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REDUCING PESTICIDE RESIDUES ON TOMATO THROUGH APPROPRIATE POST-SPRAY HARVESTING TIME AND POSTHARVEST WASHING

[1]Tong Socheath, [1]Borarin Buntong, [1]Sok Vibol, [2]Thavrak Huon and [3*]Antonio Acedo Jr.

[1]Division of Research and Innovation, Royal University of Agriculture, Phnom Penh, Cambodia.

[2]Rectorate, Royal University of Agriculture, Phnom Penh, Cambodia.

[3]Institute of Crop Science, University of the Philippines Los Banos, Philippines.

*Corresponding author

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ABSTRACT

Pesticide residues are a serious problem in Cambodia's vegetable sector. This study determined the pesticide residue levels on local and imported tomatoes in Phnom Penh markets and the effects of harvesting time after pesticide spraying and postharvest washing methods. Locally produced tomatoes had lower pesticide residues than imported tomatoes in supermarkets and wet markets. All pesticide levels were lower than the Codex Maximum Residue Limits (MRLs) while carbofuran, chlorfenapyr and chlorpyrifos were higher than the European Union (EU) MRLs. Field-grown tomatoes had highest pesticide residues after 1 day from spraying, which decreased thereafter but the trend differed with location. In Kandal province, all pesticides were lower than the Codex and EU MRLs after 14 days from spraying, except acetamiprid, while in Battambang province, all pesticides were not detected after 14 days from spraying. Nethouse-grown tomatoes were negative of pesticide residues except chlorpyrifos in Kandal and acetamiprid in Battambang. Removing pesticides on tomatoes inoculated with dimethoate, profenofos, endosulfan, cyhalothrin, cypermethrin, fenvalerate and deltamethrin was more effective with running tap water than 2% salt. When the two was combined (2% salt, then rinsing with tap water), the efficacy remarkably increased, removing 68.60-99.99% of the pesticides. Applying this treatment on tomatoes produced in Kandal and Battambang resulted in 60% removal of cypermethrin, the only pesticide detected. From the results, there is potential for integrating appropriate timing of harvesting and washing with combined 2% salt and water rinsing in enhancing food safety of tomatoes.

Keywords: *Solanum lycopersicum,* Food safety, Pesticide removal

1. INTRODUCTION

Vegetables are the second most important crop after rice and the most profitable agricultural activity in Cambodia. Vegetables generate more income (3-14x higher), jobs (2-6x higher) and market-oriented farmers than rice; stimulate secondary industries (e.g. packaging and logistics industries); and commercialize rural economies (Schreinemachers et al., 2018; Acedo and Buntong, 2021). Vegetables are also rich sources of vitamins, minerals, fiber and antioxidants which lower the risks of death and morbidity due to cancer, heart attack, diabetes and other chronic diseases. The World Health Organization (WHO) recommends minimum vegetable consumption of 240 grams/person/day. Cambodia failed to meet this as average consumption ranges from 96 grams/person/day (35 kg/year) in rural areas to 123 grams/person/day (45 kg/year) in urban areas. At this consumption level, about 930,000 tons of vegetables are needed for the whole population of about 17 million but local production is only about 420,000 tons, thus over 50% are imported from Vietnam, Thailand and China. However, Cambodian consumers perceived domestically produced vegetables to be better and safer than imported vegetables (CAES-UCD, 2020).

Tomato (*Solanum lycopersicum*) is an important vegetable crop in Cambodia, widely consumed fresh or cooked in various dishes. It is a rich source of vitamins (C, A and K), minerals (potassium, magnesium, calcium, phosphorus and iron), and carotenoids particularly lycopene which is a potent antioxidant with multiple health benefits (Bolton-Smith et al., 2007; Shafe et al., 2024). Market demand for tomatoes and other vegetables is increasing because of growing consumers' health consciousness and awareness of health benefits of vegetables. Similarly, consumers are now aware of quality and food safety issues which are quickly disseminated through online platforms; consequently, consumers want to be assured of the quality and food safety of vegetables they buy and eat. Assuring quality and food safety secures consumers' confidence in food systems and benefits producers and value chain stakeholders through increased market access which can generate more income.

Pesticide residues on tomato and other vegetables are a worldwide problem which is more serious in developing countries where regulations are less stringent and pesticide use is not properly monitored (WHO, 2022). Vegetable production is a high-risk venture and pests are the greatest challenge that could result in crop damage and yield loss or total crop failure. Farmers commonly use pesticides that are more than required in order to ensure harvest and income. Pesticide residues result from: i) pesticide misuse and abuse during production; ii) pesticides used in postharvest management to preserve food during storage; and iii) persistence and carry-over effect of pesticides. Pesticide residues are linked to a number of health issues, such as cancers, nervous system and brain disorders, reproductive and immune system damage, and acute poisoning. They also pose a serious burden on the environment and a significant barrier to domestic and export trade.

Cambodia ranks first among Southeast Asian countries with the highest pesticide residues on vegetables (PRETAG, 2023). This is the result of indiscriminate use of pesticides by farmers, as well as lack of knowledge of proper pesticide application. Cambodian vegetable growers use a mixture of three to four pesticides in each spraying, often weekly, sometimes twice a week, and even 2-3 days before harvest (WVC, 2024). And, pesticides do not dissipate to safe levels for consumption when farmers do not provide an adequate interval between the last spraying and harvesting. In 1994, there were only 30 pesticides in the market; this increased to 241 in 2000, of which 42 were prohibited in Vietnam and another 16 were banned in Thailand; thus, Cambodia has become a dumping ground for unwanted and dangerous pesticides. In 2009, 757 pesticides were available in the market. Studies on pesticide contamination of tomato and other vegetables in Cambodia have found high levels of pesticide residues, including organochlorine, organophosphate and carbamate exceeding maximum residue levels (MRLs) (Sareth and Preap, 2015; Sim et al., 2021; Putheary, 2024; ACTED, 2025). MRLs are standards set by individual countries for traded agricultural commodities. The increasing demand for food, the need for good income, and the attraction of advertising contribute to the widespread use of pesticides in Cambodia. The use of pesticides without following manufacturer's instructions on product label or not following the principles of good agricultural practice (e.g. Cambodia GAP) results in large amount of pesticide residues on products. To reduce the problem, there is a need to establish concrete data on the effect of pesticide application intervals and explore safe postharvest washing treatment that could remove pesticide residues on produce for integration in value chain improvement.

2. MATERIALS AND METHODS

2.1 Assessment of pesticide residues on tomatoes in markets

Tomato samples (pink to light red stage) produced in Cambodia (cv. Mongal) and imported from Vietnam (cv. Thaise) were collected from a supermarket and a wet market in Phnom Penh. The samples were packed in properly sealed bags, then placed in a cold container (ice box with ice), and transported to the Pesticide Residue Laboratory of the Division of Research and Innovation, Royal University of Agriculture (RUA), Phnom Penh. Upon arrival, the samples were stored at -20ºC prior to analysis to prevent loss of pesticide residues if any. Four replicate samples were subjected to pesticide residue analysis for Acetamiprid, Carbofuran, Chlorfenapyr, Cypermethrin, Fipronil and Chlorpyrifos.

2.2 Effect of time interval between pesticide application and harvest

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Tomato cv. Mongal was used in experimental trails in nethouse and open field production in Kandal province (Por Krom Village, Trey Sla Commune, Sa Ang District) and Battambang province (Ta Se village, Tamun commune, Thma Kol district). The nethouse-grown tomato was not applied with pesticide as the nethouse served as a pest barrier. The open field-grown tomatoes were sprayed with commercial pesticides and the fruits were harvested after 1, 3, 7, 10 and 14 days from spraying. The harvested fruit samples were packed in tightly sealed bags, placed in an ice box, and transported to the Pesticide Residue Laboratory at RUA. Upon arrival, the samples were stored at -20ºC before analysis. Triplicate samples were used for pesticide residue analysis for Acetamiprid, Carbofuran, Chlorfenapyr, Cypermethrin, Fipronil and Chlorpyrifos.

2.3 Effect of postharvest washing

Tomatoes (cv. Mongal) at the mature green to breaker stage were randomly selected from a local farm, packed in tightly sealed bags, placed in icebox, and transported to the Pesticide Residue Laboratory at RUA. Upon arrival, the samples were stored at -20ºC prior to use. The tomato samples were inoculated with a solution containing seven chemical compounds - Profenofos, Beta-Endosulfan, Cypermethrin, Lambda-Cyhalothrin, Dimethoate, Fenvalerate and Deltamethrin. The inoculated fruits were then subjected to the following washing treatments: no wash (control), soaking in 2% salt solution for 5 min, washing in running tap water for 1 min, and soaking in 2% salt solution for 5 min followed by rinsing in running tap water for 1 min. After which, triplicate tomato samples were subjected to pesticide residue analysis for the 7 compounds as aforementioned. In a subsequent study, the most effective washing method was used for tomatoes taken from a farm in Kandal and in Battambang harvested from plants after 7 days from spraying with commercial pesticides. Triplicate samples were subjected to pesticide residue analysis for Acetamiprid, Carbofuran, Chlorfenapyr, Cypermethrin, Fipronil and Chlorpyrifos.

2.4 Pesticide residue analysis

Pesticide residue was quantified by GC/MS analysis following the method of Zou and Zhai (2015). After overnight freezing at -20ºC, the frozen tomato samples were sliced into small pieces, ground finely, and 10g of the ground sample was placed into a 50 ml centrifuge tube added with 10 ml acetonitrile. The mixture was vortexed for 1 min and then extraction agent Aglilent Bound Elut QuEChERs EN Salt was added, shaken for 1 min at 500 rpm, and centrifuged at 4000 rpm for 5 min. Six ml of upper layer was transferred to a 15-ml dispersive Solid Phase Extraction (dSPE) tube, vortexed for 1 min, and centrifuged at 4000 rpm for 5 min. One ml of the upper layer of sample was transferred into a vial for GC/MS analysis. High-purity standards of pesticides (e.g. Acetamiprid, Carbofuran, Chlorfenapyr, Cypermethrin, Fipronil and Chlorpyrifos) were used.

2.5 Data analysis

The results were analyzed using Quantitative Software and imported into Microsoft Excel 2010. The results were calculated relative to the original mass of the sample. The results were then compared with the Codex and EU MRLs.

3. RESULTS AND DISCUSSION

3.1 Assessment of pesticide residues on tomatos in markets

Six pesticides - acetamiprid, carbofuran, chlorfenapyr, cypermethrin, fipronil and chlorpyrifos, were detected in all tomato samples collected from supermarket and wet market, except on locally produced tomatoes in supermarkets which were negative of fipronil and chlorpyrifos and 25% of the same tomatoes which were negative of acetamiprid (Table 1). Supermarket tomatoes had lower amounts of the 6 pesticides than wet market tomatoes regardless of source. Similarly, local tomatoes had lower pesticide residues than imported tomatoes regardless of market. All residue levels of the pesticides were lower than the Codex MRL, except fipronil which has no Codex MRL yet. Relative to the EU MRL, the levels of acetamiprid, cypermethrin and fipronil were lower while those of carbofuran, chlorfenapyr and chlorpyrifos were higher.

Table 1: Pesticide residues on locally produced and imported tomatoes from supermarket and wet market in Phnom Penh.

Pesticide	Local tomato (mg/kg x 10^{-2})		Imported tomato (mg/kg x 10^{-2})		MRL (mg/kg x 10^{-2})	
	Supermarket	Wet market	Supermarket	Wet market	Codex[1]	EU[2]
Acetamiprid	0.20±0.06*	1.04±0.36	4.88±0.79	6.16±0.55	20.0	50.0
Carbofuran	0.59±0.05	4.04±0.79	0.7±0.12	6.85±0.72	10.0	0.2
Chlorfenapyr	5.01±0.37	7.85±2.63	7.49±0.91	13.58±0.73	40.0	1.0
Cypermethrin	4.82±0.20	6.98±1.99	7.44±1.98	19.89±1.97	20.0	50.0
Fipronil	ND*	0.37±0.22	0.35±0.09	0.47±0.20	-	0.5
Chlorpyrifos	ND	2.16±0.46	3.13+0.85	2.80±0.48	50.0	1.0

Values are means + SD of 4 replicates. Values are divided by 100 (shown as 10^{-2}) to get the actual values.
*detected in 75% of samples; ND-not detected
[1]https://www.fao.org/fao-who-codexalimentarius/codex-texts/dbs/pestres/pesticides/en/, https://asean.org/wp-content/uploads/2022/03/Crops-1-DATABASE-ASEAN-MRLs-Oct-2021_for-public-domain.pdf
[2]https://ec.europa.eu/food/plant/pesticides/eu-pesticides-database/start/screen/products/details/116

Several studies have reported that vegetables from supermarkets generally have lower pesticide residue levels compared to those from traditional or wet markets. Hu et al (2020) obtained lower detection rate of pesticide residues on vegetables from supermarkets than from farmers' markets. Supermarkets usually have stricter quality control leading to lower residue levels on their produce. Some supermarket chains conduct rigorous testing for pesticide residues and have traceability systems to identify the source of produce. Alita et al (2020) added that supermarkets often source their produce from larger farms that adhere to stricter quality control. Supermarkets have a

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centralized system for buying produce, allowing them to enforce quality standards across their suppliers. In addition, supermarkets may clean, wash and process vegetables before selling them, further reducing pesticide residues. On the other hand, wet markets rely on individual vendors with varying practices and have a wider variety of sources with less oversight, potentially leading to higher pesticide levels on their produce. Also, wet markets may source produce from smaller farms with less access to information and resources regarding pesticide management. Similar situation exists in other countries. In Thailand, for example, supermarkets are considered to have safer vegetables than wet markets, as supermarkets have stricter quality control measures and food safety standards, leading to a perception that their produce is less likely to be contaminated with pesticides (Wanwimolruk et al., 2016). Supermarkets typically have better hygiene practices with proper storage and handling procedures, while wet markets may have inconsistencies in sanitation depending on the vendor. These processes and activities to ensure quality and food safety are value added activities contributing to higher prices of supermarket produce compared to those in traditional markets. However, many consumers are willing to pay for the high price of vegetables in supermarkets as they have high expectation that supermarket produce is safe from pesticide contamination. It is important to note that not all supermarkets are equal; even within supermarkets, differences in quality control may exist.

Cambodian consumers perceived that locally produced vegetables are better and safer than imported vegetables (CAES-UCD, 2020). Unregulated imports have resulted in many chemicals banned by the Cambodian Government being readily available on the domestic market. Consumers frequently associate imported vegetables with high contamination by chemical and pesticide residues (SNV, 2022; Mossiman et al., 2023), which has been circulating and known in the country for at least the past 20 years (EJF, 2002). There is truth to the belief that imported tomatoes are laden with pesticide residues based on the evidence established in the present study in which local tomatoes have lower pesticide residues than imported tomatoes.

Local and imported tomatoes from supermarkets and wet markets can be considered as safe for human consumption as they contained pesticide residues lower than the Codex MRLs. Codex MRLs are reference point of governments worldwide to establish their respective national MRLs. In the absence of national MRLs, the Codex standards are used. The Association of Southeast Asian Nations (ASEAN) MRLs also adopted the Codex standards which are additionally referenced by governments of ASEAN countries.

Furthermore, the six pesticides detected in this study have half-lives of about one week or less (acetamiprid 5-6d; carbofuran 4-5d; chlorfenapyr 2-5d; cypermethrin 4-5d; fipronil 4-7d and chlorpyrifos 3-4d) (Fantke et al., 2014). These pesticides could therefore quickly evaporate or lost from the produce. This may have contributed to the low levels of the pesticides detected in this study. However, even if present at low concentrations, pesticides could accumulate in the human

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body and repeated exposure to low doses could lead to higher levels of the pesticide in the human body, causing chronic toxicity and health disorders such as cancers and organ failures. This is the case of fipronil which can accumulate in the human body, especially in fat tissue as it is a lipid-soluble insecticide that can be ingested or absorbed through the skin (Jackson et al., 2009). Acetamiprid, carbofuran, chlorfenapyr, cypermethrin and chlorpyrifos may present low risk because these pesticides are rapidly metabolized and excreted from the human body through the urine or feces (Wallace, 2014; Song, 2014; Wołejko et al., 2022).

3.2 Effect of time interval between pesticide application and harvest

Pesticide spraying in field-grown tomato resulted in detectable levels of acetamiprid, chlorfenapyr, cypermethrin and chlorpyrifos while carbofuran and fipronil were not detected (Table 2). This was sustained up to 14 days after spraying in Kandal and 7-10 days after spraying in Battambang. The residues of the four pesticides were expectedly highest after 1 day from spraying and decreased thereafter but the trend differeed with location. In Kandal, chlorphyrifos levels were very high (2.5039 mg/kg) after 1d from spraying and sharply decreased to 0.0145 mg/kg after 10-14 days from spraying which was way below the Codex MRL (0.5 mg/kg) but still higher than the EU MRL (0.01 mg/kg). Acetamiprid decreased slowly from about 0.8 mg/kg after 1 day from spraying to about 0.4 mg/kg after 14 days from spraying which was still higher than the Codex MRL (0.2 mg/kg) but lower than the EU MRL (0.5 mg/kg). Low levels of chlorfenapyr and cypermethrin were obtained after 1-14 days from spraying which were all lower than the Codex and EU MRLs, except for chlorfenapyr levels which were lower than the EU MRL only after 14 days from spraying. On the other hand, in Battambang, the residue levels for the four pesticides were all high after 1 day from spraying ranging from 1.48-2.46 mg/kg. Thereafter, the pesticide residue levels steeply decreased so that after 7-10 days from spraying, residue levels were lower than the Codex and EU MRLs. After 14 days from spraying, all pesticides were undetectable. In the nethouse, the plants were negative of pesticide residues except chlorpyrifos in Kandal and acetamiprid in Battambang. However, the amounts of pesticides residues from both locations were lower than the Codex and EU MRLs.

Table 2: Pesticide residues on tomatoes after 1-14 days from spraying in Kandal and Battambang provinces.

Province/ Pesticide	Pesticide level (mg/kg x 10^{-2})						MRL (mg/kg x 10^{-2})	
	Nethouse, no spray	Open-field (days from pesticide application)						
		1	3	7	10	14	Codex	EU
Kandal								
Acetamiprid	ND	80.02	73.42	66.04	59.67	42.62	20.0	50.0
Chlorfenapyr	<LOD	7.47	5.33	3.04	1.49	0.56	40.0	1.0
Cypermethrin	<LOD	15.31	4.00	10.12	7.15	2.92	20.0	50.0
Chlorpyrifos	0.80	250.39	143.38	88.54	1.45	1.45	50.0	1.0
Battambang								
Acetamiprid	0.76	246.07	79.93	3.66	0.76	ND	20.0	50.0
Chlorfenapyr	ND	160.08	56.45	6.82	0.89	ND	40.0	1.0
Cypermethrin	ND	171.61	31.55	6.99	2.16	ND	20.0	50.0
Chlorpyrifos	ND	148.48	31.52	0.86	ND	ND	50.0	1.0

Values are means $\pm$ SD of 3 replicates. Values are divided by 100 (shown as 10-2) to get the actual values.
ND-not detected; LOD-limit of detection-5 ppb
See additional notes in Table 1.

The results show that the longer the harvesting period after spraying, the more pesticides are lost from the fruit. According to the study of Bhatt et al (2019), pesticides were not immediately lost from tomatoes after 1 day from application, that is, the pesticides were attached to the fruit, stem or leaves. Acetamiprid and chlorpyrifos were also found to decrease faster than other compounds because they evaporate more easily, taking only 3 days after spraying (Kang et al., 2021). However, the results of the present study do not support this. Both pesticides had almost the same rate of loss as the other two pesticides, chlorfenapyr and cypermithrin, particularly in Battambang, probably because these four pesticides have almost the same half life (acetamiprid 5-6d; chlorfenapyr 2-5d; cypermethrin 4-5d; and chlorpyrifos 3-4d) (Fantke et al., 2014). Individually, cypermethrin when sprayed on tomatoes primarily remains on the plant surface and external tissues, degrading relatively quickly through processes like hydrolysis (breakdown by water) (FAO, 2007). Most of the residue dissipate within a few days due to factors like sunlight and rain, leaving minimal amounts absorbed into the fruit itself; the majority of the breakdown occurs on the plant external parts, not translocating deep into the tomato flesh. The acidity of tomatoes can accelerate the breakdown of cypermethrin through hydrolysis. Chlorfenapyr at the recommended dose in tomato as foliar application is reported to be safe from both environmental contamination and consumer safety standpoints because of its low persistence and has been found to be below detection limit after 9-14 days from application (Patra et al., 2018). Chlorpyrifos is a non-systemic broad-spectrum organophosphate insecticide which dissipate quickly by volatilization (Christensen et al., 2009). Acetamiprid when applied on tomatoes also quickly dissipated to below EU MRL after 5 days from application (Badawy et al., 2019). The dissipation rate gave a half life of 2.07 days

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which is shorter than that reported by Fantke et al (2014). Furthermore, Kandil et al (2011) revealed that all components of pesticides are reduced when exposed to direct sunlight; the longer the time of exposure to the sun, the more pesticide components are lost. This study was conducted in January with about 12 hours of sunlight and temperatures of 30-34ºC. In addition, tomatoes have a smooth surface, making it easy for pesticides to fall off from the fruit.

The results obtained in Kandal deviated from that in Battambang, particularly the gradual loss of acetamiprid and the low levels of chlorfenapyr and cypermethrin. Location of tomato production can impact the level of pesticide residues due to factors like climate, soil conditions, farming practices, cropping intensity and pest pressure (Elgueta et al., 2020).

Moreover, the study provided evidence for the benefits of protected cultivations as shown by the very low pesticide residues on nethouse-produced tomatoes. Trevizan et al (2005) also found that the amount of pesticide residues on tomatoes grown in nethouses was much lower than that of tomatoes grown in open field. Nethouses excluded various types of insects, such as leafhoppers, aphids and spider mites, and pesticide residues on tomatoes may come from the soil, water sources, or pesticide drift from neighboring field (Pavani et al., 2020).

3.3 Effect of postharvest washing

The seven pesticides being examined were present in uninoculated tomatoes and the residue levels were all higher than the Codex and EU MRLs, except profenofos and endusulfan (Table 3). The residue levels ranged from 0.101 mg/kg for dimethoate (Codex MRL-0.01 mg/kg) to 15.731 mg/kg for deltamethrin (Codex and EU MRLs-0.3 and 0.1 mg/kg, respectively) while that of profenofo and endusulfan were 8.635 and 0.046 mg/kg which were lower than the Codex MRL of 10 and and 0.5 mg/kg, respectively. After inoculating with the pesticides, the residue levels shoot up, ranging from 24.484 mg/kg for fenvalerate to 366.951 mg/kg for endosulfan. All washing treatments reduced the pesticide residue levels on tomatoes, except for profenofos treated with 2% salt. Washing with salt solution was less effective than running tap water in removing the pesticides, except for endusulfan which was reduced by more than 60% by either wash treatments. However, when the two washing treatments were combined (i.e. 2% salt washing followed by tap water washing), pesticide removal remarkably increased, ranging from about 70% for cypermethrin and deltamethrin to over 99% for dimethoate and endusulfan but the levels of all seven pesticides were still higher than the Codex and EU MRLs.

Applying 2% salt plus tap water washing on tomatoes harvested from Kandal and Battambang after 7 days from spraying, residues of cypermethrin, the only pesticide detected, decreased by about 60% in both locations (Table 4). Cypermethrin levels on washed tomatoes were about 0.041 mg/kg from Kandal and 0.027 mg/kg from Battambang, both were lower than the Codex and EU

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MRL of 0.2 and 0.5 mg/kg, respectively. Cypermethrin levels before washing were also lower than the Codex and EU MRLs.

Table 3: Residue levels on tomatoes after pesticide inoculation in response to different washing treatments.

Pesticide	Amount of pesticide residues (mg/kg)					MRL (mg/kg)	
	Without pesticide inoculation	With pesticide inoculation					
		No wash (control)	2% salt	Tap water	2% salt + tap water	Codex	EU
Dimethoate	0.101	34.858	31.612 (9.3%)	10.723 (69.2%)	0.093 (99.7%)	0.01	*
Profenofos	8.635	239.540	268.633 (-)	78.307 (67.3%)	12.732 ((94.7%)	10.0	*
Endosulfan	0.046	366.951	124.465 (66.1%)	142.351 (61.2%)	0.053 (99.99%)	0.5	*
Cyhalothrin	5.514	44.843	39.711 (11.4%)	21.706 (51.6%)	6.683 (85.1%)	0.3	*
Cypermethrin	12.482	69.133	37.467 (45.8%)	30.268 (56.2%)	21.813 (68.6%)	0.2	0.5
Fenvalerate	0.840	24.484	18.512 (24.4%)	11.325 (53.7%)	2.154 (91.2%)	0.03	0.01
Deltamethrin	15.731	40.702	30.717 (24.5%)	24.465 (39.9%)	12.125 (70.2%)	0.3	0.1

*EU MRL under review
Values are means of 3 replicates. Values in parentheses are percentage reduction relative to No Wash.

Table 4: Pesticide residues on tomatoes in Kandal and Battambang with or without 2% salt plus tap water washing.

Pesticide	Kandal			Battambang		
	Before washing (mg/kg)	Aftrer washing (mg/kg)	% Reduction	Before washing (mg/kg)	Aftrer washing (mg/kg)	% Reduction
Dimethoate	ND	ND	N/A	ND	ND	N/A
Profenofos	ND	ND	N/A	ND	ND	N/A
Endosulfan	ND	ND	N/A	ND	ND	N/A
Cyhalothrin	ND	ND	N/A	ND	ND	N/A
Cypermethrin	0.1019	0.0410	59.76	0.0699	0.0270	61.3
Fenvalerate	ND	ND	N/A	ND	ND	N/A
Deltamethrin	ND	ND	N/A	ND	ND	N/A

Values are means of 3 replicates. ND-not detected, N/A-not applicable

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Several studies have shown that postharvest washing can remove pesticide residues. Mahugija et al (2021) employed the common household washing in tap water on tomatoes which reduced residues of profenofos by 47%, endosulfan by 44%, cypermethrin by 70% and cyhalothrin by 57% while the other pesticides (chlorothalonil, pirimiphos methyl, chlorpyrifos and metalaxyl) decreased by 45-78%. Although household washing removed large amounts of pesticide residues, significant amounts of some pesticides remain and can pose health risks to the consumers. Earlier studies on tomato using different washing treatments including tap water washing obtained lower rates of reduction of pesticide residues of less than 50% (Ghani et al., 2010; Satpathy et al., 2012; Randhawa et al., 2014).

Pesticide residues usually accumulate on the surface of tomatoes. Running tap water could wash out the residues through the flow of water causing significant reduction of pesticides residues (Al-Taher et al., 2013). On the other hand, salt or sodium chloride (NaCl) has the ability to extract pesticides including fat-soluble compounds. Vemuri et al (2014) showed that salt water washing together with a water flow can reduce pesticide residues by 89%. These findings were corroborated by the results of the study of Islam et al (2022) which showed that salt water soaking and then rinsing with water was the most effective in reducing pesticide residues. These finding are further substantiated by the results of the present study.

Lately, ACTED (2025) reported that to reduce the risk of pesticide consumption associated with fresh vegetables including tomatoes in Cambodia, soaking for 20 minutes in water with 10% salt, followed by rinsing and 5-minute blanching in boiling water could remove more than 50% of each pesticide residue, though it was recommended to verify this in further studies. The present study shows that 2% salt is enough followed by rinsing or washing in running tap water. This could remove more than 50% up to 99.99% of pesticide residues.

4. CONCLUSION

Locally produced tomatoes had lower pesticide residues than imported tomatoes in both supermarkets and wet markets, supporting the perception that local tomatoes are safer than imported tomatoes. On field-grown tomatoes, pesticide residues were highest after 1 day from spraying and decreased thereafter but the trend differed with location and pesticide. In Kandal, all pesticides were lower than the Codex and EU MRLs after 14 days from spraying, except acetamiprid, while in Battambang, all pesticides were not detected after 14 days from spraying. Nethouse-grown tomatoes were negative of pesticide residues except chlorpyrifos in Kandal and acetamiprid in Battambang but both were lower than the Codex and EU MRLs. Removing pesticides on tomatoes inoculated with dimethoate, profenofos, endosulfan, cyhalothrin, cypermethrin, fenvalerate and deltamethrin was more effective with running tap water than 2% salt. When the two was combined (2% salt, then rinsing with tap water), the efficacy remarkably increased, removing about 68.60-99.99% of the pesticides. Applying this treatment on tomatoes produced in Kandal and Battambang resulted in 60% removal of cypermethrin, the only pesticide detected. From the results, it is recommended to harvest tomatoes 14 days after pesticide spraying and to wash the harvested fruits with combined 2% salt and tap water rinsing to reduce the pesticide residue problem.

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