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Persistence and dissipation behavior of pesticide residues in parsley (*Petroselinum crispum*) under field conditions

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Abstract

The residue level, dissipation behavior, and dietary intake risk of chlorpyrifos-methyl, dimethoate, permethrin, iprodione, metalaxyl, and propargite in parsley (*Petroselinum crispum*) were investigated under field conditions. Extraction and determination of pesticide residues were carried out by a quick, easy, cheap, effective, rugged, and safe (QuEChERS) method and a gas chromatography/tandem mass spectrometry (GC/MS/MS) system, respectively. Dissipation of chlorpyrifos-methyl, dimethoate, permethrin, iprodione, metalaxyl, and propargite in parsley followed the first-order kinetics with a half-life ($t_{1/2}$) of 3.33, 3.30, 2.94, 3.52, 4.10, and 3.38 days, respectively. Based on the dissipation pattern and the maximum residue limits (MRL), preharvest intervals (PHI) of 25, 13, 18, 24, 1, and 16 days are suggested for chlorpyrifos-methyl, dimethoate, permethrin, iprodione, metalaxyl, and propargite in parsley, respectively. The estimated daily intake (EDI) of pesticides ranged from 7.37E-05 (dimethoate) to 8.00E-04 (metalaxyl) mg/kg. The chronic risk assessment showed that the hazard quotient (HQ) was <1 and Hazard Index (HI, indicating the cumulative exposure to pesticide residues) was <100%, demonstrating that an intake of pesticide residues from parsley was safe for humans.

Keywords: half-life; parsley; field conditions; post-harvest interval; GC/MS/MS; method validation

1. Introduction

Parsley (*Petroselinum crispum*) with bright green color and a mild, bitter flavor is one of the world's most popular flowering herbs (Charles, 2012; Farzaei *et al.*, 2013). It is mainly cultured as an annual culinary herb in Europe and Western Asia (Charles, 2012). This vegetable is used as a fresh product or a dried spice. It is an excellent source of antioxidants, antibacterial, and antifungal components (Farzaei *et al.*, 2013). The effects of the ingested antioxidant compounds by the consumption of this vegetable on the reduction of cardiovascular disease and some types of cancer have been documented (Brizzolari *et al.*, 2019; Frączek *et al.*, 2019; Fredotović and Puizina, 2019; Shin *et al.*, 2018). Leaves of parsley had various pharmacological attributes, including anticancer, hepatoprotective, neuroprotective, immunosuppressant, anti-diabetic/coagulant so on, and are used to treat gastrointestinal, disorders, kidney stones, inflammation, amenorrhea, and halitosis (Agyare *et al.*, 2017; Charles, 2012; Farzaei *et al.*, 2013).

The use of pesticides is one of the ways to enhance production efficiency (Badawy *et al.*, 2019; Heshmati *et al.*, 2019; Heshmati and Nazemi, 2018). Pesticides are mixtures of chemical compounds for killing, destroying, or mitigating the threat of pests (Pallarés *et al.*, 2020; Serefoglu and

Serefoglu, 2016). Although, pesticides prevent or minimize crop loss due to pests, their residues in agricultural products are a major concern with regard to food safety (Aydin and Ulvi, 2019; Hamidi *et al.*, 2019; Nazemi *et al.*, 2016; Shoeibi *et al.*, 2013). In order to maintain human health, pesticide residues in agricultural products and foodstuff should be lower than the maximum residue limit (MRL) set by the legal authority of European Commission (European Commission, 2005; Razzaghi *et al.*, 2018).

As different pests, such as insects and fungi, can grow on parsley (Hershman *et al.*, 1986; Webb, 2006), it is crucial to apply pesticides in order to prevent its yield loss. The occurrence of pesticide residues in parsley has been previously documented (El-Shahawi, 1997; Esturk *et al.*, 2014; Horská *et al.*, 2020; Szpyrka *et al.*, 2015). Quick, easy, cheap, effective, rugged, and safe sample preparation (QuEChERS) method was one of the most important methods for the extraction of pesticide residues from different food products, including parsley samples (Razzaghi *et al.*, 2018). The advantages of the QuEChERS method are the low cost and fast sample preparation, reduced requirements for reagent, and the simultaneous extraction of several pesticide residues (Kolberg *et al.*, 2011; Lehotay *et al.*, 2010). According to previous studies, gas chromatography (GC), gas chromatography/tandem mass spectrometry (GC/MS/MS), or liquid chromatography/tandem mass spectrometry (LC/MS/MS), are the most commonly used methods or techniques to look for pesticide residues in parsley (Esturk *et al.*, 2014; Horská *et al.*, 2020). Chlorpyrifos-methyl, dimethoate, permethrin, iprodione, metalaxyl, and propargite are commonly used in parsley cultivation in Iran and some other countries (Horská *et al.*, 2020). While no information (except on metalaxyl) is available regarding persistence and the waiting periods or pre-harvest interval (PHI) of these pesticide residues in parsley. PHI is number of days between the actual application of a pesticide and when a crop can be harvested such that the pesticide residue level has reached below MRL (Horská *et al.*, 2020). Therefore, dissipation studies will help to determine the waiting periods for these pesticide residues in parsley.

In this regard, this study was aimed to determine the dissipation behavior of insecticides (chlorpyrifos-methyl, dimethoate, and permethrin), fungicides (iprodione and metalaxyl) and acaricides (propargite) in parsley under filed conditions, and to assess their risk for the benefit of parsley consumers.

2. Materials and methods

Chemicals and reagents

The reference substances of chlorpyrifos-methyl, dimethoate, permethrin, iprodione, metalaxyl, and propargite were bought from Dr. Ehrenstorfer Co. (Augsburg, Germany). For spraying of parsley, trade forms of mentioned pesticides were purchased from Mahan Inc. (Tehran, Iran). Acetonitrile, sodium chloride, magnesium sulfate all in the analytical grade were purchased from Merck (Darmstadt, Germany). Supelco (Bellefonte, USA) donated the primary secondary amine (PSA), graphitized carbon black (GCB), perfluorotributylamine (PFTBA), and triphenylmethane (TPM). Other chemicals were of analytical grade and were purchased from Merck (Darmstadt, Germany). TMP was utilized as an internal standard. The mass spectrometer performance was checked daily using PFTBA according to the manufacturer's tuning procedures.

Field experiments

The field experiment was conducted in September of 2018 in Hamadan, Iran. Parsley was cultivated in several separate plots. Each plot had an area of 16 m^2 and was sprayed with one type of pesticide using a portable sprayer (Ronix, Model: RH-6005, Tehran, Iran) with standard flat-fan nozzles and a water volume of 12 L. Chlorpyrifos-methyl (Dursban 40.8% water emulsifiable concentrates or EC), dimethoate (Roxion 40% EC), permethrin (Ambush 10% EC), iprodione (52.5% wettable powder or WP), metalaxyl (Ridomil 5 granule or GR), and propargite (Omite 57% water-based emulsion or EW) were separately applied to three test plots at the recommended dosages of 400, 816, 100, 525, 100, and 570 g of active ingredient per hectare (g.a.i./ha), respectively. During the culturing of parsley and the field trial, no rain was reported, and the mean daily temperature, air humidity, and wind speed were 22°C, 32%, and 10 km/h, respectively. Parsley samples were collected at 2 h, and after 2, 4, 6, 10, 15, and 20 days after spraying. During sampling, approximately 1.5 kg of parsley was collected from each plot and transferred to the laboratory. After the addition of dry ice to parsley samples, they were ground with a mill (Romer mill, Stylemaster Drive, USA). Fifty grams of milled samples were weighted and utilized for pesticide residue analysis.

Extraction of pesticide residues

To extract pesticide residue from the parsley sample, the QuEChERS method was applied (Badawy *et al.*, 2020; Heshmati *et al.*, 2019; Hua *et al.*, 2019) according to Figure 1.

Apparatus and chromatographic conditions

A GC/MS/MS (model 7000C, Agilent, Santa Clara, CA, USA) equipped with an autosampler (model Agilent 7693, Agilent, Santa Clara, CA, USA) and an HP-5 capillary column (30 m × 0.25 mm I.D., 0.25 μm film thicknesses) was used to determine pesticide residue concentration. The oven temperature was programmed as follows: the initial temperature was 75°C, then it was increased to 120°C with a 25°C/min ramp, afterward it was increased to 300°C with a 5°C/min ramp, and this temperature was maintained for 11 min. The helium (purity of 99.99%) was utilized as carrier gas (He) with a flow rate of 1 mL/min. Other conditions of tandem mass spectrometer include the injector temperature, 250°C; the quadrupole temperature, 150°C; and the ion source temperature, 230°C; and ionization energy, 70 eV. The mass spectrometer was operated in the electron ionization (EI) mode and involved multi-reaction monitoring (MRM), while a GC/MS/MS injector was used in the splitless mode. The optimized GC/MS/MS parameters are shown in Table 1.

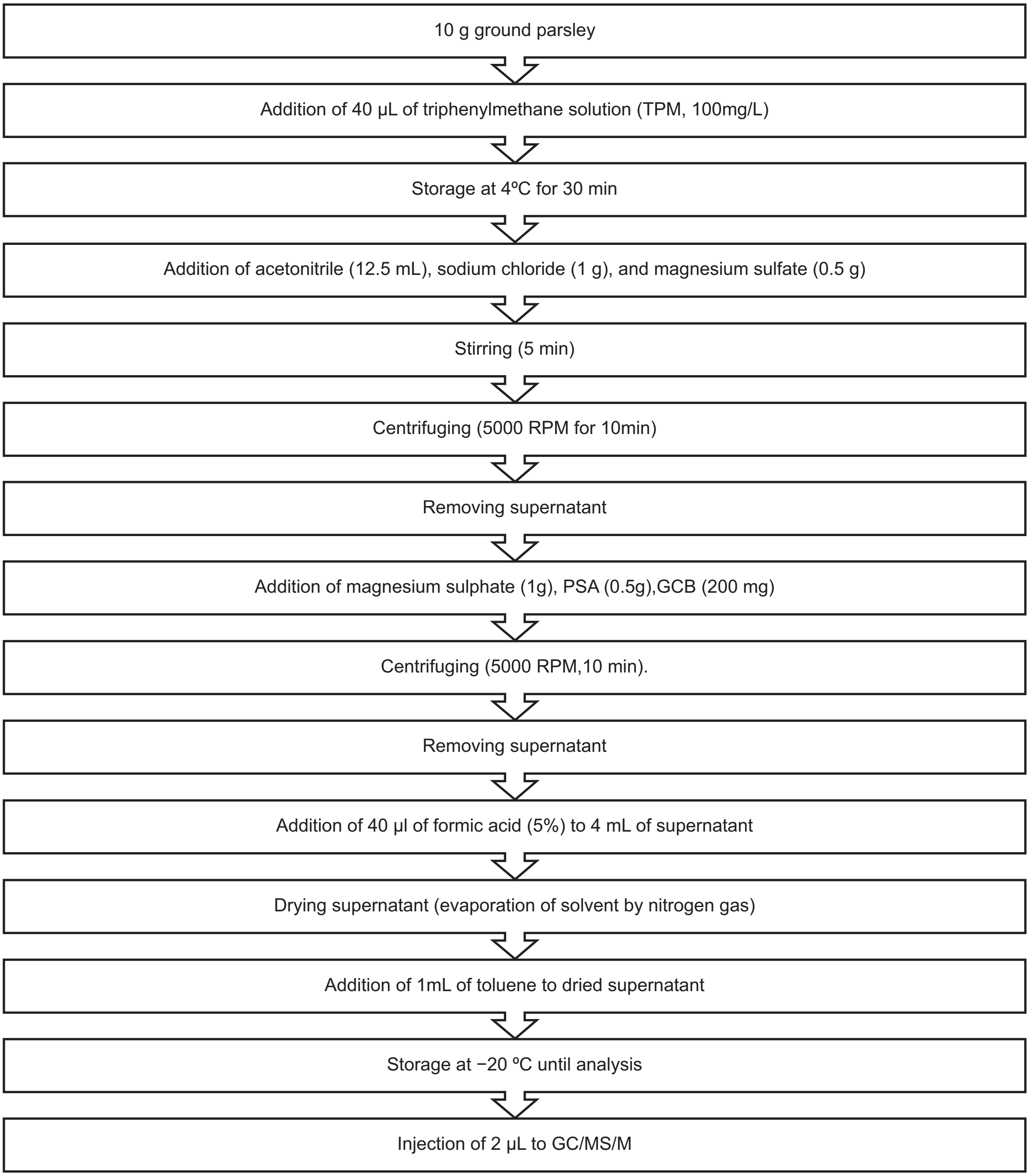

Figure 1. The diagram of QuEChERS method used for the extraction of pesticide.

Method validation

For method validation, linearity, recovery, the limit of detection (LOD), and the limit of quantification (LOQ) were determined. External calibration curves, along with matrix-matched methods, were performed for pesticide residues in the concentration of 0.005–0.400 mg/kg. To assess the accuracy and precision of the analysis method, the recovery experiments were performed. For recovery, blank parsley samples were fortified with 0.005, 0.010, and 0.020 mg/kg of a standard solution of each pesticide. Then, the pesticide residue of spiked samples was extracted and measured following the above procedures. At each fortification level, five replicates were carried out. This experiment was repeated three consecutive days to obtain test precision. Recovery was calculated from the dividing of found pesticide content in spiked samples to real content. LOD and LOQ were considered as signal-to-noise ratio (S/N) of 3:1 and 10:1, respectively (Maznah *et al.,* 2018).

Risk assessment

For long-term risk assessment, the estimated daily intake (EDI), HQ (Hazard Quotient), and Hazard Index (HI) were determined according to the following equations (Cámara *et al.*, 2020; Gui *et al.*, 2019; Milinčić *et al.*, 2020; Pallarés *et al.*, 2020; Tandon, 2016; Yang *et al.*, 2020).

$$\mathrm{EDI(mg / kg\,bw / day)} = \frac{\mathrm{STMR\,(mg / kg) \times FI(kg / day)}}{\mathrm{bw(kg)}} \quad \text{(Equation 1)}$$

$$\mathrm{HQ} = \frac{\mathrm{EDI}}{\mathrm{ADI}} \times 100\% \quad \text{(Equation 2)}$$

$$\mathrm{HI} = \sum \mathrm{HQ} \quad \text{(Equation 3)}$$

supervised trials median residue (STMR) (mg/kg), FI (food intake, kg/day), bw (body weight, kg), and the accepted daily intake (ADI) (mg/kg bw/day) indicated the supervised trials' median residue (Dong *et al.,* 2017), daily per capita consumption of parsley (58 g) in Iran (Heshmati *et al.,* 2020a; ISIRI, 2010; Mehri *et al.*, 2019), the bodyweight of adults (70 kg), and the ADI, respectively. The STMR is the median of pesticide residues' level in the edible portion of a food substance applied in supervised trials according to maximum good agricultural practice (GAP) conditions (FAO, 2002). HI was the cumulative exposure to pesticide residues, which is estimated by summing HQ of each pesticide residue. If HI exceeds 100%, the risk is not acceptable (Cámara *et al.*, 2020; Milinčić *et al.*, 2020; Yang *et al.*, 2020).

Statistical analysis

To determine the degradation kinetics of each pesticide, its residue level versus time was plotted, and the maximum R^2 (the squared correlation coefficients) for different curves was determined to obtain the best curve for degradation kinetics. The degradation of whole pesticides followed first-order rate equation, that is, $C_t = C_0e^{-kt}$, where C_0 and C_t, indicated the level of the pesticide residues after 2 h of spraying on day t, while K and t are the degradation rate constant and time, respectively (Galietta *et al.*, 2010). The $t_{1/2}$ (necessary time for the reduction of pesticide residues' concentration to 50% of its initial level) and PHI were determined with the following equations (Chen *et al.*, 2016):

$$t_{1/2} = \frac{\ln 2}{k} \quad \text{(Equation 3)}$$

$$\mathrm{PHI} = \frac{\ln(\text{MRL of pesticide}/C_0)}{-k} \quad \text{(Equation 4)}$$

K and t are the degradation rate constant and time, respectively.

Table 1. The retention time, diagnostic ions, and the selected quantification ion for the pesticide residue analysis.

Name of pesticide	Retention time	Diagnostic ions	Quantification ion	Collision energy (eV)	Product ion (m/z)	Parent ion (m/z)
Chlorpyrifos-methyl	30.04	314 (545), 257.8, 197 (999), 199 (956)	314	10	168.9	196.8
Dimethoate	16.901	86.9 (999), 93 (618), 124.8 (502)	124.8	5	198.9	203
Permethrin	33.930	183.0 (999), 164.9 (172), 162.9 (204)	183.0	10	149	391
Iprodion	29.860	186.8 (570), 313.9 (965), 243.7 (150)	186.8	10	245	313
Metalaxyl	20.710	206.1 (999), 159.9 (650), 132.0 (649), 249.0 (499)	206.1	10	117	132
Propargite	29.113	350.2 (20), 201 (150), 134.9 (999), 173 (252)	350.2	15	107.1	134.8

MRL of chlorpyrifos-methyl, dimethoate, permethrin, iprodione, metalaxyl, and propargite in parsley was considered as 0.02, 0.02, 0.05, 0.02, 3, and 0.02 mg/kg, respectively (Commission Regulation, 2017a, 2017b, 2017c, 2018a, 2018b, 2019).

3. Results and discussion

Method validation

The data of method validation is presented in Table 2. The recovery range of chlorpyrifos-methyl, dimethoate, permethrin, iprodione, metalaxyl, and propargite was 99.02–102.71, 92.73–98.53, 98.53–114.98, 90.69–98.37, 93.15–98.90, and 94.36–104.06%, respectively.

The LOD for chlorpyrifos-methyl, dimethoate, permethrin, iprodione, metalaxyl, and propargite was 1.78, 0.12, 3.82, 1.11, 1.35, and 2.44 μg/kg, respectively. The LOQ values obtained for pesticides were lower than their MRL, and coefficients of determination (R^2) of the calibration curve were >0.999. Therefore, the established method was suitable and satisfactory for analysis.

The dissipation of chlorpyrifos-methyl, dimethoate, permethrin, iprodione, metalaxyl, and propargite in parsley

The dissipation curves of chlorpyrifos-methyl, dimethoate, permethrin, iprodione, metalaxyl, and propargite under field conditions are presented in Figure 2. Two hours after pesticide application, the initial deposits of chlorpyrifos-methyl, dimethoate, permethrin, iprodione, metalaxyl, and propargite were 4.748, 0.259, 2.757, 2.098, 3.348 and 0.474 mg/kg, respectively. The data regarding the dissipation behavior of the analyzed pesticide in parsley, such as kinetic equation, half-lives, and R^2,are given in Table 3. Half-life values for chlorpyrifos-methyl, dimethoate, permethrin, iprodione, metalaxyl, and propargite were 3.33, 3.30, 2.94, 3.52, 4.10, and 3.38 days, respectively. The highest PHI (25 days) was related to chlorpyrifos-methyl, while metalaxyl had the lowest PHI (1 day). After 28 days in field conditions, residue levels of chlorpyrifos-methyl, dimethoate, permethrin, iprodione, metalaxyl, and propargite decreased to 98.59, 98.46, 99.20, 98.33, 95.31, and 98.31%, respectively.

The dissipation pattern of dimethoate in other crops was partly different from our findings. In papaya and guava, $t_{1/2}$ of dimethoate was reported as 3.07–5.04 and 2.8–3.3 days; both these findings were similar to our results, while $t_{1/2}$ of this pesticide in chili fruits (1.94 days) and mango (2 days) was lower than the findings (3.30 days) of the present study (Ahuja *et al.*, 2005; Bhattacherjee and

Table 2. Validation method date, including recovery, relative standard deviations (RSDs), calibration equation, determination coefficient (R^2), limit of detection (LOD), and limit of quantification (LOQ).

Parameters			Chlorpyrifos-methyl	Dimethoate	Permethrin	Iprodion	Metalaxyl	Propargite
Recovery (%) and RSD (%)	Spiking level (mg/kg)							
	0.005	Mean (%)	101.32	92.73	106.16	98.37	98.84	102.46
		RSD (%)	1.89	2.54	3.15	4.2	2.51	3.4
	0.01	Mean (%)	102.71	98.53	114.98	90.69	98.9	104.06
		RSD (%)	3.1	2.98	4.55	1.09	1.41	2.65
	0.02	Mean (%)	99.02	96.23	98.53	95.4	93.15	94.36
		RSD (%)	5.09	2.08	3.64	4.45	1.68	2.56
Calibration curve equation			y = 27270x – 276434	y = 6012/8x – 22339	y = 23819x – 512182	y = 24735x – 150292	y = 29303x + 24821	y = 21426x – 469851
95% Confidence intervals of the calibration curve equation		Slope	26183 to 28358	5547 to 6479	21059 to 26579	23523 to 25946	26659 to 31947	19208 to 23644
		Y-intercept	–481319 to -71549	–110092 to 65413	–1032187 to 7823	–378530 to 77946	–473387 to 523029	–887780 to –51923
		X-intercept	2.698 to 17.19	–11.51 to 17.41	–0.3570 to 40.41	–3.262 to 14.82	–19.08 to 15.24	2.609 to 38.91
R^2			0.9992	0.9969	0.9931	0.9988	0.9958	0.9945
LOD (μg/kg)			1.78	0.12	3.82	1.11	1.35	2.44
LOQ (μg/kg)			5.3	0.37	11.47	3.33	4.05	7.33

Dikshit, 2016; Khan *et al.*, 2009; Varghese *et al.*, 2011). The half-life of dimethoate in our study (3.30 days) was lower than that reported for chilly (4.7 days) and okra (5.21 days) (Waghulde *et al.*, 2011). The PHI of dimethoate in parsley (132 days) was higher than that in papaya (3–5 days), guava (3 days), and mango (6–7 days), while it was lower than that in chili (13.63 days) and pomegranate (31.5 days at the standard dose of application and 43.0 days at a double dose of application) (Ahuja *et al.*, 2005; Bhattacherjee and Dikshit, 2016; Khan *et al.*, 2009; Utture *et al.*, 2012; Varghese *et al.*, 2011).

The half-life (3.33 days) and PHI (25 days) for chlorpyrifos obtained in this study were longer than those reported for green mustard ($t_{1/2}$: 1.1–1.5 days and PHI: 4 days) (Chai *et al.*, 2009). In other studies dependent on chlorpyrifos formulates, its $t_{1/2}$ in orange, peach, tomato, table grape, and wine grape was 8–13, 9.1–14, 6.9–9.1, 7.7–13.9, and 6.6–13.3 days, respectively (Angioni *et al.*, 2011).

The dissipation of metalaxyl has previously been investigated (Chen *et al.*, 2010; Liu *et al.*, 2012; Malhat, 2017; Ramezani and Shahriari, 2015; Rattan and Sharma, 2012). The $t_{1/2}$ of this pesticide on watermelon, tomato, and cucumber was reported as 3.2–3.5, 1.18, and 3–35 days, respectively. While these findings were lower than that of the current study (4.10 days) (Chen *et al.*, 2010; Malhat, 2017; Rattan and Sharma, 2012); a higher $t_{1/2}$ (4.9 days) was reported for grape samples (Liu *et al.*, 2012). The calculated waiting period of 1 day for the safe consumption of parsley sprayed with metalaxyl in the current study was similar to corresponding values for cucumber (Ramezani and Shahriari, 2015; Rattan and Sharma, 2012). However, Malhat (2017) reported longer waiting periods (7 days) for tomato (Malhat, 2017). The PHI of pesticides had correlations with their MRL (Heshmati *et al.*, 2020b). A shorter PHI of metalaxyl in parsley was related to greater MRL (3 mg/kg) of this pesticide in comparison with another pesticide.

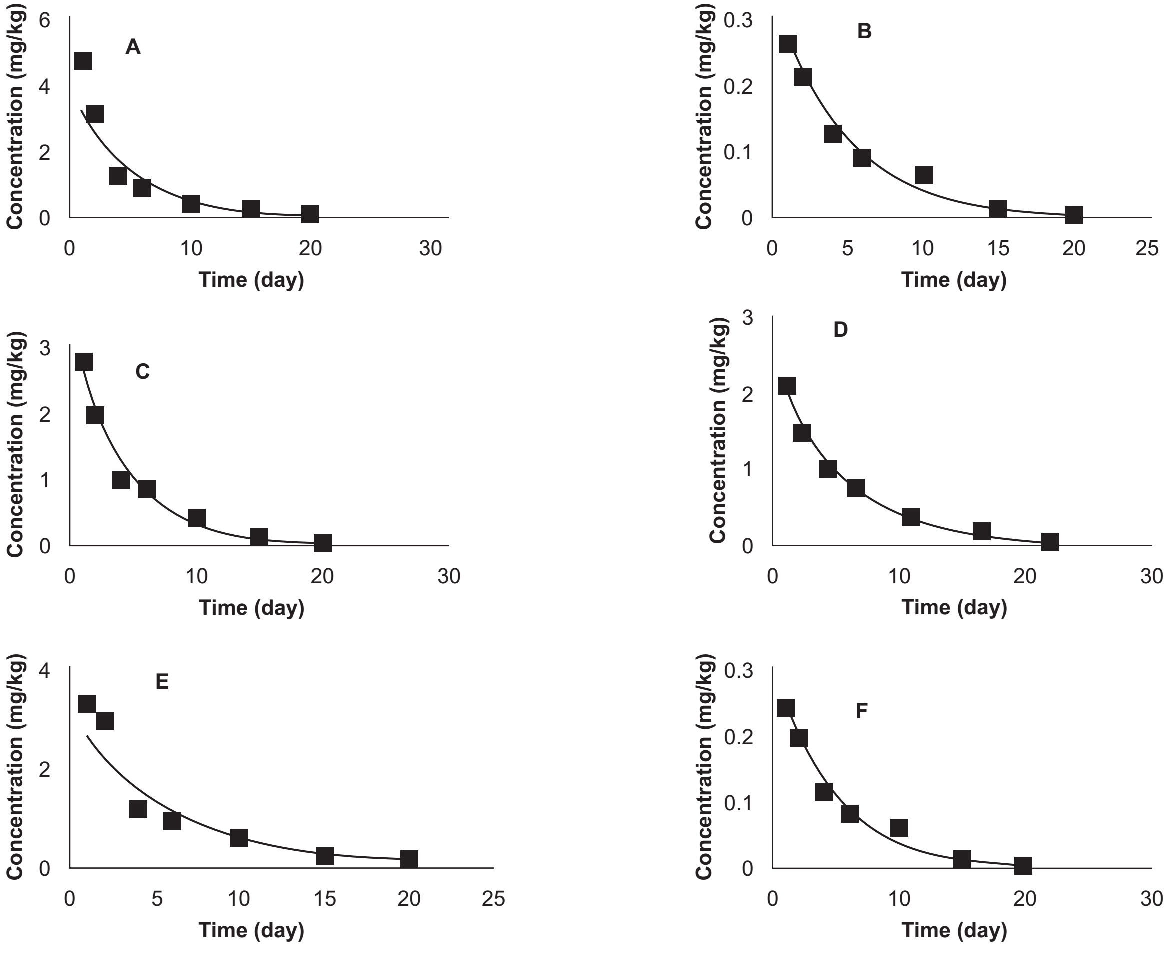

Figure 2. Dissipation of A: chlorpyrifos methyl, B: dimethoate, C: permethrin, D: iprodione, E: metalaxyl, and F: propargite in parsley under field conditions.

Table 3. The initial deposits (mg/kg), regression equation, R^2, half-life ($t_{1/2}$), and preharvest intervals (PHI) of pesticides in parsley.

	Chlorpyrifos-methyl	Dimethoate	Permethrin	Iprodione	Metalaxyl	Propargite
Initial deposits (mg/kg)	4.748	0.259	2.757	2.098	3.348	0.474
Regression equation	$y = 4.0061e^{-0.208x}$	$y = 0.3347e^{-0.21}$	$y = 3.3444e^{-0.2367x}$	$y = 2.4335e^{-0.197x}$	$y = 3.455e^{-0.1694x}$	$y = 0.5031e^{-0.205x}$
R^2	0.9675	0.97683	0.9801	0.9763	0.968	0.9776
$t_{1/2}$ (day)	3.33	3.30	2.94	3.52	4.10	3.38
PHI (day)	25	13	18	24	1	16

Propargite is an effective acaricide, which is utilized for a large number of crops (Kumar *et al.*, 2005). The half-life of propargite in green tea leaves, apple, and Brinjal Fruits was, respectively, 1.79, 2.61, 6.2–10m and 3.07–3.54 days (Kang *et al.*, 2009; Kumar *et al.*, 2005; Lou *et al.*, 2008), while $t_{1/2}$ of this pesticide in our study was 3.38 days. In the current study, we found that a waiting period of 16 days was needed for the safe consumption of parsley to prevent any health hazards due to propargite, while shorter waiting periods were advised for other crops, such as 1 day for the brinjal fruit (Kang *et al.*, 2009).

The half-life of iprodione in our study (3.52 days) was shorter than that in tomato (6.8 days) and similar to that in sweet cherry (3.47 days) (Lazić *et al.*, 2016; Omirou *et al.*, 2009). The occurrence of permethrin was reported for some vegetables, although little published information was found regarding its $t_{1/2}$ and PHI (George, 1985).

The reasons for discrepancies of $t_{1/2}$ and PHI values in our study when compared with previous studies were related to the differences in effective factors on pesticide dissipation. The dissipation pattern of pesticides depended on pesticide formulations and physical–chemical properties (vapor pressure and solubility), climate conditions (temperature, humidity, sunlight), plant characteristics (genus and species), location of application of the pesticide, and the number and dosage of pesticide applications (Chai *et al.*, 2009; Heshmati *et al.*, 2020b; Jacobsen *et al.*, 2015; Kumar *et al.*, 2005). Therefore, the variations in these factors in various studies resulted in different $t_{1/2}$ and PHI values being obtained and reported for each pesticide.

Risk assessment

The findings of risk assessment are summarized in Table 4. STMR for chlorpyrifos-methyl, dimethoate, permethrin, iprodione, metalaxyl, and propargite were 0.876, 0.089, 0.851, 0.750, 0.965, and 0.166 mg/kg, respectively. In a previous study, the estimated STMR of chlorpyrifos in rice and cabbage, respectively, was 0.01 and 0.227 mg/kg (Chen *et al.*, 2012), which was lower than our findings. As shown, the pesticide EDI ranged from 7.37E-05 (dimethoate) to 8.00E-04 (Metalaxyl) mg/kg bw/day, and HQ of all them were <100%. HI of six pesticides was lower than 100%, and this finding is similar to previous studies (Cámara *et al.*, 2020; Milinčić *et al.*, 2020; Yang *et al.*, 2020). Overall, these results showed that for the recommended dose of pesticide, the long-term exposure of consumers to dimethoate,

Table 4. Dietary intake risk assessments of dimethoate, chlorpyrifos methyl, permethrin, iprodione, metalaxyl, and propargite through parsley consumption.

Pesticide	STMR (mg/kg)	EDI (mg/kg bw/day)	ADI (mg/kg bw/day)	HQ (%)
Chlorpyrifos-methyl	0.876	7.26E-04	0.010	7.26
Dimethoate	0.089	7.37E-05	0.002	3.69
Permethrin	0.851	7.05E-04	0.050	1.41
Iprodione	0.750	6.21E-04	0.020	3.11
Metalaxyl	0.965	8.00E-04	0.050	1.60
Propargite	0.166	1.38E-04	0.030	0.46
				HI = 17.52

HQ: Hazard Quotient; HI, Hazard Index; ADI, accepted daily intake; STMR.

chlorpyrifos-methyl, permethrin, iprodione, metalaxyl, and propargite residues through parsley consumption is relatively negligible. However, it's necessary to calculate EDI of mentioned pesticide through other crop consumption on which these pesticides may be used.

4. Conclusion

This study is the first report on dissipation behavior and dietary intake risk of chlorpyrifos-methyl, dimethoate, permethrin, iprodione, metalaxyl, and propargite in parsley (*Petroselinum crispum*) under the field conditions. Dissipation of chlorpyrifos-methyl, dimethoate, permethrin, iprodione, metalaxyl, and propargite in parsley followed the first-order kinetics with $t_{1/2}$ of 3.33, 3.30, 2.94, 3.52, 4.10, and 3.38, respectively. Based on the dissipation pattern and MRL, PHI of 25, 13, 18, 24, 1, and 16 days are suggested for chlorpyrifos-methyl, dimethoate, permethrin, iprodione, metalaxyl, and propargite in parsley, respectively. The risk assessment showed HQ was <1 for spraying the mentioned pesticide on parsley, and therefore, they were safe for humans. Finally, the results of the current study would be used as a reference for establishing PHI of chlorpyrifos-methyl, dimethoate, permethrin, iprodione, metalaxyl, and propargite in parsley to provide guidance on the safe and proper use of these pesticides. However, the current investigation was devoted to assessing the EDI of pesticides through parsley consumption. It is, however, necessary to calculate EDI of mentioned pesticides through the consumption of other crops.

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Conflict of interest

No potential conflict of interest was reported by the authors.

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