malathion and tau-fluvalinate compared with the systemic ones. In compliance with our results, Yang et al. (2017) reported that sodium bicarbonate solutions were more effective in removing surface-contact pesticides from apples, while it was not completely effective in removing systematic insecticide residues which have penetrated into the fruit.

Changes in fruit quality

Fresh cherry fruits are extremely delicate and may be easily damaged during the improper preparation or packaging steps (Gonçalves et al., 2007). Fruit size, fruit colour, stem colour, firmness, sweetness, total soluble solids, dry matter content and cracking are all considered as important fruit quality traits (Kappel et al., 1996; Gonçalves et al., 2007; Kovács et al., 2009; Romano & Cittadini, 2014). Fruit firmness is the combination of skin and flesh strength and affects consumer acceptance and shelf life (Kappel et al., 1996). Losses of firmness, colour and flavour in addition to dessiccation, stem discoloration and mould growth are the major causes of product rejection by the consumer (Habib et al., 2017). Changes in fruit characteristics after washing and during storage at 4°C for 8 days are shown in Table 3. The changes in water soluble dry matter content were statistically insignificant ($F_{9,29}$=1.08; p>0.05). Firmness and colour characteristics (L, a, b) of the fruits were affected by the treatments (firmness: $F_{9,29}$=4.42, p<0.01; L: $F_{9,29}$=3.31, p=0.01; a: $F_{9,29}$=4.98, p<0.01; b: $F_{9,29}$=4.06, p<0.01). Treatments of sodium hydroxide (1 and 0.5%) solutions caused slight changes in the firmness and colour characteristics of the fruits compared to washing with tap water. 5% sodium bicarbonate treatment caused a decrease in the value, that denotes a colour change towards green. The changes in cherry fruit qualities during transportation, storage and some pre-treatments were previously investigated by several researchers (Habib et al., 2017; Simsek & Sufer, 2021), but there is limited information about the effects of washing on the quality of the cherry fruits. Similar with our findings, Simsek & Sufer (2021) reported insignificant colour changes of cherries after citric acid pre-treatments compared with the control. Results of the sensory evaluation showed that (Table 4), the effects of treatments on the fruit and stem characteristics were significant and application of 5% sodium bicarbonate and 1 and 0.5% sodium hydroxide solutions caused marked decreases in the appearance, fruit colour, stem colour, texture and general acceptability scores of the samples.

Table 3. Changes in fruit quality characteristics after storage at 4°C for 8 days

Treatment		Water soluble dry matter (%)	Firmness (kg/cm^2)	Colour parameters		
				L	a	b
Tap water		14.30±1.27^{a*}	2986.95±79.39^{a}	22.31±0.08^{ab}	18.38±0.17^{a}	5.03±0.15^{ab}
Citric acid solutions	2.5%	15.37±0.84^{a}	2553.19±0.40^{ab}	22.86±0.40^{ab}	19.09±0.43^{a}	5.26±0.24^{a}
	5%	15.77±0.73^{a}	2484.40±136.41^{ab}	23.47±0.05^{ab}	18.33±0.53^{a}	5.02±0.20^{ab}
	10%	16.23±0.82^{a}	2653.82±202.36^{ab}	23.46±0.14^{ab}	16.42±0.25^{ab}	4.53±0.05^{ab}
Sodium bicarbonate	1.25%	16.50±1.00^{a}	2393.97±53.43^{ab}	22.49±0.79^{ab}	14.79±0.52^{ab}	3.70±0.20^{ab}
	2.5%	15.10±0.82^{a}	2405.83±67.34^{ab}	23.32±0.10^{ab}	15.58±0.55^{ab}	4.04±0.25^{ab}
	5%	16.50±0.21^{a}	3018.61±172.45^{a}	21.62±0.39^{b}	12.51±2.34^{b}	3.46±0.44^{b}
Sodium hydroxide	0.1%	16.07±0.82^{a}	2778.22±144.52^{a}	22.94±0.71^{ab}	15.08±0.89^{ab}	4.12±0.66^{ab}
	0.5%	14.90±0.25^{a}	2456.48±251.18^{ab}	24.48±0.35^{a}	18.07±0.79^{a}	5.28±0.29^{a}
	1%	14.33±0.70^{a}	1956.72±174.85^{b}	23.81±0.58^{ab}	15.54±0.69^{ab}	4.93±0.36^{ab}

*Means with different letters are significantly different at p<0.05.

Table 4. Sensory evaluation of textural and visual changes in sweet cherry samples

Treatment		Appearance	Colour	Stem colour	Texture	General acceptability
Tap water		6.63±0.38^{a*}	6.45±0.31^{a}	5.90±0.59^{a}	6.63±0.41^{ab}	6.27±0.38^{a}
Citric acid solutions	2.5%	6.90±0.25^{a}	6.63±0.27^{a}	6.90±0.43^{a}	7.45±0.38^{a}	6.72±0.35^{a}
	5%	5.18±0.26^{ab}	5.45±0.41^{ab}	5.72±0.44^{a}	6.09±0.56^{ab}	5.36±0.33^{ab}
	10%	5.00±0.46^{abc}	5.54±0.43^{ab}	6.09±0.60^{a}	6.18±0.53^{ab}	5.36±0.43^{ab}
Sodium bicarbonate	1.25%	6.63±0.41^{a}	6.54±0.34^{a}	6.36±0.50^{a}	6.45±0.38^{ab}	6.36±0.38^{a}
	2.5%	5.81±0.48^{a}	6.09±0.36^{a}	5.27±0.48^{a}	5.90±0.54^{ab}	5.45±0.54^{a}
	5%	3.81±0.56^{bc}	3.45±0.54^{c}	2.18±0.35^{b}	3.09±0.51^{c}	2.45±0.28^{c}
Sodium hydroxide	0.1%	5.90±0.41^{a}	5.81±0.44^{ab}	5.36±0.54^{a}	5.54±0.56^{ab}	5.72±0.48^{a}
	0.5%	3.09±0.57^{cd}	3.90±0.62^{bc}	4.81±0.61^{a}	4.72±0.55^{bc}	3.54±0.47^{bc}
	%1	1.63±0.30^{d}	3.09±0.41^{c}	4.90±0.68^{a}	4.36±0.65^{bc}	2.27±0.33^{c}

*Means with different letters are significantly different at p<0.05.

Conclusion

Pesticide residues on agricultural commodities may cause some adverse health effects for consumers but their use during agricultural practices is inevitable due to the prevention of product losses. Treatment of fruits with different washing solutions may be an alternative way of reducing pesticides residues on consumer products. Thus, applications of citric acid (10%), sodium bicarbonate (2.5%) and sodium hydroxide (0.5%) solutions resulted significant reductions in the residue concentrations of lambda-cyhalothrin and malathion. However further research is necessary for the optimisation of their use due to the restrictions caused by their negative effects on the sensory and quality characteristics of delicate agricultural commodities. Instead of relying on washing methods, it is recommended to take actions to reduce pesticide residue in growing sweet cherry. However, it is a positive development that the use of some systemic insecticides (dimethoate and omethoate) has been banned in Türkiye in recent years.

Acknowledgements

This study was funded by Bursa Uludağ University Scientific Research Projects Unit with Grant number FKA-2021-320. The authors thank Prof. Dr. Ayşegül Kumral for her critical reading and scientific corrections of the manuscript.

References

Acoglu, B. & P. Y. Omeroglu, 2021. Effectiveness of different type of washing agents on reduction of pesticide residues in orange (*Citrus sinensis*). LWT, 147 (1): 111690.

Aguilera, A., A. Valverde, F. Camacho, M. Boulaid & L. García-Fuentes, 2012. Effect of household processing and unit to unit variability of azoxystrobin, acrinathrin and kresoxim methyl residues in zucchini. Food Control, 25 (2): 594-600.

Akkaya, H., 2021. 0900 Ziraat Kiraz Çeşidinin Çatlama Ve Meyve Kalitesi Üzerine Biyofilm Uygulama Rejimlerinin Etkisi. Ordu Üniversitesi Fen Bilimleri Enstitüsü. Bahçe Bitkileri Ana Bilim Dalı (Unpublished) Yüksek Lisans Tezi. Ordu, 64 s (in Turkish with abstract in English).

Al-Taher, F., Y. Chen, P. Wylie & J. Cappozzo, 2013. Reduction of pesticide residues in tomatoes and other produce. Journal of Food Protection, 76 (3): 510-515.

Bilginer, S., L. Demirsoy & H. Demirsoy, 1999. "The effects of vapor gard, GA3 and calcium hydroxide applications on fruit cracking in Turkoglu sweet cherry, 14-17". 3. Turkish National Horticulture Congress in Turkey (14-17 September, Ankara, Türkiye), 1058 pp (in Turkish).

BKUTARIM, 2023. Republic of Türkiye, Ministry of Food, Agriculture and Livestock, General Directorate of Food and Control, Department of Plant Protection Products. Plant Protection Products Database. (Web page: https://bku.tarim.gov.tr/Arama/Index) (Date accessed: December, 2023)

Çatak, H. & O. Tiryaki, 2020. Insecticide residue analyses in cucumbers sampled from Çanakkale open markets. Turkish Journal of Entomology, 44 (4): 449-460.

Chaovanalikit, A. & R. E. Wrolstad, 2004. Total anthocyanins and total phenolics of fresh and processed cherries and their antioxidant properties. Journal of Food Science, 69 (1): 67-72.

Chen, H., X. Liu, D. Yang & P. Yin, 2013. Degradation pattern of gibberellic acid during the whole process of tea production. Food Chemistry, 138 (2-3): 976-981.

Đorđević, T. M., S. S. Šiler-Marinković, R. D. Đurović, S. I. Dimitrijević-Branković & J. S. Gajić Umiljendić, 2013. Stability of the pyrethroid pesticide bifenthrin in milled wheat during thermal processing, yeast and lactic acid fermentation, and storage. Journal of the Science of Food and Agriculture, 93 (13): 3377-3383.

Doymaz, İ. & O. İsmail, 2011. Drying characteristics of sweet cherry. Food & Bioproducts Processing, 89 (1): 31-38.

Duman, A., U. Çiftçi & O. Tiryaki, 2021. Farklı yıkama işlemlerinin üzümlerde tebuconazole kalıntısına etkisi. ÇOMÜ Ziraat Fakültesi Dergisi, 9 (2): 259-269 (in Turkish with abstract in English).

EU (European Commission), 2023. Pesticides Database. (Web page: http://ec.europa.eu/food/plant/pesticides.en) (Date accessed: December, 2023).

FAO, 2021. FAOSTAT, Crop Data Base. Food and Agriculture Organization United Nations. (Web page: http://www.fao.org/faostat/en/#data/QC/visualize) (Date accessed: December, 2023).

Ferretti, G., T. Bacchetti, A. Belleggia & D. Neri, 2010. Cherry antioxidants: from farm to table. Molecules, 15 (10): 6993-7005.

Gao, L. & G. Mazza, 1995. Characterization, quantitation, and distribution of anthocyanins and colorless phenolics in sweet cherries. Journal of Agricultural Food Chemistry, 43 (2): 343-346.

Gonçalves, B., A. P. Silva, J. Moutinho-Pereira, E. Bacelar, E. Rosa & A. S. Meyer, 2007. Effect of ripeness and postharvest storage on the evolution of colour and anthocyanins in cherries (*Prunus avium* L.). Food Chemistry, 103 (3): 976-984.

Habib, M., M. Bhat, B. N. Dar & A. A. Wani, 2017. Sweet cherries from farm to table: A review. Critical Reviews in Food Science and Nutrition, 57 (8): 1638-1649.

Harinathareddy, A., N. B. L. Prasad & K. Lakshmi Devi, 2014. Effect of household processing methods on the removal of pesticide residues in tomato vegetable. Journal of Environmental Research and Development, 9 (1): 50-50.

Hazarhun, G., N. A. Kumral, B. Gümül, A. Kolcu & S. Ertaş, 2022. "Optimization of a LC-MS/MS Method for the detection of pesticides currently registered for Sweet Cherry, 2". I. Gıda Kimyası Kongresi (03-06 March 2022, Antalya, Türkiye), 135 pp (in Turkish).

Holland, P. T., D. Hamilton, B. Ohlin & M. W. Skidmore, 1994. Effects of storage and processing on pesticide residues in plant products. Pure and Applied Chemistry, 66 (2): 335-356.

Kappel, F., B. Fisher-Fleming & E. Hogue, 1996. Fruit characteristics and sensory attributes of an ideal sweet cherry. HortScience, 31 (3): 443-446.

Karabulut, O. A., S. Lurie & S. Droby, 2001. Evaluation of the use of sodium bicarbonate, potassium sorbate and yeast antagonists for decreasing postharvest decay of sweet cherries. Postharvest Biology and Technology, 23 (3): 233-236.

Kovács, E., G. Muskovics & R. Perlaki, 2009. Relationship of colour and other quality parameters of sweet cherry during development and ripening. Acta Alimentaria, 38 (4): 415-426.

Kumral, A., V. Turgu, E. Yıldız, N. A. Kumral, R. N. Çevik, İ. Sevinç, G. Karapapak, A. N. Yüksel & E. Ersöz, 2019. Kuru kayısılarda ferrik oksit ve ozon gazı uygulamalarının, kuru meyve akarı *Carpoglyphus lactis* (L.) (Acari: Carpoglyphidae) kaynaklı mikrobiyal bulaşma yüküne ve meyve kalite parametrelerine etkisinin belirlenmesi. Bursa Uludağ Üniversitesi Ziraat Fakültesi Dergisi, 33 (1): 67-82 (in Turkish with abstract in English).

Lehotay, S. J., 2007. Pesticide residues in foods by acetonitrile extraction and partitioning with magnesium sulfate gas chro-matography/mass spectrometry and liquid chromatography/tandem mass spectrometry. Journal of AOAC International, 90 (2): 485-520.

Lozowicka, B., M. Jankowska, I. Hrynko & P. Kaczynski, 2016. Removal of 16 pesticide residues from strawberries by washing with tap and ozone water, ultrasonic cleaning and boiling. Environmental Monitoring and Assessment, 188 (1): 51-70.

Martínez-Romero, D., N. Alburquerque, J. M. Valverde, F. Guillén, S. Castillo, D. Valero & M. Serrano, 2006. Postharvest sweet cherry quality and safety maintenance by Aloe vera treatment: a new edible coating. Postharvest Biology and Technology, 39 (1): 93-100.

McGuire, R. G., 1992. Reporting of objective color measurements. HortScience, 27 (12): 1254-1255.

Merck, 2023. Merck Safe Data Sheets. (Web page: https://www.sigmaaldrich.com/TR/en/documents-search?tab=sds) (Date accessed: February, 2024).

OECD (Organisation for Economic Co-operation and Development), 2008. Test no. 508: Magnitude of the pesticide residues in processed commodities, OECD guidelines for the testing of chemicals, Section 5. Paris: OECD Publishing. (Web page: https://doi.org/10.1787/9789264067622-en.OECD) (Date accessed: February, 2024).

Osman, K. A., A. I. Al-Humaid, K. N. Al-Redhaiman & R. A. ElMergawi, 2014. Safety Methods for Chlorpyrifos Removal from Date Fruits and its Relation with Sugars, Phenolics and Antioxidant Capacity of Fruits. Journal of Food Science Technology, 51 (9): 1762-1772.

Ozturk, B., E. Bektas, E. Aglar, O. Karakaya & S. Gun, 2018. Cracking and quality attributes of jujube fruits as affected by covering and pre-harvest Parka and GA3 treatments. Scientia Horticulturae, 240 (1): 65-71.

Polat, B. & O. Tiryaki, 2020. Assessing washing methods for reduction of pesticide residues in Capia pepper with LC-MS/MS. Journal of Enviromental Science and Health, Part B. 55 (1): 1-10.

Polat, B., 2021. Reduction of some insecticide residues from grapes with washing treatments. Turkish Journal of Entomology, 45 (1): 125-137.

PPDB, 2023. Pesticide properties database, University of Hertfordshire. (Web page: http://sitem.herts.ac.uk/aeru/ppdb/en/atoz.htm) (Date accessed: December, 2023).

Prior, R. L., 2003. Fruits and vegetables in the prevention of cellular oxidative damage. The American Journal of Clinical Nutrition, 78 (3): 570-578.

Radwan, M. A., M. M. Abu-Elamayem, M. H. Shiboob & A. Abdel-Aal, 2005. Residual behaviour of profenofos on some field-grown vegetables and its removal using various washing solutions and household processing. Food and Chemical Toxicology, 43 (4): 553-557.

Randhawa, M. A., M. N. Anjum, M. S. Butt, M. Yasin & M. Imran, 2014. Minimization of imidacloprid residues in cucumber and bell pepper through washing with citric acid and acetic acid solutions and their dietary intake assessment. International Journal of Food Properties, 17 (5): 978-986.

Romano, G. S. & E. D. Cittadini, 2014. Postharvest colour dynamics of 'bing' and 'newstar' sweet cherry. Acta Horticulture, 1020 (1): 153-156

SANTE, 2021. Analytical quality control and method validation procedures for pesticide residues analysis ın food and feed: SANTE 11312/2021. (Web page: https://www.accredia.it/en/documento/guidance-sante-11312-2021-analytical-quality-control-and-method-validation-procedures-for-pesticide-residues-analysis-in-food-and-feed/) (Date accessed: December, 2023).

Simon, J. Y., 2014. The Toxicology and Biochemistry of Insecticides. CRC Press, Taylor & Francis Group, London, UK, 380 pp.

Simsek, M. & Ö. Süfer, 2021. Effect of pretreatments on refractance window drying, color kinetics and bioactive properties of white sweet cherries (*Prunus avium* L. stark gold). Journal of Food Processing and Preservation, 45 (11): e15895.

Tarhan, S., G. Ergunes & O. F. Taser, 2006. Selection of chemical and thermal pretreatment combination to reduce the dehydration time of sour cherry (*Prunus cerasus* L.). Journal of Food Process Engineering, 29 (6): 651-663.

Tiryaki, O. & B. Polat, 2023. Effects of washing treatments on pesticide residues in agricultural products. Gıda ve Yem Bilimi Teknolojisi Dergisi, 29 (1): 1-11.

Tiryaki, O., 2016. Validation of QuEChERS method for the determination of some pesticide residues in two apple varieties. Journal Environmental Science and Health, Part B, 51 (10): 722-729.

TUİK, 2021. Turkish Statistical Institute. (Web page: https://biruni.tuik.gov.tr/medas/?kn=92&locale=tr) (accessed December, 2023) (in Turkish).

Yalçın, M., N. Turgut, C. Gökbulut, S. Mermer, S. C. Sofuoğlu, V. Tari & C. Turgut, 2023. Removal of pesticide residues from apple and tomato cuticle. Environmental Science and Pollution Research, 30 (6): 15821-15829.

Yang, T., J. Doherty, B. Zhao, A. J. Kinchla, J. M. Clark & L. He, 2017. Effectiveness of commercial and homemade washing agents in removing pesticide residues on and in apples. Journal of Agricultural and Food Chemistry, 65 (44): 9744-9752.

Yildirim, A. N. & F. Koyuncu, 2010. The effect of gibberellic acid applications on the cracking rate and fruit quality in the '0900 Ziraat'sweet cherry cultivar. African Journal of Biotechnology, 9 (38): 6307-6311.

Table S1. Chemical and toxicological characteristics pesticides (PPDB, 2023)

Pesticide	Chemical group	Mode of action	Toxicological features					
			ADI (mg kg^{-1} bw day^{-1})	ARfD (mg kg^{-1} bw day^{-1})	Oral LD_{50} (mg kg^{-1} bw)	Dermal LD_{50} (mg kg^{-1} bw)	Inhalation LD_{50} (mg kg^{-1} bw)	WHO Classification
Acetamiprid	Neonicotinoids	Insecticide	0.025	0.025	146	2000	>1.15	II
Dimethoate	Organophosphorus	Insecticide	0.001	0.01	245	2000	1.68	II
Lambda-cyhalothrin	Synthetic pyrethroids	Insecticide	0.0025	0.005	56	632	0.066	II
Malathion	Organophosphorus	Insecticide	0.03	0.3	1778	2000	>5	III
Tau-fluvalinate	Synthetic pyrethroids	Insecticide	0.005	0.05	546	2000	>0.56	III
Omethoate	Organophosphorus	Insecticide	0.0003	0.002	50	145	0.3	Ib

ADI: Acceptable daily intake, ARfD: Acute reference dose, Oral LD_{50}: Acute oral lethal dose for mammals, Dermal LD_{50}: Dermal lethal dose for mammals, Inhalation LD_{50}: Inhalation lethal dose for mammals, WHO: World Health Organisation, 1b: Highly hazardous; II: moderately hazardous, III: slightly hazardous.

Table S2. Pesticide information and optimized LC-MS/MS conditions

Pesticide	CAS number	Molecular weight	Molecular formula	Ionization	Precursor ion	Product ion	Collision energy (V)	Retention time (min.)
Acetamiprid	135410-20-7	222.67	$C_{10}H_{11}ClN_4$	[M+H]+	223.1	126.1; 56.2	17, 11	2.67
Dimethoate	60-51-5	229.26	$C_5H_{12}NO_3PS_2$	[M+H]+	230.0	198.9; 125.0	3, 17	3.54
Lambda-cyhalothrin	91465-08-6	449.85	$C_{23}H_{19}ClF_3NO_3$	[M+H]+	467.1	450.0; 225.0	6, 14	7.88
Malathion	121-75-5	330.36	$C_{10}H_{19}O_6PS_2$	[M+H]+	330.9	285.0; 127.0	38, 4	6.33
Tau fluvalinate	102851-06-9	502.90	$C_{26}H_{22}ClF_3N_2O_3$	[M+H]+	503.1	208.1; 181.1	15, 25	8.92
Omethoate	1113-02-6	213.20	$C_5H_{12}NO_4PS$	[M+H]+	213.9	182.9; 125.0	4, 16	1.27

Table S3. Validation parameters for the tested pesticides

Pesticide	Concentration range (µg kg^{-1})	R^2	LOD (µg kg^{-1})	LOQ (µg kg^{-1})	Spike level (µg kg^{-1})	Repeatability (µg kg^{-1})	RSD_r (%)	Reproducibility (µg kg^{-1})	RSDwr (%)	Mean recovery (%)
Acetamiprid	2.5-250	0.9996	2.94	3.97	10	10.72-10.69	0.77-0.99	11.18	5.72	111.82
					50	54.26-54.75	0.85-0.74	56.08	5.16	112.16
Dimethoate	2.5-250	0.9993	2.64	2.98	10	10.66-10.59	1.01-0.96	11.13	11.13	111.35
					50	51.86-52.34	0.89-0.46	51.23	51.23	102.46
Lambda-cyhalothrin	2.5-250	0.9953	2.96	4.04	10	10.19-9.28	11.41-12.18	10.14	10.14	101.39
					50	50.47-50.83	5.00-8.45	50.46	50.46	100.91
Malathion	2.5-250	0.9984	2.58	2.76	10	10.07-9.74	2.45-3.23	11.37	11.37	113.74
					50	49.19-49.79	3.81-1.47	53.44	53.44	106.88
Tau fluvalinate	2.5-250	0.9968	2.75	3.34	10	10.63-10.45	3.39-5.21	10.52	10.52	105.24
					50	52.50-53.60	1.85-2.71	52.08	52.08	104.16
Omethoate	2.5-250	0.9997	2.56	2.70	10	10.17-10.10	0.84-0.59	10.65	10.65	106.55
					50	49.35-50.15	0.61-0.72	51.88	51.88	103.76