The effect of household processing on the decline pattern of dimethomorph in pepper fruits and leaves

Sung-Woo Kim a, A.M. Abd El-Aty a,b,**, Md. Musfiqur Rahman a, Jeong-Heui Choi a, Young-Jun Lee a, Ah-Young Ko c, Ok-Ja Choi d, Hee Nam Jung d, Ahmet Hacimuftuoğlu e, Jae-Han Shim a,*

a Biotechnology Research Institute, College of Agriculture and Life Sciences, Chonnam National University, Yongbong-ro 77, Buk-gu, Gwangju 500-757, Republic of Korea
b Department of Pharmacology, Faculty of Veterinary Medicine, Cairo University, 12211 Giza, Egypt
c Department of Food & Cooking Science, Sunchon National University, 413 Jungangno Sunchon, Jellanam-do 540-742, Republic of Korea
d Department of Medical Pharmacology, Medical Faculty, Ataturk University, Erzurum, Turkey
e Biotechnology Research Institute, College of Agriculture and Life Sciences, Chonnam National University, Yongbong-ro 77, Buk-gu, Gwangju 500-757, Republic of Korea

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A B S T R A C T

The effects of various household processes, including washing, boiling, frying, parboiling, and drying under different conditions (water amount, boiling times, and temperatures) on the residual levels of dimethomorph were evaluated in pepper fruits and leaves grown under plastic greenhouse conditions. The original quick, easy, cheap, effective, rugged, safe (QuEChERS) method (after modification) and liquid chromatography–tandem mass spectrometry (LC/MS/MS) were used for extraction and analysis to determine the sample residues. The results of recovery tests in processed and unprocessed pepper fruits and leaves ranged from 73.6 to 106.2% with relative standard deviations of 1.62–12.4%. Among various processes, washing and parboiling (78.4–85.8% at single and 75.7–89.9% at double dose) and drying after washing and parboiling (95.3–97.3% at single dose) were the most effective household methods to attenuate the analyte residues in pepper fruits and leaves, respectively. We conclude that processing leads to extensive reduction of pesticide residue levels in pepper fruits and leaves, particularly following washing and cooking operations.

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1. Introduction

Dimethomorph [(E, Z)-4-[3-(3-chlorophenyl)-3-(3,4-dimethoxyphenyl)]acryloyl]morpholine, consists of E and Z-isomers in approximately equal proportions (Fig. 1). It is a local systemic fungicide that effectively controls late blight, downy mildew, and crown and root rot in vines, potatoes, tomatoes, and other crops (Cohen, Baider, 1995; Liu et al., 2012). Dimethomorph is necessary to prevent Phytophthora blight, a disease resulting in serious threats to pepper production (Hwang & Kim, 1995; Ristaino & Johnston, 1999). Pesticides are widely used in food production to increase food security, despite that they may have hazardous effects on consumers (Keikotlhaile, Spanoghe, & Steurbaut, 2010; Radwan, Abu-Elamayem, Shiboob, & Abdel-Aal, 2005).

Pepper is an annual herbaceous plant that is very popular worldwide because of its profitability for farmers and high nutritional value containing vitamins A, B, C, carotene, polyphenols, flavonoids, quercetin, and luteolin. Peppers are used as an ingredient in many regional cuisines because of their attractive color and unique spicy aroma (Kim et al., 2007; Minguiez-Mosquera, JarBn-Galh, & Garrido-Fernhdez, 1994; Sousa et al., 2006). In Korean cuisine, the typical forms of consuming pepper and pepper leaf are “jjigae” which is made by boiling the washed pepper with vegetables in hot water; “bokkeum” in which the washed pepper is fried, or “namul” prepared by mixing parboiled leaves with several seasonings (Lee & Jung, 2009).

One of the most common routes of pesticide exposure is via consumption of both raw and processed foods (Han et al., 2014;
Various food processing operations can alter pesticide structure and result in a relative decrease and/or increase of residues in cooked foods (Bajwa & Sandhu, 2014; Holland, Hamilton, Ohlin, & Skimore, 1994; Park et al., 2011). Therefore, it is imperative to monitor and control the residues in processed as well as in raw foods to protect human health from the hazardous effects of pesticides (Park et al., 2011). The characteristics of pesticides, including solubility, hydrolysis rate constant, volatility, octanol–water partition coefficient, physical location of residues, and thermal degradation are very important to accurately estimate the effects of processing on the dissipation of residues in foods (Holland et al., 1994; Kaushik, Satya, & Naik, 2009). Common food processing operations along with the degree of residue removal in each process have been studied previously for pyridaben and tralomethrin in washed peppers (Valverde, Aguilera, Rodriguez, Boulaid, & Begrani, 2002), profenofos in washed, blanched and fried hot and sweet peppers (Radwan et al., 2005), and dichlofluanid, flusilazole, folpet, iprodione, l-cyhalothrin, and lufenuron in washed, blanched and dried hot pepper leaves (Lee & Jung, 2009).

Literature considering the effects of processing on dimethomorph residue in sweet pepper and pepper leaves is very scarce. Therefore, the objectives of this study were to investigate the decrease of dimethomorph content in pepper fruits and leaves using various food processing operations, including washing, boiling, frying, parboiling, and drying at different water volumes, times, and temperatures. The analyte was extracted with the QuEChERS method, which was modified in accordance with the analyte properties, matrix composition, equipment, and analytical techniques available in the laboratory (Anastassades, Lehotay, Stajnbaher, & Schenck, 2003; Lehotay et al., 2010; Park et al., 2011; Wilkowska & Biziuk, 2011).

2. Materials and methods

2.1. Chemicals and reagents

An assured standard of dimethomorph (purity: 99.8%) was provided by Dr. Ehrenstorfer GmbH (Augsburg, Germany). High performance liquid chromatography (HPLC)-grade acetonitrile (MeCN) was purchased from Burdick and Jackson (Ulsan, Republic of Korea). Anhydrous magnesium sulfate (MgSO₄) and sodium chloride (NaCl, purity: 99.5%) were supplied by Junsei Chemical Co. Ltd. (Kyoto, Japan). Formic acid was obtained from Daejung Chemicals & Materials (Siheung, Republic of Korea). Primary secondary amine (PSA) and C₁₈ were purchased from Agilent Technologies (Palo Alto, CA, USA). All other chemicals were of analytical or HPLC grade.

2.2. Field trial

A field trial was conducted in a greenhouse located in the experimental plot of the Chonnam National University, Gwangju, Republic of Korea. Control samples were collected before pesticide application. Commercial dimethomorph (suspension concentrate, Festival®, 18% active ingredient, Dongbang Agro, Seoul, Republic of Korea) was sprayed on pepper plants at the single and double dose rate. Pepper fruit and leaf samples were collected at 2 days after application. Approximately 5 kg of pepper fruits and leaves were randomly collected from each plot in polyethylene bags, kept in ice, and transported to the laboratory for processing.

2.3. Pepper fruit and leaf processing

The samples were processed as follows to determine the changes in dimethomorph concentrations in pepper fruits and leaves: washing, boiling (after washing), stir-frying (after washing), parboiling (after washing), and drying (after washing and parboiling). All sample processing were carried out in triplicate, and the processed samples were blended, chopped, grinded, and frozen at −21 °C pending analysis.

2.3.1. Unprocessed samples

Impurities such as diseased or inedible parts were removed from samples. The pepper fruit and leaf samples were treated as described below for an analytical sample.

2.3.2. Washing

The pepper fruit and leaf samples (50 g each) were rinsed three times by distilled water immersion (pepper fruits, 200 mL; leaves, 1000 mL) in a stainless vessel (diameter/height, 24/8 cm for pepper fruits; 34/11 cm for leaves). The washed samples were left for 1 h in a colander to drain at room temperature.
2.3.3. Parboiling

The washed pepper fruit and pepper leaf samples (50 g each) were placed in boiling distilled water and parboiled at different temperatures, and water volumes. To investigate the effect of parboiling time, various times of 1, 2, 3, and 4 min were tested at fixed temperature and water volumes (pepper fruits/leaves, 100 °C, 300/1000 mL). Additionally, boiling water volumes of 200/500, 300/1000, 400/1500, and 500/2000 mL at a fixed temperature and time (100 °C, 1 min) were assessed to evaluate their effect on pepper fruits/leaves. The excess water on the parboiled samples was squeezed out by hand pressure.

2.3.4. Stir frying

The washed and strained pepper fruits (50 g) were put into an electric frying pan (SHC-1300, Sunhak Electric, Seoul, Republic of Korea) controlled at different temperatures. Times of 0.5, 1, 1.5, and 2 min were tested at a fixed stir-frying temperature of 140 °C. To determine the effect of frying temperature, the frying pan temperatures were set to 120, 140, 160, and 180 °C at a fixed time of 1 min.

2.3.5. Drying

Pepper leaves (200 g) were rinsed with 4000 mL water in a stainless vessel (diameter: 45 cm, height: 13 cm) three times, and the water was strained off. The washed samples were parboiled in 2000 mL and 100 °C water in an aluminum pot (diameter: 22.5 cm, height: 9.5 cm) for 1 min. The parboiled samples were dried at 40, 60, 80, and 100 °C using a drying oven (HB-502L, Hanbaek, Seoul, Republic of Korea), to investigate the effect of drying temperature.

2.4. Sample extraction

The original QuEChERS method (Anastassiades, Lehotay, Štajnbaher, & Schenk, 2003) with slight modification was used to extract the analyte from pepper fruits (10 g) and leaves (5 g). MeCN (pepper fruits/leaves: 10/20 mL), 4 g magnesium sulfate (MgSO₄), and 1 g NaCl were added to a 50 mL Teflon centrifuge tube containing homogenized samples (pepper fruits, 10 g; leaves, 5 g). The tubes were immediately shaken vigorously for 1 min with a vortex-mixer and centrifuged at 4500 rpm for 5 min at 5 °C. The supernatant (4 mL) was transferred to a 15 mL Teflon centrifuge tube containing C₁₈ (pepper fruits/leaves: 50/200 mg) and PSA (pepper leaves: 200 mg). The tubes were shaken vigorously for 1 min and centrifuged at 4500 rpm for 5 min. Two mL of the pepper fruit upper layer was aspirated into a 2 mL vial, whereas 2 mL of the upper layer of pepper leaves was taken to a 20 mL vial, evaporated under nitrogen gas, and dissolved in 1 mL of MeCN for analysis by liquid chromatography–electrospray ionization–tandem mass spectrometry (LC–ESI/MS/MS).

2.5. LC–ESI/MS/MS analysis

The LC/MS/MS system, consisting of a Waters Alliance 2695 Separation Module and Waters TQ detector API tandem quadrupole mass spectrometer (Milford, MA, USA) was used for analysis. Samples were separated on a Phenomenex-Gemini 3 μm C₁₈ 100 A column (50 × 2.0 mm) (Torrance, CA, USA). A binary solvent system, consisting of 0.1% formic acid in water (A) and MeCN (B), was run in gradient mode. The mobile phase gradients (A and B) started at 95:5 for 0–5 min, ramped to 5:95 for 5–10 min, held at 5:95 for 10–15 min, and maintained at 95:5 for 15.1–20 min. The flow rate was 0.25 mL/min, and column temperature was maintained at 35 °C. A 5 μL aliquot of the extracted sample solution was injected.

The MS/MS system was operated in ESI⁻ with multiple reaction monitoring (MRM) mode. Two MS/MS transitions were selected to detect the analyte. The first product ion having higher intensity was used for quantitation and the second product ion having lower intensity was chosen for confirmation. The MS source conditions were: capillary voltage, 3.6 kV; source temperature, 150 °C; desolvation temperature, 350 °C; desolvation gas (N₂) flow, 600 L/h; and con gas (N₂) flow, 50 L/h. The Masslynx software ver. 4.1 program was used for data analysis.

2.6. Method validation

A standard stock solution of dimethomorph was prepared in MeCN at 100 mg/L and stored at −40 °C. The working solutions for sample fortification and making calibration curves were diluted in MeCN. Matrix-matched calibrations were used for quantitation. Linearity was assessed via the determination coefficient (R²) at six points of 0.03, 0.1, 0.5, 1.0, 1.5, and 2.0 mg/kg. Three and ten times the signal-to-noise ratio was used to estimate limit of detection (LOD) and limit of quantitation (LOQ), respectively.

Recovery tests were carried out by spiking working standard solutions into blank or processed pepper fruit/leaf samples at three different fortification levels (pepper fruits: 0.3, 0.6, and 1.5 mg/kg; leaves: 0.6, 1.2, and 3.0 mg/kg) in triplicate. The spiked samples were left to equilibrate for 2 h before extraction to allow the spiked solution to penetrate the matrix and then extracted according to the procedures above. Recovery percentage was calculated by comparing peak area of the analyte in the spiked samples and those of the standard solutions at identical concentrations. The relative standard deviation (RSD) (RSD = standard deviation/mean × 100%) was calculated to evaluate precision.

2.7. Statistical analysis

The paired t-test was used to compare the changes in the amounts of the analyte in processed and unprocessed pepper fruits and leaves. Pearson’s correlation coefficient test was performed to evaluate the effect of water volume, temperature, and time on processing. The analysis was carried out using the IBM SPSS Statistics 20.0 program (IBM, Armonk, NY, USA). A P < 0.05 was considered significant.

3. Results and discussion

3.1. Analytical method

Because pepper leaves contained more matrix interfering with the analysis of dimethomorph than pepper fruits, we used PSA and more C₁₈ to remove interference in the pepper leaves.

Good linearity and high determination coefficients (R² > 0.99) were obtained for calibration curves prepared in pepper fruits/leaves. The LOD/LOQ of dimethomorph in pepper fruits and leaves were 0.01/0.03 and 0.02/0.06 mg/kg, respectively. The LOQs values were lower than the dimethomorph minimum residue limits set by the Ministry of Food and Drug Safety, Republic of Korea (0.5 mg/kg, MDFS, 2013) and CODEX (5.0 mg/kg, Codex, 2013). The recovery rates of dimethomorph in processed and unprocessed pepper fruits and leaves were satisfactory at 73.6–106.2% with relative standard deviations of 1.6–12.4% (Table 1).

3.2. Dimethomorph residue in pepper fruits and/or leaves

Washing, parboiling, stir-frying, and drying were chosen to represent Korean cuisine processing methods.
3.2.1. Effect of washing

The analytical method was applied to field-incurred pepper fruits and leaves acquired from a greenhouse. The residual levels of dimethomorph in unprocessed and washed pepper fruits and leaves are shown in Table 2. The residual levels in the unprocessed pepper fruits sprayed at single and double dose rates were 2.09 and 4.74 mg/kg, which decreased significantly \( P < 0.05 \) to 1.42 and 2.18 mg/kg after washing, respectively. The residue level in the unprocessed and washed pepper leaves that were sprayed at a single dose was 35.74 mg/kg, which decreased significantly \( P < 0.001 \) to 5.60 mg/kg after washing. As the effect of washing on the decline in dimethomorph concentration was clearly noticed at a single dose, further residual change at double the recommended dose was not investigated. Notably, washing reduced the residual levels to 32.1–84.3% compared to those in unprocessed pepper fruits and leaves. This finding was consistent with that reported by Lee et al. (2006) and Lee and Jung (2009). In contrast, Ling et al. (2011) reported decreased rates of 0.23, 3.65, 10.6, 36.3, and 84.3% following washing of eggplant, and tomato after washing, respectively. The variations in declining residue behavior are attributed to surface area, type, and thickness and wax amounts on the cuticle (Krol, Arsenault, Pylypiw, & Mattina, 2000; Ling et al., 2011; Randhawa, Anjum, Ahmed, & Randhawa, 2007). The effectiveness of washing to remove pesticide residues varies depending on location (external or systemic), age of the residue, pesticide characteristics, nature of the commodity, and the washing conditions (López-Fernández, Rial-Oteró, & Simal-Gándara, 2013). The different types of washing processes used in home or commercial preparation are very effective to remove loosely attached residues on various fruits and vegetables (Street, 1969).

3.2.2. Effect of parboiling

Mean residual levels in parboiled pepper fruits, which were applied in single and double doses, are shown in Table 3. The levels declined significantly \( P < 0.05 \) to 0.3–0.45 mg/kg (single dose) and 0.53–1.15 mg/kg (double dose) in pepper fruits and to 2.7–5.49 mg/kg \( P < 0.001 \) in leaves. Notably, parboiling pepper fruits and leaves reduced residues to 75.7–89.9% compared to those of unprocessed samples. A strong negative correlation for the effect of boiling water volumes of 200–500 mL and 500–2000 mL on the decrease in dimethomorph residue was observed in pepper fruits (double dose, Pearson's \( r = -0.94 \)) and leaves (Pearson's \( r = -0.65 \)), respectively (Table 3). This result means that residue levels decreased significantly in pepper fruits \( P < 0.01 \) and leaves \( P < 0.05 \) with increasing boiling water volumes, compared to those of unprocessed samples. Boiling time (1–4 min) had no effect on residue levels in pepper leaves, but it significantly reduced the level of dimethomorph in pepper fruits (Pearson's \( r = -0.72 \)).

Kwon et al. (2009) found that the reduced rates of pesticide residues on spinach (bifenthrin, metalaxyl, and procymidone), chard (bifenthrin, and imidacloprid), and mallow (bifenthrin, chlorpyrifos, and imidacloprid) were 66–98% following washing and boiling. The loss of pesticide residues during heat processing may be due to evaporation, co-distillation, or thermal degradation, which varies with the chemical nature of an individual pesticide (Sharma, Satya, Kumar, & Tewar, 2005). Abou-Abar and Abou-Donia (2001), and Ali (1983) found that heat, strong adsorption of pesticide onto plant tissues, and/or the poor solubility of the pesticide in water can affect the decrease of pesticide residues from boiled foodstuffs.

3.2.3. Effect of stir frying/drying

The residual levels of dimethomorph in stir-fried pepper fruits and dried leaves are shown in Table 4. Mean residual levels of dimethomorph on stir-fried pepper fruits at single and double doses were 0.73–1.51 and 1.53–1.88 mg/kg, respectively. Residues decreased significantly following stir-frying of pepper fruits \( P < 0.05 \) or drying leaves \( P < 0.001 \). Stir-frying pepper fruits and drying pepper leaves reduced the residues to 27.9–97.3% compared to that of unprocessed samples. All reduction ratios of the processed samples were calculated by comparing the residues of unprocessed samples, which were quantified from 10 g (pepper fruits) and 5 g (leaves) subsamples. All processed samples were also extracted from the same amount of subsamples. The point is that the weight of the analytical samples was changed by the processes. In particular, the weight changes caused by drying were profound, indicating that the subsamples (5 g) of dried pepper leaf sample were definitely different from those of unprocessed samples, and the quantifiable residues from the dried samples should never be directly compared with those of unprocessed samples. The relative increase or decrease in pesticide residue caused by a sample process is called the “concentration factor”. Concentration factors of pepper fruits and leaves processed by washing, parboiling, and stir-frying were from 0.70 to 1.07, which was negligible. In contrast, the

### Table 1

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Pepper fruits</th>
<th>Determination coefficient</th>
<th>Spiked level (mg/kg)</th>
<th>Mean recovery (RSD, %)</th>
<th>LOD/LOQ (mg/kg)</th>
<th>Pepper leaves</th>
<th>Determination coefficient</th>
<th>Spiked level (mg/kg)</th>
<th>Mean recovery (RSD, %)</th>
<th>LOD/LOQ (mg/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unprocessed</td>
<td>0.9998</td>
<td>0.3</td>
<td>77.8 (7.25)</td>
<td>0.01/0.03</td>
<td>0.9978</td>
<td>0.6</td>
<td>89.2 (7.20)</td>
<td>0.02/0.06</td>
<td></td>
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<tr>
<td></td>
<td>0.6</td>
<td>77.7 (6.13)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>106.2 (6.67)</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>1.5</td>
<td>82.3 (1.62)</td>
<td></td>
<td></td>
<td></td>
<td>3.0</td>
<td>91.8 (3.11)</td>
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<tr>
<td></td>
<td>0.5</td>
<td>76.9 (2.34)</td>
<td></td>
<td>0.01/0.03</td>
<td>0.991</td>
<td>1.2</td>
<td>843 (5.81)</td>
<td>0.02/0.06</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>1.5</td>
<td>73.6 (4.42)</td>
<td></td>
<td></td>
<td></td>
<td>3.0</td>
<td>92.3 (3.25)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Parboiling</td>
<td>0.9955</td>
<td>0.3</td>
<td>74.1 (2.45)</td>
<td>0.01/0.03</td>
<td>0.9937</td>
<td>0.6</td>
<td>83.8 (12.39)</td>
<td>0.02/0.06</td>
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<tr>
<td></td>
<td>0.6</td>
<td>78.6 (6.73)</td>
<td></td>
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<td></td>
<td>1.2</td>
<td>96.0 (6.76)</td>
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<tr>
<td></td>
<td>1.5</td>
<td>89.3 (2.50)</td>
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<td></td>
<td></td>
<td>3.0</td>
<td>102.9 (5.21)</td>
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</tbody>
</table>

* Relative standard deviation.

### Table 2

<table>
<thead>
<tr>
<th>Part of pepper</th>
<th>Application dose</th>
<th>Mean residues (SD, mg/kg)</th>
<th>Reduction ratio (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fruit</td>
<td>Single</td>
<td>2.09 (0.08)</td>
<td>1.42 (0.05)</td>
</tr>
<tr>
<td></td>
<td>Double</td>
<td>4.74 (0.96)</td>
<td>2.18 (0.19)</td>
</tr>
<tr>
<td>Leaf</td>
<td>Single</td>
<td>35.74 (0.76)</td>
<td>5.60 (0.16)</td>
</tr>
</tbody>
</table>

Determination coefficient, mean recovery and LOD and LOQ of dimethomorph in pepper fruits and leaves \( n = 3 \).
concentration factor of pepper leaves processed by drying was 5.8–6.2, which was considerable. Therefore, the dimethomorph residues extracted and quantified from dried pepper leaves (5 g subsample) should be compensated, for a correct comparison of the residues considering the amount of unprocessed subsample, and all residues in dried pepper leaves were compensated using the concentration factor, and the reduction ratio was calculated.

The effects of temperature and time on reducing the residual levels of dimethomorph in stir-fried pepper fruits were significant at a single dose (Pearson’s r = −0.79/−0.78, temperature/time; P < 0.01) but were not at a double dose. The effect of temperature was significant in dried leaves (Pearson’s r = −0.83; P < 0.01). Therefore, stir-frying pepper fruits and drying pepper leaves at a single dose had a strong positive effect on loss of dimethomorph residues. Ling et al. (2011) reported that the reductions of chlorpyrifos on frying without water washing were 5.13, 7.54, 10.3, 63.2, and 93.3% in cucumber, garlic sprouts, tomato, eggplant, and cabbage, respectively. Frying as a type of cooking is affected by time, processing temperature, degree of moisture loss and cooking system (open or closed). In general, the heat involved in cooking increases rates of degradation and volatilization of residues in food (Holland et al., 1994). In contrast, Lee et al. (2006) found diminution

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Table 3
Dimethomorph residues in parboiled pepper fruits and leaves (n = 3).

<table>
<thead>
<tr>
<th>Part of peppers</th>
<th>Treatment</th>
<th>Dosage</th>
<th>Mean residual level (SD, mg/kg)</th>
<th>The amount of water (pepper fruits/leaves, mL)</th>
<th>Pearson’s r</th>
<th>Time (min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fruits</td>
<td>Parboiling</td>
<td>Single</td>
<td>0.45 (0.03)</td>
<td>200/500</td>
<td>0.45 (0.02)</td>
<td>1</td>
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<tr>
<td></td>
<td></td>
<td>RR (%)</td>
<td>78.4</td>
<td>0.85</td>
<td>0.85</td>
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<tr>
<td></td>
<td></td>
<td>Double</td>
<td>0.99 (0.03)</td>
<td>300/1000</td>
<td>0.96</td>
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<tr>
<td></td>
<td></td>
<td>RR (%)</td>
<td>5.8</td>
<td>400/1500</td>
<td>5.84</td>
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<td></td>
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<td>400/1500</td>
<td>500/2000</td>
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Table 4
Residual levels of dimethomorph in fried pepper fruits and dried pepper leaves (n = 3).

<table>
<thead>
<tr>
<th>Part of peppers</th>
<th>Treatment</th>
<th>Dose</th>
<th>Mean residual level (SD, mg/kg)</th>
<th>The amount of water (pepper fruit/pepper leaves, mL)</th>
<th>Pearson’s r</th>
<th>Time (min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leaves</td>
<td>Parboiling</td>
<td>Single</td>
<td>5.49 (0.17)</td>
<td>120/40</td>
<td>5.8</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>RR (%)</td>
<td>79.1</td>
<td>140/60</td>
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<td>160/80</td>
<td>180/100</td>
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**P < 0.05.
*P < 0.01.

RR: reduction ratio.

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Fig. 2. Liquid chromatography–tandem mass spectrometry chromatograms of dimethomorph in unprocessed and processed samples (A); unprocessed pepper fruits (B); washed pepper fruits (C); boiled pepper fruits (D); fried pepper fruits (E); unprocessed pepper leaves (F); washed pepper leaves (G); parboiled pepper leaves, and (H) dried pepper leaves.
rates (calculated including loss of moisture) of 17–55% for cypermethrin, bifenthrin, chlorfenapyr, esfenvalerate, and imidacloprid in pepper leaves after drying and parboiling. Loss of moisture in food during drying was remarkable when compared with other food processing methods. Furthermore, Cabras et al. (1998) reported that the residual level of procymidone in plums after drying was 0.22 mg/kg, which corresponded to 59% of the residue in the unprocessed fruit. Therefore, it is important to evaluate the change in moisture during drying to accurately determine the effect of drying on food processing. The representative MRM transition chromatograms of dimethomorph in unprocessed and processed pepper fruits and leaves are shown in Figs. 2 and 3.

4. Conclusions

The reduction of dimethomorph residue levels in pepper fruits and leaves through various household processes was evaluated. Washing with distilled water decreased the pesticide residues to 32.01% in pepper fruits and 84.3% in leaves at a single dose and 54.0% in pepper fruits at a double dose. The effect of washing was less effective than that of other treatments. The most effective processing operation to decrease the pesticide residues was the combination of washing and boiling in pepper fruits (81.6% at single dose, 83.2% at double dose) and drying after washing and parboiling in pepper leaves (96.2% at single dose).

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