PESTICIDE RESIDUE MANAGEMENT IN HARVESTED CAPSULES OF SMALL CARDAMOM, *Elettaria cardamomum* Maton.

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by

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THESIS

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2020

DECLARATION

I, hereby declare that this thesis entitled **"PESTICIDE RESIDUE MANAGEMENT IN HARVESTED CAPSULES OF SMALL CARDAMOM, *Elettaria cardamomum* Maton."** is a bonafide record of research work done by me during the course of research and the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

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CERTIFICATE

Certified that this thesis entitled **"PESTICIDE RESIDUE MANAGEMENT IN HARVESTED CAPSULES OF SMALL CARDAMOM, *Elettaria cardamomum* Maton."** is a record of research work done independently by Ms. Aparna Joseph under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to her.

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LIST OF ABBREVIATIONS AND SYMBOLS USED

%	Per cent
@	At the rate of
^0C	Degree Celsius
ANOVA	Analysis of Variance
BHC	Benzene hexachloride
CD	Critical Difference
CRM	Certified Reference Material
DDT	Dichloro Diphenyl Trichloroethane
DF	Dilution Factor
ECD	Electron Capture Detector
et al	And others
FPD	Flame Photometric Detector
GOK	Govt. of Kerala
G	Gram
GC- MS	Gas Chromatograph- Mass Spectrometry
HPLC	High Performance Liquid Chromatography

Kg	Kilogram
L^{-1}	Per Litre
LC- MS/MS	Liquid Chromatography- Mass spectroscopy
LOQ	Limit of quantification
Mg	Milligram
Ml	Millilitre
NaCl	Sodium chloride
$NaHCO_3$	Sodium bicarbonate
$NaCO_3$	Sodium carbonate
PAMSTEV	Production and Marketing of Safe to Eat Vegetables
QuEChERS	Quick, Easy, Cheap, Effective, Rugged and Safe
RSD	Relative Standard Deviation
SD	Standard Deviation
Sp.	Species
Viz	Namely

Introduction

1. INTRODUCTION

India has a prominent role in the production of spices around the world. Among this, small cardamom, “queen of spices” is an important export oriented spice which acts as a source of foreign exchange earnings to the country. India was the leading producer of cardamom before Guatemala took India’s supremacy as the top producer of small cardamom in the mid-eighties. Currently India is second in position for small cardamom production around the world. Kerala is the major state growing small cardamom in the country followed by Karnataka and Tamil Nadu with 78 per cent of the total production (Bagalkoti *et al*., 2019).

With the arrival of chemical pesticides the agriculture sector in our country expanded astonishingly. Farmers started practicing the use of pesticides in high quantities with a dire drive to protect the crop produce which resulted in multiple pesticide residues in the cured produce at unacceptable levels. Monocropping of cardamom in Western Ghats of South India for several years resulted in high incidence of different pest and diseases. Without the help of chemical pesticides it became impossible to control them, which led to the indiscriminate use of chemicals in cardamom field. Most of the cultivation of small cardamom in southern India involves high use of chemical pesticides to the extent of more than 15 rounds of pesticide application per season. Based on the number of rounds of chemical sprays and quantity of chemicals used, cardamom could be rated as the highest pesticide consuming rainfed crop in the world (Murukan *et al.,* 2011).

The data generated through monitoring studies of the Annual Plan Scheme “Production and Marketing of Safe to Eat Vegetables” funded by Department of Agricultural Development and Farmer’s Welfare, Government of Kerala revealed the over dependence and abuse of pesticides as evident from the range of chemically different pesticides like chlorpyriphos, quinalphos, profenophos, cypermethrin, lambda cyhalothrin, ethion and bifenthrin (GOK, 2019). Many importing countries have well developed facilities and technologies to check the residue level. Hence residue in imported material above the maximum level will lead to the rejection of the commodities and the farmers will not get their margin. In 2017, out of 448 total spice import detentions from all over the world by US Food and Drug Administration, 232 spice lots were from India, which was more than half (Sebastian and Praveen, 2019). Consumers are becoming increasingly quality conscious and every exporting country has its own food safety and health standards. To export cardamom, the producers must maintain the quality of capsules in agreement with that of exporting countries.

Of late, cardamom farmers are in a perturbed state due to the alarming situation in the near future in connection with the return of consignments from foreign countries. It is high time to standardize simple, cost effective and rugged methods in the management of pesticide residues in cardamom and strategies are to be explored to ensure safe food to the consumers and to lift up the financial status of the state. Though different decontamination studies have been reported in various agricultural commodities, studies related to decontamination of cardamom or any spices are scanty. Therefore it necessitates the assessment of simple, economically feasible commercial and household techniques in the management of pesticide residues in fresh and dry cardamom capsules. In consideration of the above facts, study entitled "Pesticide residue management in harvested capsules of small cardamom, *Elettaria cardamomum* Maton." was undertaken in Idukki district with the following objectives

- To document the pesticide use pattern in cardamom in Idukki district
- To evaluate the effect of different decontamination methods for the removal of pesticide residues from fresh and dry small cardamom capsules

Review of Literature

2. REVIEW OF LITERATURE

Small cardamom (*Elettaria cardamomum*) is known as the “Queen of Spices” which belongs to the family Zingiberaceae. It originated from the mountains of the south-western parts of the Indian Peninsula (Chempakam and Sindhu, 2008). Currently, India is the second largest producer and exporter of cardamom with share of 18.40 per cent in world’s cardamom export (Bagalkoti *et al*., 2019). The production of small cardamom is confined to the southern states mainly Kerala which accounts for 87 per cent of the area under small cardamom followed by seven per cent in Karnataka (Thomas *et al.,* 2019).

Incidence of pest and disease is the major reason for the low production and productivity of cardamom. Indiscriminate use of chemicals results in pesticide residues beyond tolerable limits, leading to rejection of many consignments of spices from India. With the strict regulations imposed by the EPA, cardamom capsules with pesticide residues as a contaminant have a chance of being rejected by the hitherto importing countries, which in turn would have a major say in foreign revenues (Kumar *et al.,* 2009; Bhardwaj *et al*., 2011). Since cardamom is an important export commodity in Kerala, the presence of pesticide residues should be below tolerance limit. Hence, decontamination of pesticide residue assumes significance in cardamom.

2.1 PESTICIDE RESIDUES IN SPICES

2.1.1 Cardamom

A study conducted by Sullivan (1980) reported the presence of organochlorine pesticides like DDT, BHC, dieldrin and endrin in cardamom samples imported to India. A monitoring study conducted by Nair *et al.* (2013) showed that the cardamom samples under study contained quinalphos residues above MRL fixed by FSSAI and the insecticides detected except quinalphos were not at all registered for use in cardamom. Chlorpyriphos, profenophos, ethion, lambda cyhalothrin, and bifentrin were the insecticides detected from cardamom samples.

A study conducted by Seena (2013) on pesticide residues in cardamom reported that 173 samples out of 180 samples analyzed, showed the presence of pesticide residues and quinalphos (121 samples) was the most common contaminant followed by lambda cyhalothrin, cypermethrin, chlorpyriphos and profenophos. Monitoring study conducted by Beevi *et al.* (2014) for two consecutive years reported that during the first year (2012) the most common pesticide residues detected from soils under cardamom cultivation was endosulfan sulphate (40%) followed by chlorpyriphos (32%), quinalphos (30%) and beta-endosulfan (30%). In second year (2013), quinalphos was the major contaminant (46%) followed by chlorpyriphos (42%), imidacloprid (28%), endosulfan sulphate (22%), profenophos (18%), p,p' -DDE (16%), bifenthrin (14%), ethion (6%), cypermethrin and indoxacarb (2% each).

Nair (2013) reported that all small cardamom samples collected from Thiruvananthapuram during January to June 2012 showed the presence of pesticide residues at different levels. Cypermethrin was found from all samples analyzed. In another study, cardamom samples were reported to be contaminated with chlorpyriphos (0.34 mg kg^{-1}), quinalphos (0.07-1.89 mg kg^{-1}), carbendazim (0.19 mg kg^{-1}), acetamiprid (0.08 mg kg^{-1}), cypermethrin (0.12-0.45 mg kg^{-1}), acephate (0.32 mg kg^{-1}), imidacloprid (0.28-0.50 mg kg^{-1}), metalaxyl (0.06 mg kg^{-1}), triazophos (5.15 mg kg^{-1}), lambda cyhalothrin (0.30 mg kg^{-1}) and malathion (0.19 mg kg^{-1}) (GOK, 2018).

The results of the studies on monitoring of pesticide residues in spices all over India revealed that, out of 1,242 samples analyzed, 681 (54.8%) were identified with pesticides residues and maximum number of MRL exceedance was found in the case of cardamom samples. Ethion, quinalphos, acetamiprid, triazophos, bifenthrin, imidacloprid, cypermethrin, chlorpyriphos, carbendazim and tebuconazole were the commonly detected pesticides from cardamom in India (CSS on MPR, 2019).

2.1.2 Mint leaves

Mint (*Mentha arvensis* L) is an aromatic perennial herb which is distributed mostly in the Northern hemisphere. Results of the project "PAMSTEV, Govt. of Kerala" revealed that mint leaves collected from various markets across Kerala showed the presence of pesticide residues. Chlorpyriphos (0.07-0.40 mg kg^{-1}), profenophos (0.19 mg kg^{-1}) imidachloprid (0.12 mg kg^{-1}), omethoate (0.07 mg kg^{-1}) and tebuconazole (0.20 mg kg^{-1}) were the pesticides detected (GOK, 2018; GOK, 2019).

2.1.3 Coriander leaves

A study conducted by Bhanot *et al*. (2002) revealed that methyl demeton, malathion, and fenvalerate were the pesticides commonly reported from coriander. From market samples of coriander leaves, ethion (1.44 mg kg^{-1}), fenvalerate (0.23 mg kg^{-1}), bifenthrin (6.27 mg kg^{-1}), quinaphos (4.39 mg kg^{-1}) and acetamiprid (0.06 mg kg^{-1}) were detected (GOK, 2018; GOK, 2019).

2.1.4 Chilli

The major pesticides detected from chilli included ethion, chlorpyriphos, phosphamidon, cypermethrin and fenvalerate (Awasthi *et al.,* 2001). From dried red chilli and chilli powder collected from Kerala, pesticides like profenophos (3.31mg kg^{-1}), bifenthrin (0.11 mg kg^{-1}), ethion (1.39-4.40 mg kg^{-1}), cypermethrin (0.07 mg kg^{-1}) and fenpropathrin (0.65 mg kg^{-1}) were obtained (GOK, 2018).

2.1.5 Cumin and fennel

The residues of chlorpyriphos, cyfluthrin, carbendazim, acetamiprid, clothianidin, imidacloprid, thiamethoxam and quinalphos were detected from cumin and fennel seeds bought from public markets (Chandran, 2019). Chlorpyriphos (1.04 mg kg^{-1}), cyfluthrin (0.19 mg kg^{-1}), carbendazim (0.30 mg kg^{-1}), acetamiprid (0.74mg kg^{-1}), chlothianidin (0.17 mg kg^{-1}), imidacloprid (0.98 mg kg^{-1}) and thiamethoxam (0.09 mg kg^{-1}) were the commonly detected insecticides in the cumin seeds got from Kerala. In the case of fennel, chlorpyriphos (0.23 mg kg^{-1}) and quinalphos (3.48 mg kg^{-1}) were detected (GOK, 2019).

2.1.6 Ginger

Only tebufenpyrad (0.40 mg kg^{-1}) was detected from the market sample of ginger (GOK, 2019).

2.1.7 Black pepper

No pesticides were detected from black pepper analyzed in Kerala. Quinalphos (1.3 mg kg^{-1}) was detected from black pepper from Karnataka (CSS ON MPR, 2019).

2.1.8 Ajwain

Malathion (0.55 mg kg^{-1}) and quinalphos (0.75 mg kg^{-1}) were the chemicals detected from ajwain, (GOK, 2019).

2.2 DECONTAMINATION OF PESTICIDE RESIDUES THROUGH DIFFERENT COMMERCIAL AND HOUSEHOLD PRACTICES

Different processing techniques at commercial and household levels could be used for decontamination of cardamom capsules. Several researchers and food processors have been taking interest in the extent of removal of various pesticides by different processing methods and it was observed that by processing or some household preparations like washing, cooking etc., pesticide residues in plant produce are reduced (Dikshit *et al*. 2003). The rate of dissipation and movement of pesticides depends mainly on its physicochemical parameters and surrounding environmental conditions (Bajwa and Sandhu, 2014).

2.2.1 Washing

Washing is the most easy and simple decontamination method done initially in household and commercial preparations. A fair quantity of loosely attached pesticides on the surface of agricultural commodities could be eliminated by different washing processes (Street, 1969). The extent of residue reduction by washing depends on the volatile nature of pesticide, solubility in water, hydrolysis rate constant and octanol-water partition coefficient (Kow), in association with the actual location of the residues (Tomer and Sangha, 2013).

Mathew *et al*. (1999) conducted a study and reported that, when fresh cardamom was washed rigorously with water, the initial deposit of mancozeb on capsules treated at the normal dose reached below maximum residue limit of 3 mg kg^{-1} on the third, day while in the higher dose it took 4 days. Washing of chilli in water accomplished a reduction of 58.86 per cent of spiromesifen residues (Varghese, 2011), while Yang *et al.* (2012), reported 100 per cent pesticide removal in ginger by washing.

Washing of okra fruits with normal water for 10 min resulted in reduction of 42.06 to 45.45, 26.32, 41.75, 50.28, 26.32 and 93.72 per cent for deltamethrin, alphamethrin, triazophos, ethion, cypermethrin and profenophos, respectively (Parmar *et al.*, 2012). A study conducted by Muralikrishna (2015) reported that 37.37 to 80.50 per cent of the initial residues of chorpyriphos, quinalphos, ethion, malathion, profenophos, dimethoate, bifenthrin and lambda cyhalothrin were reduced from amaranth by dipping in water for 10 minutes followed by washing for three times in water.

Rinsing fresh produce under tap water helps to reduce the levels of captan, malathion, permethrin, endosulphan, methoxychlor and chlorothalonil from different food crops (Krol *et al.*, 2000). Washing in running tap water removed 77 per cent organophosphate and 27 to 44 per cent synthetic pyrethroid residues from brinjal (Kumari, 2008). Different decontamination practices on removal of pesticide residues from spices and leafy spices are presented in Table 1.

2.2.2 Chemical solutions

Washing agricultural commodities in chemical solutions was found to be effective in decontamination than plain water (Krol *et al.*, 2000). A study conducted by Zohair (2001) reported that washing in acidic or alkaline solution was an effectual method for minimizing the pesticide residues. Acidic solution was more predominant in the elimination of the organophosphate pesticides than alkaline solutions (Kin and Huat, 2010).

A study conducted by Andrade *et al.* (2015) reported that washing with 10 % sodium bicarbonate and 10 % vinegar were more efficient in removing imidacloprid and thiamethoxam residues from tomatoes. The efficacious method for decontaminating organophosphate and synthetic pyrethroid insecticides from ginger was 2% tamarind solution and 2% common salt solution (Aaruni and Mathew, 2016). According to Rodrigues *et al.* (2017) washing in 5 % sodium bicarbonate solution removed 83 per cent of chlorothalonil residues from tomato.

Dipping chilli in 2 % salt solution, 2 % tamarind solution, 2 % vinegar solution, 1 % turmeric solution resulted in the removal of triazophos, fipronil and acephate (Kumar *et al*., 2000; Xavier *et al*., 2014). Dipping peppermint leaves in 2 % synthetic vinegar and 2 % turmeric followed by washing in water showed a noticeable removal of organophosphates (27.74 to 58.42 %) and synthetic pyrethroids (29.34 to 49.20%) residues (Aaruni, 2016).

Table 1. Decontamination practices on removal of pesticide residues from spices and leafy spices

Sl. No	Commodity	Type of treatments	Pesticides	Removal (%)	Reference
A. Washing					
1	Hot pepper	Washing in tap water	Profenophos	81.06	Radwan *et al.*, 2005
	Sweet pepper			85.16	
2	Coriander leaves	Dipping in tap water for five minutes followed by washing.	Dimethoate	38.30	Aaruni, 2016
			Quinalphos	40.20	
			Chlorpyriphos	61.24	
			Profenophos	45.42	
			Ethion	21.39	
3	Curry leaves	Dipped in water for 10 min, followed by washing with water	Dimethoate	26.01	Swarupa *et al.*, 2016
			Quinalphos	11.93	
			Imidacloprid	33.17	

B. Treatment with different chemical solutions					
4	Cumin	Dipping for five minutes in 2% commercial tamarind paste	Organophosphate	14.38-54.49	Aaruni, 2016
			Synthetic pyrethroids	14.27-36.17	
		Dipping in two per cent common salt for five minutes	Organophosphate	19.56-61.14	
			Synthetic pyrethroids	17.63-48.70	
		Dipping for five minutes in two per cent synthetic vinegar	Organophosphate	26.88-69.50	
			Synthetic pyrethroids	31.51-49.87	
		Dipping in KAU veggie wash (10 mL L^{-1}) for five minutes	Organophosphate	19.70-61.84	
			Synthetic pyrethroids	19.27-55.00	
5	Chilli	Soaking in 2% salt solution for 10 minutes	Phosalone	65.05	Raghu *et al.*, 2015
		Dipping in 0.1% baking soda ($NaHCO_3$) for 10 minutes		55.75	
		Soaking in 4% acetic acid solution for 10 min		67.87	
		Dipping in 10 % NaCl solution	Chlorantraniliprole	62.02	Ahlawat *et al.*, 2019

C. Cooking					
6	Capsicum	Boiling	Parathion	96.50	Satpathy *et al.*, 2012
			Methyl parathion	88.40	
			Malathion	93.90	
			Fenitrothion	100	
			Chlorpyriphos	97.60	
			Carbaryl	68.00	
7	Sweet pepper	Frying	Dicofol	100	EL-Saeid and Selim, 2016
			Dimethoate	62.00	
			Cypermethrin	100	

A study conducted by Varghese, (2011) reported that treating chilli in 2 % baking soda solution removed residues of propargite (86.25%), imidacloprid (83.75%), spiromesifen (79.41%) and ethion (48.90%). Vijayasree *et al.* (2014) studied the potency of washing with 2 % tamarind and 2 % common salt in minimizing the pesticide residues from cowpea. The results showed that, 83.50 and 75.98 per cent removal of spinosad residues was obtained when washed with tamarind and common salt respectively. A decontamination study conducted by Amir *et al.* (2019) in spinach by using different chemical solutions revealed that, from acidic solutions, acetic acid and from salt solution, sodium carbonate showed a greater reduction power in removing different pesticides.

A study conducted by Saini and Kumar (2016) used alum as a coagulant for the removal of two different organophosphorous pesticides *viz.,* methyl parathion and chlorpyriphos. They observed a removal of 77.50 and 79.00 per cent removal of methyl parathion and chlorpyriphos from waste water.

2.2.3 Cooking

The rate of degradation and volatilization of pesticide residues were increased by the heat involved in cooking and the rate of hydrolysis was increased by the addition of water (Amvrazi, 2011).

The methods and prerequisite used in cooking are wide-ranging. Temperature, time, moisture loss and whether the system is open or closed are the key factors that determine the residue levels (Holland *et al.,* 1994). In heating, the volatilization, hydrolysis and thermal degradation of pesticide residues occurs at elevated temperature which leads to its disappearance (Balinova *et al.,* 2006).

A study conducted by Lalah and Wandiga (2002) reported that, by cooking alone, 56.70 and 64.20 per cent malathion was removed from maize and bean respectively. The blanching process removed 98.06 per cent of the deposited profenophos, whereas frying almost completely removed its residues from sweet pepper (Radwan *et al.,* 2005). According to Chauhan *et al.* (2012) the per cent reduction of bifenthrin due to washing followed by boiling ranged from 36.44 to 42.10 and 38.04 to 45.23 at lower and higher doses under room conditions.

Yang *et al.* (2012) reported that by cooking alone entire pesticide content was removed (100 %) from ginger whereas Aaruni and Mathew, (2016) reported that a combination of peeling, washing and cooking was an effective method to efface pesticide residues of organophosphates (52.83 to 75.72 %) and synthetic pyrethroids (56.55 to 77.11%) from ginger.

Nagayama (1996) observed that residues of organophosphorous pesticides in spinach and strawberries were decreased on cooking. A complete removal of diazinon and malathion residues and 96 per cent removal of fenitrothion and quinalphos residues were observed in brinjal by dipping in 2% common salt solution for 15 minutes followed by washing under tap water plus cooking (Begum *et al.*, 2016). According to Ling *et al.* (2011) frying, boiling and microwave heating reduced chlorpyriphos residues in cabbage by 93.30, 55.00 and 60.30 per cent respectively. With boiling and microwave heating, chlorpyriphos residue in tomato was reduced by 75.90 and 67.20 per cent, respectively.

2.2.4 Decortication

Majority of the pesticides applied directly to crops go through a very limited movement in the body wall. As a result of that, residues of these chemicals are confined to the outer regions where they are biddable to removal in peeling, hulling or trimming operations (Kaushik *et al.*, 2009). The process of removal of outer cover of cardamom is called decortication. Decortication process had significant effect on the removal of pesticide residues as majority of the residues are present only in capsule cover.

Nair (2013) reported that chlorpyriphos (73.65-86.81%), quinalphos (71.00-94.00 %), profenophos (48.00-89.00 %), cypermethrin (86.00-99.00%) lambda-cyhalothrin (89.00-100 %), ethion (86.00%) and bifenthrin (66.00%) were removed through decortication.

Materials and Methods

3. MATERIALS AND METHODS

The study on "Pesticide residue management in harvested capsules of small cardamom, *Elettaria cardamomum* Maton" was carried out during 2018 to 2020. The field experiment was conducted at Cardamom Research Station, Pampadumpara. The main objectives were to document the pesticide use pattern in cardamom in Idukki district and to evaluate the effect of different decontamination methods for the removal of pesticide residues from fresh and dry small cardamom capsules. Cardamom samples for the pesticide residue analysis were collected from the experimental area and brought to the Pesticide Residue Research and Analytical Laboratory (PRRAL), AINP on Pesticide Residue, College of Agriculture, Vellayani. Samples were analyzed using Gas Chromatography (GC), Gas chromatography–mass spectrometry (GC-MS) and Liquid Chromatography- Tandem spectrometry (LCMS/MS).

3.1 DOCUMENTATION OF PESTICIDE USE PATTERN IN CARDAMOM

An elaborative survey was carried out to study the pesticide use pattern in the major cardamom growing areas in Idukki district during 2018-19. A desirable questionnaire was prepared to collect the data with respect to pesticide use pattern in cardamom growing areas. Twenty five cardamom farmers were interviewed to collect the details. Information on land holding, extent of irrigation, adoption of pest management strategies, major pesticides used, source of technical information, equipments used for application of pesticides, frequency of application, awareness about the presence of pesticide residues in cardamom, safety measures adopted, reason for non-adoption, health hazards experienced, disposal of containers and major pests were also recorded.

3.2 VALIDATION OF METHODS FOR PESTICIDE RESIDUE ANALYSIS IN SMALL CARDAMOM

Validation of Multi Residue Method (MRM) in cardamom was conducted by modified Standard Method "AOAC 18th edition 2007:2007.01". Validation parameters *viz*., Limit of Detection (LOD), Limit of Quantification (LOQ), Recovery and Repeatability (Zanella *et al*., 2000) were evaluated for pesticides selected for study (Table 2) under laboratory conditions at PRRAL, College of Agriculture, Vellayani.

Table 2. List of pesticides selected for the study

Sl. No.	**Pesticide**	**Trade name**	**Dosage /ha**	
			a.i. (g)	**Formulation (g or mL)**
1	Quinalphos	Ekalux 25 EC	125	500
2	Chlorpyriphos	Tagban 20EC	200	1000
3	Dimethoate	Tafgor 30EC	225	750
4	Ethion	Fosmite 50EC	750	1500
5	Profenophos	Kemcron 50EC	500	1000
6	Cypermethrin	Challenger 10 EC	75	750
7	Lambda cyhalothrin	Karate 5EC	15	300
8	Fenvalerate	Fenval 20EC	100	500
9	Imidacloprid	Confidor 17.8SL	26.7	150
10	Carbendazim	Bavistin 50WP	250	500

3.2.1 Chemical Reagents, Glassware and Equipments

The following glassware, chemical reagents and equipments were used for this study

Laboratory glasswares

1. Centrifuge tubes 15 mL and 50 mL
2. Beaker 100, 250, 500 mL
3. Turbovap tubes 20 and 30 mL
4. Graduated test tubes 10 and 20 mL.
5. Conical flask 250 mL
6. Micropipette 1 and 5 mL
7. Microsyringe 10 and 500 µL
8. Funnel 75 mm
9. Round bottom vacuum flask 500 mL

Chemical reagents

1. Acetonitrile HPLC grade
2. Acetone HPLC grade
3. Acetonitrile AR grade
4. Sodium chloride AR grade
5. Magnesium sulphate (hydrated) AR grade
6. Sodium sulphate AR grade (anhydrous)
7. Primary Secondary Amine (PSA)
8. n-Hexane HPLC grade
9. Florisil AR grade

Equipments

1. Electronic weighing balance
2. Blender
3. Homogenizer
4. Mechanical shaker

5. Laboratory centrifuge
6. Hot air oven
7. Vortex shaker
8. Turbovap LV
9. Gas Chromatograph – (Shimadzu GC 2010 A)
10. LC MS/MS

Entire glass wares were washed with water followed by 1% labolene and once again washed with tap water, distilled water and finally rinsed with distilled acetone. Then glassware were dried at room temperature and after drying were kept in hot air oven at 50° C for 3 h. Syringes were rinsed with acetone and n-hexane. Solvents were glass distilled before use. Sodium chloride, sodium sulphate, and magnesium chloride were activated in hot air oven at 45° C for 5 h.

3.2.2 Preparation of Standard Pesticide Mixture

Certified reference materials (CRM) of different pesticides *viz*., quinalphos, chlorpyriphos, dimethoate, ethion, profenophos, cypermethrin, lambda cyhalothrin, fenvalerate, imidacloprid and carbendazim with purity ranging from 95.10 to 99.99 per cent were purchased from M/s Sigma Aldrich (Table 3).

Table 3. Purity of Certified Reference Material (CRM) used in the preparation of pesticide mixture

Sl No	Pesticide group	Certified Reference Material	Purity %)
1	Organophosphates	Chlorpyriphos	99.90
		Dimethoate	98.20
		Ethion	97.80
		Profenophos	98.20

		Quinalphos	99.20
2	Synthetic pyrethroids	Cypermethrin	95.10
		Fenvalerate	98.70
		Lambda cyhalothrin	97.40
3	Organocarbamate	Carbendazim	98.69
4	Neonicotinoid	Imidacloprid	99.90

Stock solution (1000 mg kg^{-1}) of certified reference materials (CRM) of quinalphos, chlorpyriphos, dimethoate, ethion, profenophos, cypermethrin, lambda cyhalothrin, fenvalerate, was prepared by dissolving weighed quantity of analytical grade materials of the pesticides in a minimal amount of distilled acetone and diluted with n-hexane: toluene (1:1). From this primary stock solution, intermediate standards of 100 mg kg^{-1} of individual pesticide were prepared. Then separate working standard mixtures with a concentration level of 10 mg kg^{-1} were prepared. For that, aliquots of intermediate standards of each pesticide group were transferred to separate volumetric flask. Using n-hexane the final volume was made. Working standard mixture (10 mg kg^{-1}) containing ten different pesticides were made and it was then serially diluted to lower concentrations of 0.50, 0.25, 0.10, 0.075 and 0.05 mg kg^{-1}.

Stock solutions 1000 µg mL^{-1} of the insecticides *viz.*, imidacloprid and carbendazim were prepared by dissolving a weighed quantity of the analytical grade material in HPLC grade methanol. The stock solutions were serially diluted to prepare an intermediate stock of 100 µg mL^{-1}. The intermediate stock solutions were further diluted with HPLC grade methanol to prepare working standard mixtures of each insecticide for residue quantification using LC-MS/MS by positive electro spray ionization. The working standard mixtures were serially diluted to obtain 1.00, 0.50, 0.25, 0.10, 0.05, 0.01 and 0.005 µg ml^{-1} of analytical grade insecticides.

3.2.3 Standardization of Conditions of Gas Chromatograph (GC)

3.2.3.1 GC-ECD

Gas Chromatograph (Shimadzu 2010) equipped with ^{63}Ni Electron Capture Detector (ECD), fitted with DB-5 column (dimethyl polysiloxane, 30m X 0.25mm, 0.5µm film thickness) was used for the determination of residues of cypermethrin, lambda cyhalothrin and fenvalerate . The operating temperature at injection port was 250°C and at detector port it was 300°C. Oven temperature was set as 170°C for 10 minutes, raised at the rate of 1.5°C/ minutes to 220°C for 10 minutes and in the end, it was raised at the rate of 4°C/ minutes for seven minutes. Total program duration was fixed as 70 minutes. Split ratio of 1:10 was set in the auto sampler (Shimadzu ADL 20S) and auto injector (AOC 20i). The carrier gas used was ultra high pure nitrogen (99.99 %) with flow rate of 0.79 mL min^{-1} and linear velocity of 26.00 cm S^{-1}.

3.2.3.2 GC-FPD

Residue estimation of quinalphos, chlorpyriphos, dimethoate, ethion and profenophos was done with Gas chromatography equipped (Shimadzu 2010 AT) with Flame Photometric Detector (FPD). Target compounds were separated by using DB-5 capillary (30 × 0.25× 0.25 µm film thickness), column with nitrogen gas as carrier. Zero air and hydrogen were used for generating flame. Operating conditions of GC were column flow (1 mL min^{-1}), injector temperature (250º C), detector temperature (280ºC) and column oven temperature programmed between 170 to 270º C @3.5º C. The residues of insecticides were confirmed in GC-MS (Shimadzu GC- MS QP 2010 Plus). Helium was used as carrier gas in GC-MS operated with Electron Impact Ionization (70eV). In GC-MS, injector temperature, column, column flow was similar to that of GC. Simultaneous SIM/Scan mode was selected for the confirmation of quinalphos, chlorpyriphos, dimethoate, ethion and profenophos. The ions (m/z) selected for the confirmation of quinalphos were 146, 118, 157 and 156 and those for dimethoate were 87, 93, 125 and 63 (Table 4).

Table 4. The ions (m/z) selected for the confirmation of insecticides in GC- MS

Sl. No.	Insecticides	Selected ions (m/z)
1	Quinalphos	146, 118, 158, 157
2	Chlorpyriphos	314, 197, 199, 258
3	Dimethoate	87,93,125,63
4	Ethion	231, 97, 125, 153
5	Profenophos	339, 97, 139, 208
6	Cypermethrin	163, 181, 165, 209
7	Lambda Cyhalothrin	181, 197, 141, 208
8	Fenvalerate	167, 125, 225, 152

3.2.4 Standardization of Conditions of L C MS/MS

The chromatographic separation was achieved by using Waters Acquity UPLC system equipped with a reversed phase Atlantis d c- 18 (100x 2.1 mm, 5µm particle size) column. The gradient system including the following eluent compounds which was used as mobile phase for the separation of residues *viz.,* (A) 10% methanol in water + 0.1% formic acid+ 5 mM ammonium acetate and (B) 10% water in methanol+ 0.1% formic acid+ 5 mM ammonium acetate. The gradient elution was carried out as follows, 0 min isocratic 20% B, increased to 100% B in 9 min, decreased to the initial composition of 20% B in 10 min and held to 12 min for re-equilibration. The injection volume was 10 µl and the flow rate remained constant at 0.8 ml min^{-1}. The temperature of the column was maintained at 400^0C. From the LC system, effluent was introduced into triple quadrupole API 3200 MS/MS system equipped with an electro spray ionization interface (ESI), operating in the positive ion mode. The source parameters were temperature 600^0C, ion spray voltage 5,500 V, ion gas (GSI) 50 psi, ion gas (GS2) 60 psi and curtain gas 13 psi. The data on the information on Multiple Reaction Monitoring (MRM) of insecticides in LC MS/MS is presented in Table 5.

Table 5. Multiple Reaction Monitoring (MRM) of insecticides in LC MS/MS

Sl.No.	Insecticides	MRM transitions	
		Quantitative ion	Qualitative ion pair
1	Imidacloprid	256.10	209
			175
2	Carbendazim	192.10	160
			132

3.2.5 Determination of Limit of Detection (LOD)

Under set standard GC conditions two micro litre of each working standard (0.50, 0.10, 0.075, 0.05, 0.025 and 0.01 mg kg^{-1}) was injected in the Gas Chromatograph. Each standard was injected three times. LOD is the lowest concentration of pesticide that could be identified under standard GC conditions. Based on that, LOD of the instrument was calculated for each pesticide.

3.2.6 Determination of Limit of Quantification (LOQ)

Limit of Quantification (LOQ) is the lowest level fulfilling the method performance acceptability criteria (mean recoveries for each representative commodity in the range 70 - 120 %, with a RSD < 20 %).

3.2.7 Determination of Recovery and Repeatability

To know the proficiency of extraction and clean up procedures chosen for the study and to establish the reliability of the method, recovery studies were conducted.

3.2.7.1 Sample Processing of Cardamom

250 g of cardamom sample was blended into coarsely powdered form, from which a representative sample of 8 g was taken in 250 mL centrifuge bottle. To this sample, 40 mL distilled water was added. After mixing it well, it was kept for 10 min at room temperature. To this mixture, 40 ml acetonitrile was added and mixed. 5g NaCl was added to this mixture and shook for 20 minutes on a platform shaker at 200 rpm. The samples were centrifuged at 8000 rpm for 8 min at 8^{o}C and kept in a freezer at -18 ^{o}C for 20 minutes. From this, 16 ml supernatant was taken and moved to a 50 mL centrifuge tube carrying 8 g anhyd. Na_2SO_4. It was then vortexed for 30 seconds. From this, 12 mL supernatant was added to a 15 mL centrifuge tube holding 1.2 g anhy. $MgSO_4$ and 0.2 g Primary Secondary Amine (PSA). The mixture was again vortexed for 30 seconds and centrifuged (4500 rpm, 5 min, 8^{o}C). After that 3 mL and 2mL of the upper layer was added to 30 mL test tubes and with the help of turbovap (50^{o}C) solvent was evaporated for LC and GC-MS/MS analysis respectively. This was done by the constant flow of nitrogen using a nitrogen generator. The dry residue was reconstituted to 1 ml using n-hexane for Gas Chromatograph and 1.5 ml using methanol which was filtered through a 0.2 micron filter for LC analysis. Another 4 ml acetonitrile extract was evaporated to near dryness in TurboVap at 45^{o}C and

reconstituted to 1 ml with n-Hexane for GC-ECD/FPD analysis. These were then analyzed by GC-MS or GC-MS/MS and LC-MS/MS or LC-HRMS.

3.2.8.2 Residue Quantification and Recovery Calculation

The quantity of residue was determined based on the peak area of the chromatogram obtained for various pesticides

The residues were estimated using the formula,

Residues in substrate = Result from chromatogram (Concentration of the analyte obtained from the instrument including dilution factor)

or

$$\text{Residues in substrate} = \frac{\text{(Sample area x Std concentration x D.F)}}{\text{Standard area}}$$

$$\text{D.F = Dilution Factor} = \frac{\text{Volume of solvent taken for extraction x Volume made up (final)}}{\text{Sample weight x Volume of extract taken for final con.}}$$

$$\text{Percentage recovery (\%)} = \frac{\text{Concentration of pesticide residue obtained x 100}}{\text{Concentration of pesticide residue added}}$$

3.3 EFFECT OF DIFFERENT DECONTAMINATION PRACTICES ON THE REMOVAL OF PESTICIDE RESIDUES FROM FRESH CARDAMOM AT HARVEST

Organically grown uniform aged cardamom plants were selected from Cardamom Research Station, Pampadumpara, Kerala Agricultural University. The selected plants were uniformly treated with a mixture of ten pesticides (Table 2) which were selected on the basis of data obtained from documentation study. Capsules were harvested one week after spraying and were treated with different decontamination practices. The experiment was laid out in completely randomized block design (CRD) with four replications and an untreated control.

Following decontamination methods were assessed for their effectiveness in removing pesticide residues from cardamom:-

T1 – Washing the harvested cardamom capsules in water for three times and shaking for 10 minutes in 2% sodium carbonate solution followed by curing for 15 h

T2 - Washing the harvested cardamom capsules in water for three times and shaking for 10 minutes in 2% sodium bicarbonate solution followed by curing for 15 h

T3 - Washing the harvested cardamom capsules in water for three times and shaking for 10 minutes in 2% alum solution followed by curing for 15 h

T4 - Washing the harvested capsules in water for three times followed by curing for 15 h

T5 – Curing the harvested capsules for 15 h without washing.

The samples were homogenized by using a mixer grinder and 25g of each sample was taken from each replication for residue analysis. The analytical procedure for residue estimation was followed as described under section 3.2.7.1. The residues present in treated and untreated cardamom samples were estimated and the percentage of removal of residues was calculated.

The percentage of residue removal was calculated by using the following formula.

Percentage of residue removal =

$$\frac{\text{(Amount of residue in untreated sample – Amount of residue in treated sample) x100}}{\text{Amount of residue in untreated sample}}$$

3.4 ASSESSING THE EFFECT OF DIFFERENT HOUSEHOLD PRACTICES ON THE REMOVAL OF PESTICIDE RESIDUES IN DRY CARDAMOM CAPSULES

Cardamom samples were collected from the field as per the description in 3.3. The harvested samples were washed in water and subjected to curing for 15 hours. The cured samples were collected and treated with following household practices. The laboratory experiment was laid out in completely randomized block design (CRD) with three replications and an untreated control was maintained for comparison.

T1- Dipping for 10 minutes in 2% suspension of commercial tamarind paste followed by 3 washings in tap water and drying

T2 - Dipping for 10 minutes in 2% solution of common salt followed by 3 washings in tap water and drying

T3 - Dipping for 10 minutes in 2% synthetic vinegar followed by 3 washings in tap water and drying

T4- Decortication (Removal of outer covering of cardamom pods)

T5 - Washing capsule in water for three times + Cooking (closed pan) for 10 minutes

T6 - Dipping in KAU veggie wash at 10 mLL^{-1} for 5 minutes followed by 3 washings in tap water and drying

T7 - Washing in tap water three times and drying

T8- Untreated control

Samples were homogenized. 25g of each sample from three replications were collected and residue present in treated and untreated samples were estimated. The percentage removal of residues was calculated by using the formula as mentioned in 3.3

STATISTICAL ANALYSIS

The data on various parameters were analysed statistically by using Analysis of Variance technique (ANOVA) (Panse and Sukhatme, 1967) and significance was tested by 'F' test (Snedecor and Cochran, 1967). In the cases where effects were found to be significant, CD values were calculated at 5% and 1% probability levels.

Results

4. RESULTS

The results on the study “Pesticide residue management in harvested capsules of small cardamom, *Elettaria cardamomum* Maton are presented below under following headings.

4.1 DOCUMENTATION OF PESTICIDE USE PATTERN IN CARDAMOM

Results of survey on socio economic status, major pests, source of pesticides, cost for plant protection measures, source of technical information, equipments used for application of pesticides, major pesticides used, rate, time, frequency and method of application of pesticides in Idukki are presented below.

4.1.1 Socioeconomic Status of Farmers

Data on average size holdings of farmers are shown in Table 6**.** 36 per cent farmers were having an area of two to five acres of land and 29 per cent were having an area in between one to two acres. Farmers with area of less than one and more than five acres were 14 per cent each. Among the respondents, only seven per cent was having an area of more than ten acres. Regarding the extent of irrigation, 64 per cent farmers were giving irrigation while the rest grew cardamom as a rain fed crop.

4.1.2 Major Pest Management Strategies Followed in Idukki

To control the major pests in cardamom, 92 per cent farmers were using prophylactic application of pesticides. Eight per cent of respondents followed integrated pest management practices and none of them used biocontrol measures and botanicals (Table 7).

4.1.3 Pesticides Commonly Used

Details of commonly used pesticides are given in Table 8. Among different pesticides used, lion share was occupied by insecticides followed by fungicides. Insecticides belonging to organophosphate, synthetic pyrethroid and organocarbamate groups were the commonly used ones. Quinalphos (100%) was used by all the farmers in the field. Dimethoate (64%) chlorpyriphos (64%), profenophos (20%), ethion (20%) and monocrotophos (12%) were the organophosphorous pesticides used. Mostly used synthetic pyrethroid was lambda cyhalothrin (100%) followed by cypermethrin (60%), fenvalerate (36%) and bifenthrin (8%). In the case of organocarbamates, thiodicarb (12%) and carbosulfan (8 %) were the insecticides used. Imidacolprid (96 %) was the major new generation molecule adopted which was followed by thiamethoxam (24 %). In the case of fungicides, all farmers used bordeaux mixture. Other fungicides included copper oxy chloride (92%), carbendazim (80%), mancozeb (72 %) and fosetyl-Al (20%).

4.1.4 Information on Pesticide Use in Cardamom

The data on information on pesticide use in cardamom is presented in Table 9.

4.1.4 .1 Source of Technical Information

Forty per cent of farmers got technical information from pesticide dealers. Thirty per cent farmers relied on their own decisions for pest management. 20 per cent farmers depended on other progressive farmers, while ten per cent farmers got their information from Agricultural officers. However, nobody sought information from company representatives and media.

4.1.4 .2 Type of Sprayer Used

Among various sprayers used, power sprayer (80%) was used by majority of the farmers which was followed by motorized sprayer (20%). None of them used rocker sprayer for pesticide application

4.1.4 .3 Frequency of Pesticide Application

Most of the farmers applied pesticide at 20 to 30 days interval (80%). Ten per cent each applied pesticides at fortnightly intervals and forty days interval.

4.1.4 .5 Awareness Regarding the Adverse Health Effects of Pesticides

Thirty per cent farmers were very cognizant about the dreadful health effects of pesticides. 60 per cent of farmers were cautious with the adverse effects of pesticides to a certain extent, whereas 10 per cent of farmers were completely uneducated and ignorant about the deleterious effects of pesticides.

4.1.4 .6 Adoption of Safety Measures While Spraying

In the case of safety measures, 80 per cent farmers were using gloves as a safety measure during pesticide application. Mask was adopted by 10 per cent farmers. None of them were using boots during pesticide application and 10 per cent farmers were not using any safety measures.

4.1.4 .7 Reason for Non-Adoption of Safety Measures

The main reason for the non adoption of safety measures during pesticide application is due to the inconvenience (80%). Lack of awareness was the reason for ten per cent farmers, while another ten per cent farmers considered it as an additional cost.

4.1.4 .8 Adverse Health Hazards Experienced

The main health hazard experienced by farmers was dizziness and headache. Ninety per cent farmers experienced dizziness and headache. Ten per cent farmers experienced dermal diseases after the application of pesticides. None of them experienced any stomach pain and general weakness.

4.1.4 .9 Disposal of Pesticide Containers

After the use of pesticides ten per cent farmers discarded the empty containers in the field and sixty per cent farmers burnt the containers. Thirty per cent farmers buried the pesticide containers and no one depended drainage channels for disposal.

Table 6. Socio-economic status of the farmers in Idukki district

Holding size	Percentage of farmers
Below 1 acre	14.00
1-2 acres	29.00
2-5 acres	36.00
More than 5 acres	14.00
More than 10 acres	7.00
Extent of irrigation	
Irrigated	64.00
Rainfed	36.00

Table 7. Major pest management strategies followed in Idukki district

Pest management strategies	Percentage of farmers
Integrated Pest Management (IPM)	8.00
Prophylactic application of Pesticides	92.00
Biological control Measures	-
Use of botanicals	-

Table 8. Pesticides commonly used in the cardamom plantations in Idukki district

Pesticides used	**Percentage of farmers using pesticide**
Insecticides	
Organophosphates	
Quinalphos	100.00
Chlorpyriphos	64.00
Dimethoate	64.00
Profenophos	20.00
Ethion	20.00
Monocrotophos	12.00
Synthetic pyrethroids	
Cypermethrin	60.00
Lambdacyhalothrin	100.00
Fenvalerate	36.00
Bifenthrin	8.00
Carbamates	
Thiodicarb	12.00
Carbosulfan	8.00
New molecules	
Imidacloprid	96.00

Thiamethoxam	24.00
Fungicides	
Bordeaux mixture	100
Copper oxy chloride	92.00
Carbendazim	80.00
Mancozeb	72.00
Fosetyl	20.00

Table 9. Information on pesticide use in the cardamom plantations in Idukki district

Particulars	Percentage of farmers
Source of technical information	
Agriculture officers	10.00
Pesticide retailers/dealers	40.00
Company representatives	-
Other progressive farmers	20.00
Own decisions	30.00
Media	-
Type of sprayer used	
Power sprayer	80.00
Motorized sprayer	20.00
Rocker sprayer	-
Frequency of pesticide application	

Fortnightly interval	10.00
20-30 days interval	80.00
40 days interval	10.00
Awareness regarding the adverse health effects of pesticides	
Well Aware	30.00
Aware of some adverse effects	60.00
Totally ignorant	10.00
Adoption of safety measures while spraying	
Gloves	80.00
Mask	10.00
Boots	-
None	10.00
Reason for non-adoption of safety measures	
Lack of awareness	10.00
Inconvenience	80.00
Additional cost	10.00
Adverse health hazards experienced	
Dizziness and headache	90.00
Dermal disease	10.00
Stomach pain and general weakness	-
Disposal of pesticide containers	
Dumping in the field	10.00
Putting in drainage channels	-

Burning	60.00
Burying deep in soil	30.00

4.1.5 Major Pests in Cardamom

In cardamom, both chewing and sucking insect pests were observed (Table 10). The main sucking pests recorded were cardamom thrips *Sciothrips cardamomi* (Rank.) (Thripidae, Thysanoptera), lacewing bug *Stephanitis typicus* Dist. (Tingidae, Hemiptera), cardamom scale *Aulacaspis* sp. (Diaspididae, Hemiptera) and cowpea pod bug *Riptortus pedestris* Fabricius (Alydidae, Hemiptera).

The chewing pests recorded were shoot/capsule borer *Conogethes punctiferalis* Guen. (Pyralidae, Lepidoptera), cardamom root grub *Basilepta fulvicorne* (Jacoby) (Chrysomelidae, Coleoptera) and hairy caterpillar, *Eupterote* sp. (Eupterotidae , Lepidoptera) (plate 1, 2 and 3).

4.2 VALIDATION OF MULTI RESIDUE METHODS (MRM) FOR PESTICIDE RESIDUE ANALYSIS IN CARDAMOM

For pesticide residues analysis in cardamom, the formation of a multi residue method fulfilling the requirement of LOQ, LOD, Linearity, Recovery and Repeatability is indispensable. The results of the method validation studies of cardamom are presented below:

4.1.1 Determination Limit of Detection (LOD) ,Limit of Quantification (LOQ) and Linearity

The Limit of Detection (LOD) of 10 test pesticides was 0.01mg kg^{-1}. The Limit of Quantification (LOQ) of the analytical method for 10 pesticides was calculated as 0.05 mg kg^{-1} for GC and 0.01mg kg^{-1} for LC-MS/MS. Good linearity was found within the range of 0.01-1.0mg kg^{-1}.

Table 10. Details of pests observed in cardamom during documentation studies at Idukki

Types of pest	Particulars			
	Common name	Scientific name	Family: Order	Part of crop infested
Sucking pests	Cardamom thrips	*Sciothrips cardamomi* (Rank.)	Thripidae: Thysanoptera	Unopened leaves, leaf sheath, flower bracts and flower tubes
	Lacewing bug	*Stephanitis typicus* Dist.	Tingidae: Hemiptera	Leaves
	Cardamom scale	*Aulacaspis* sp.	Diaspididae: Hemiptera	Leaves,leaf sheath, panicles and fruit stalk.
	Cowpea pod bug	*Riptortus pedestris* F.	Alydidae: Hemiptera	Tender leaves
Chewing insects	Shoot/capsule borer	*Conogethes punctiferalis* Guen.	Pyralidae: Lepidoptera	Shoots, panicles, spikes and capsules
	Cardamom root grub	*Basilepta fulvicorne* (Jacoby)	Chrysomelidae: Coleoptera	Roots
	Hairy caterpillars	*Eupterote* sp.	Eupterotidae: Lepidoptera	Leaves

Cardamom capsules attacked by thrips

Aulacaspis sp.

Stephanitis typicus

Riptortus pedestris

Plate 1. Sucking pests recorded in cardamom

A) Caterpillar

B) Damage

C) Adult

Plate 2. Shoot/capsule borer of cardamom, *Conogethes punctiferalis*

Basilepta fulvicorne

Eupterote sp.

Plate 3. Chewing insect pests in cardamom

4.1.2 Determination of Recovery and Repeatability

The repeatability in terms of recovery percentage of the method was determined at four levels 0.05mg kg^{-1} (LOQ), 0.1 mg kg^{-1} (2 x LOQ), 0.25 mg kg^{-1} (5 x LOQ) and 0.5 mg kg^{-1}) (10 x LOQ) (Table 11).

At 0.05 mg kg^{-1} fortification level, the mean percentage recovery of pesticides were dimethoate (77.64 %), chlorpyriphos (90.00 %), quinalphos (101.48 %), profenophos (95. 87 %), ethion (111.32 %), lambda cyhalothrin (96.28 %), alpha cypermethrin (95.94 %), fenvalerate (94.21 %), imidacloprid (89.72 %) and carbendazim (92.00 %) with a relative standard deviation of 2.68 to 15.78

At 0.1 mg kg^{-1} level of fortification, the mean percentage recovery were dimethoate (75.57 %), chlorpyriphos (103.90 %), quinalphos (94.63 %), profenophos (115.88 %), ethion (111.87 %), lambda cyhalothrin (104.74 %), alpha cypermethrin (111.28 %), fenvalerate (89.77%) imidacloprid (93.90 per cent) and carbendazim (78.70 per cent) with a relative standard deviation of 2.08 to 15.31.

At 0.25 mg kg^{-1}, the mean percentage recovery were dimethoate (74.58 %), chlorpyriphos (87.01 %), quinalphos (118.86 %), profenophos (87.79%), ethion (97.35%), lambda cyhalothrin (85.18 %), alpha cypermethrin (96.18 %), fenvalerate (97.93%) imidacloprid (99.28 %) and carbendazim (84.96 %) with a relative standard deviation of 1.32 to 13.17.

At 0.5 mg kg^{-1} level of Fortification, the mean percentage recovery were dimethoate (107.50 %), chlorpyriphos (104.05 %), quinalphos (94.64 per cent), profenophos (105.71 %), ethion (110.72 per cent), lambda cyhalothrin (92.91 %), alpha cypermethrin (100.63 %), fenvalerate (75.25 %) imidacloprid (75.25 %) and carbendazim (80.20 %) with a relative standard deviation of 0.454 to 15.96.

Table 11. Recovery of pesticides in cardamom at different fortification level

Pesticides	Level of fortification							
	0.05mg kg^{-1} (LOQ)		0.1mg kg-1 (2xLOQ)		0.25 mg kg^{-1}(5xLOQ)		0.5mg kg^{-1} (10xLOQ)	
	Mean recovery (%) ± SD	RSD (%)	Mean recovery (%) ± SD	RSD (%)	Mean recovery (%) ± SD	RSD (%)	Mean recovery (%) ± SD	RSD (%)
Dimethoate	77.64±0.005	12.48	72.576±0.004	5.53	74.58±0.025	13.17	107.50±1.80	1.67
Chlorpyriphos	90.00±8.57	9.53	103.90±2.16	2.08	87.01±5.78	6.65	104.05±7.04	6.77
Quinalphos	101.48±0.004	7.55	94.63±0.006	5.95	118.86±0.027	9.13	94.64±0.076	15.96
Profenophos	95.87±0.003	6.83	115.88±0.004	3.43	87.79±7.78	8.72	105.71±0.072	13.70
Ethion	111.32±0.005	8.72	111.87±0.008	7.20	97.35±9.29	9.54	110.72±0.080	14.52
Lambda Cyhalothrin	96.28±0.007	15.11	104.74±0.016	15.31	85.18±1.12	1.32	92.91±4.07	4.38
Alpha Cypermethrin	95.94±7.63	7.95	111.28±0.007	6.38	96.18±1.61	1.67	100.63±2.64	2.62
Fenvalerate	94.21±0.007	15.78	89.77±0.012	12.98	97.93±9.97	10.18	99.12±3.18	3.21
Imidacloprid	89.72±0.003	5.71	93.90±0.004	4.51	99.28±0.004	1.78	75.25±0.002	0.45
Carbendazim	92.00±0.001	2.68	78.70±0.004	5.04	84.96±0.005	2.52	80.20±0.013	4.19

SD = Standard Deviation, RSD = Relative Standard Deviation, LOQ=Limit of Quantification (LOQ)

4.3 EFFECT OF DIFFERENT DECONTAMINATION PRACTICES ON THE REMOVAL OF PESTICIDE RESIDUES FROM FRESH CARDAMOM AT HARVEST

4.3.1 Effect of Different Decontamination Practices on the Removal of Organophosphate Insecticide Residues

The results of the effect of different decontamination practices on the removal of organophosphate insecticide residues are presented in Table 12

4.3.1.1 Dimethoate

The treatments, *viz.*, shaking in 2% sodium bicarbonate solution and 2% sodium carbonate solution for ten minutes showed notably appreciable percentage reduction of dimethoate residues, to the tune of 41.82 and 38.69 per cent respectively. Percentage reduction of residues observed in treatments like shaking in 2% alum solution after washing in water for three times (34.82 %) and washing in water for three times (34.77 %) were statistically on par.

4.3.1.2 Chlorpyriphos

Chlorpyriphos residues were reduced to a certain extent by the treatment solutions. The superior treatment was washing of cardamom capsules in water for three times followed by shaking in 2% sodium bicarbonate solution for ten minutes (58.04 %). Washing in water for three times followed by shaking in 2% sodium carbonate solution removed 38.78 per cent residues. Percentage removal of residues observed in treatments like shaking in 2% alum solution after washing in water for three times (23.77 %) and washing in water for three times (22.74 %) were statistically on par.

Table 12. Effect of decontamination practices on the extent of removal of organophosphate insecticides from fresh cardamom

Treatments	Dimethoate		Chlorpyriphos		Quinalphos	
	Residues in capsules after decontamination (mg kg^{-1})	Mean per cent removal of pesticides**	Residues in capsules after decontamination (mg kg^{-1})	Mean per cent removal of pesticides**	Residues in capsules after decontamination (mg kg^{-1})	Mean per cent removal of pesticides**
Sodium carbonate 2% *	3.38	38.69 (38.46)^{ab}	0.88	38.78 (38.50)^{b}	0.67	50.11 (45.06)^{b}
Sodium bicarbonate 2% *	3.21	41.82 (40.28)^{a}	0.60	58.04 (49.66)^{a}	0.12	90.701(77.27)^{a}
Alum 2% *	3.59	34.82 (36.11)^{b}	1.09	23.77 (29.17)^{c}	0.75	43.89 (41.49)^{b}
Washing *	3.6	34.77 (50.64)^{b}	1.11	22.47 (28.30)^{c}	1.21	9.7618.20)^{c}
Control	5.51	-	1.43	-	1.34	-
CD(0.05)	-	(3.377)	-	(2.926)	-	(10.300)

Treatments	Profenophos		Ethion	
	Residues in capsules after decontamination (mg kg^{-1})	Mean per cent removal of pesticides**	Residues in capsules after decontamination (mg kg^{-1})	Mean per cent removal of pesticides**
Sodium carbonate 2% *	5.14	50.97±3.25(45.55) [b]	9.78	41.35±4.82(39.99) [b]
Sodium bicarbonate 2% *	3.53	66.27±4.34(54.30) [a]	5.60	66.42±7.91(54.69) [a]
Alum 2% *	8.35	20.31±3.13(26.73) [d]	11.27	32.41±3.28(34.68) [c]
Washing *	7.73	26.25±2.62(30.80) [c]	11.42	31.55±5.83(34.10) [c]
Control	10.48	-	16.69	-
CD(0.05)	-	(2.917)	-	(4.704)

Values shown in parentheses are $\sin^{-1}\sqrt{x/100}$ transformed values

*Subjected to washing the harvested cardamom capsule in water for three times followed by shaking for 10 minutes in treatment solutions

** Mean of four replications

4.3.1.3 Quinalphos

Washing of cardamom capsules in water for three times followed by shaking in 2% sodium bicarbonate solution for ten minutes resulted in maximum removal of quinalphos residues (90.70 %). There was no significant difference in percentage removal of quinalphos residues when treated with 2% sodium carbonate solution (50.11%) and 2% alum solution (43.89%) for ten minutes after washing in water for three times. The treatment which gave the least removal was washing the cardamom capsules in water for three times (9.76 %).

4.3.1.4 Profenophos

All the treatments significantly differed in the elimination of profenophos residues from cardamom capsules. Among these the highest removal was observed while washing the cardamom capsules in water for three times followed by shaking in 2% sodium bicarbonate solution for ten minutes. It removed 66.27 per cent of residues. Next to this was washing in water for three times followed by shaking in 2% sodium carbonate solution for ten minutes, with a reduction of 50.97 per cent profenophos residues. 26.25 per cent residue was removed by shaking in 2% alum solution and by washing the cardamom capsules in water for three times alone removed 20.31 per cent profenophos residues.

4.3.1.5 Ethion

The decontamination technique effectually removed residues of ethion from 66.42 to 31.55 per cent. Washing in water for three times followed by shaking in 2% sodium bicarbonate solution for ten minutes showed highest removal (66.42 %). The next best treatment was shaking in

2% sodium carbonate solution for ten minutes (41.35 %). Washing in water for three times followed by shaking in 2% alum and washing in water for three times removed 32.41 and 31.55 respectively. These treatments were proved to show similarity in their effects.

4.3.2 Effect of Different Decontamination Practices on the Removal of Synthetic Pyrethroid Residues

The results on the effect of different decontamination practices on the removal of synthetic pyrethroid residues are presented in Table 13

4.3.2.1 Lambda cyhalothrin

For lambda cyhalothrin, washing in water for three times and shaking with 2% sodium bicarbonate solution for ten minutes (68.43 %) was the significantly superior treatment. The treatments *viz.*, shaking in 2% sodium carbonate solution and 2% alum solution for ten minutes after washing in water for three times reduced residues up to 47.77 and 37.53 per cent respectively. Only 3.98 per cent lambda cyhalothrin was removed by washing in water for three times.

4.3.2.2 Cypermethrin

Shaking in 2% sodium bicarbonate solution for ten minutes removed more than 60 per cent removal of cypermethrin residues. The treatments *viz.*, washing in water for three times followed by shaking with 2% sodium carbonate solution, 2% alum solution and washing in water for three times alone for ten minutes facilitated the removal of 26.77, 13.80 and 5.88 per cent residues of cypermethrin respectively. However, the percentage residue removal through these treatments was less compared to the first treatment.

Table 13. Effect of decontamination practices on the extend of removal of synthetic pyrethroid residues from fresh cardamom

Treatments	Lambda cyhalothrin		Cypermethrin		Fenvalerate	
	Residues in capsules after decontamination (mg kg^{-1})	Mean per cent removal of pesticides**	Residues in capsules after decontamination (mg kg^{-1})	Mean per cent removal of pesticides**	Residues in capsules after decontamination (mg kg^{-1})	Mean per cent removal of pesticides**
Sodium carbonate 2% *	0.65	47.77(43.70)[b]	1.26	26.77 (31.06)[b]	4.82	31.93 (34.40)[b]
Sodium bicarbonate 2% *	0.39	68.43(55.80)[a]	0.69	60.10 (50.84)[a]	2.76	60.92 (51.30)[a]
Alum 2% *	0.78	37.53(37.70)[c]	1.49	13.80 (20.60)[c]	6.01	15.10 (22.77)[c]
Washing*	1.20	3.98(11.30)[d]	1.63	5.88 (13.87)[d]	6.79	4.14 (11.05)[d]
Control	1.25	-	1.73	-	7.08	-
CD(0.05)	-	(2.965)	-	(6.099)	-	(3.907)

Values shown in parentheses are $\sin^{-1}\sqrt{x/100}$ transformed values

*Subjected to washing the harvested cardamom capsule in water for three times followed by shaking for 10 minutes in treatment solutions

** Mean of four replications

4.3.2.3 Fenvalerate

All the decontamination treatments differed in their power in reducing the residue load on cardamom capsules. Washing in water for three times followed by treating with 2% sodium bicarbonate solution for ten minutes was the finest treatment, which removed 60.92 per cent fenvalerate residues. This was followed by shaking in 2% sodium carbonate solution, 2% alum solution and washing in water for three times, which resulted in 31.93, 15.10 and 4.14 per cent reduction respectively.

4.3.3 Effect of Different Decontamination Practices on the Removal of Imidaclprid and Carbendazim Residues

The results on effect of different decontamination practices on the removal of imidaclprid and carbendazim residues are presented in Table 14

4.3.3.1 Imidacloprid

All the decontamination treatments removed imidacloprid residues from cardamom capsules to the tune of 14 to 32 per cent. Washing in water for three times followed by shaking with 2% sodium bicarbonate solution, 2% sodium carbonate solution, 2% alum solution and washing in water for three times alone were on par in their potency in removing the residues, to the tune of 30.83, 35.75, 14.58 and 26.54 per cent respectively.

4.3.3.2 Carbendazim

Considerable depletion of residue was recorded for the fresh cardamom sprayed with carbendazim from all treatments. The highest percentage of reduction was 65.15, which was obtained by washing the capsules in water

Table 14. Effect of decontamination practices on the extend of removal of neonicotinoid, imidacloprid and fungicide, carbendazim from fresh cardamom

Treatments	Imidacloprid		Carbendazim	
	Residues in capsules after decontamination (mg kg^{-1})	Mean per cent removal of pesticides**	Residues in capsules after decontamination (mg kg^{-1})	Mean per cent removal of pesticides**
Sodium carbonate 2% *	0.84	32.75±8.64(34.73)[a]	1.93	65.15 ±1.73(53.82)[a]
Sodium bicarbonate 2% *	0.87	30.83±24.30(32.58)[a]	2.41	56.55±5.63(48.78)[b]
Alum 2% *	1.07	14.58±8.39(21.52)[a]	2.51	54.70±2.05(47.70)[b]
Washing*	0.92	26.54±10.80(30.64)[a]	5.98	46.29±7.00(42.84)[c]
Control	1.26	-	5.55	-
CD(0.05)	-	(13.250)	-	(3.667)

Values shown in parentheses are $\sin^{-1}\sqrt{x/100}$ transformed values

*Subjected to washing the harvested cardamom capsule in water for three times followed by shaking for 10 minutes in treatment solutions

** Mean of four replications

for three times followed by shaking in 2% sodium carbonate solution for ten minutes. This was followed by shaking in 2% sodium bicarbonate solution and 2% alum solution which removed 56.55 and 54.70 per cent of the residues respectively. These two treatments were proved to be equivalent to each other. Percentage removal of residues in case of washing in water for three times was 46.29 per cent

4.4 EFFECT OF DIFFERENT HOUSEHOLD PRACTICES ON THE REMOVAL OF PESTICIDE RESIDUES IN DRY CARDAMOM CAPSULES

The effect of different household practices in removing the residues of different pesticides from dry cardamom capsules was studied and the percentage removal of residues in each treatment is presented below.

4.4.1 Effect of Different household practices on the removal of Organophosphate Insecticide Residues

The results are presented in the Table 15

4.4.1.1 ***Dimethoate***

More than 30 per cent residue of dimethoate was removed by washing in water for three times followed by cooking in a closed pan for 10 minutes (37.95 %) and decortication (32.75 %). These two treatments proved to be statistically on par. Dipping the capsules in 2% tamarind solution, 2% common salt solution and 2% synthetic vinegar solution eliminated the residues up to 8.90, 5.98 and 3.23 per cent only respectively. All these treatments were on a level in their effect. There was no change in the residue level of dimethoate when treated in KAU veggie wash.

4.4.1.2 *Chlorpyriphos*

Decortication by removing outer covering of cardamom capsules and cooking (closed pan) after washing in tap water for three times led to a removal of 42.00 and 36.09 per cent chlorpyriphos residues respectively. These were the foremost treatments for reducing chlorpyriphos residues. The next best treatment was dipping in 2% synthetic vinegar solution (29.54 %). Other decontamination treatments like 2%tamarind solution and 2%salt solution reduced 18.28, and 18.1 per cent of residues respectively. Dipping in KAU Veggie wash (10 mL L^{-1}) got rid of only 3.88 per cent residues of chlorpyriphos. Simple tap water washing for three times didn't remove any chlorpyriphos residues.

4.4.1.3 *Quinalphos*

Complete removal of quinalphos was observed in cardamom capsules subjected to decortication. Dipping of cardamom capsules in 2% synthetic vinegar solution recorded a removal of 35.67 per cent residues. Other decontamination treatments like 2% tamarind solution, 2% salt solution and cooking in a closed pan decreased residues at the rate of 22.73, 24.79 and 24.83 per cent respectively. There was no removal observed in the case of treatment with KAU Veggie wash (10 mL L^{-1}) and water.

4.4.1.4 *Profenophos*

With 76.22 per cent removal of residues decortication became the topmost treatment. The next best treatment was washing plus cooking in a closed pan. It gave a result of 33.92 per cent reduction in residues.

Table 15. Effect of decontamination practices on the extent of removal of residues of organophosphate insecticides from dry cardamom

Treatments	Dimethoate		Chlorpyriphos		Quinalphos	
	Residues in capsules after decontamination (mg kg^{-1})	Mean per cent removal of pesticides**	Residues in capsules after decontamination (mg kg^{-1})	Mean per cent removal of pesticides**	Residues in capsules after decontamination (mg kg^{-1})	Mean per cent removal of pesticides**
Tamarind 2%*	3.74	8.90(15.82) [b]	0.84	18.28 (25.31) [b]	0.76	22.73(28.14) [c]
Salt 2%*	3.86	5.98(13.65) [b]	0.85	18.10 (24.81) [b]	0.74	24.79(29.79) [c]
synthetic vinegar 2%*	3.98	3.23(10.35) [b]	0.73	29.54 (32.91) [ab]	0.63	35.67(36.66) [b]
Decortication*	2.76	32.75 (34.81) [a]	0.60	42.00 (40.43) [a]	00	100(89.41) [a]
Washing+cooking*	2.55	37.95 (37.99) [a]	0.66	36.09 (36.90) [a]	0.74	24.83(29.78) [c]
KAU Veggie wash*	4.11	00(0.58) [c]	0.99	3.88 (7.03) [c]	0.98	00(0.58) [d]
Washing*	4.11	00(0.58) [c]	1.03	00(0.58) [c]	0.98	00(0.58) [d]
Control	4.11	-	1.03	-	0.98	-
CD(0.05)	-	(7.381)	-	(8.148)	-	(5.079)

Treatments	Profenophos		Ethion	
	Residues in capsules after decontamination (mg kg^{-1})	Mean per cent removal of pesticides**	Residues in capsules after decontamination (mg kg^{-1})	Mean per cent removal of pesticides**
Tamarind 2%*	7.68	13.17(19) ^{d}	11.23	22.05 (27.19) ^{c}
Salt 2%*	7.05	20.32(26.79) ^{cd}	10.06	30.15 (33.04) ^{c}
synthetic vinegar 2%*	6.08	31.24(33.98) ^{bc}	7.99	44.55 (41.87) ^{b}
Decortication*	2.10	76.22 (60.87) ^{a}	1.82	87.31 (69.17) ^{a}
Washing+cooking*	5.84	33.92 (35.60) ^{b}	6.81	52.69 (46.54) ^{b}
KAU Veggie wash*	8.85	00(0.58) ^{e}	14.41	00(0.58) ^{d}
Washing*	8.85	00(0.58) ^{e}	14.41	00(0.58) ^{d}
Control	8.85	-	14.41	-
CD(0.05)	-	(8.009)	-	(7.374)

Values shown in parentheses are $\sin^{-1}\sqrt{x/100}$ transformed values

* Subjected to dipping in treatment solutions for ten minutes followed by three normal washings

** Mean of three replications

All other treatments like dipping in 2% tamarind, 2% common salt and 2% synthetic vinegar eliminated residues at the rate of 13.17, 20.23 and 33.92 per cent respectively. The treatments, KAU Veggie wash (10 mL L^{-1}) and washing in water were failed to remove any profenophos residues.

4.4.1.5 *Ethion*

The best method for removing chlorpyriphos residue was decortication (87.31 %). Dipping the capsules in 2% synthetic vinegar solution (44.55 %) and washing followed by cooking (52.69 %) were analogous in their efficacy in lowering the residues. Similarly, when the capsules were treated with 2%tamarind solution and 2%common salt solution, ethion content was reduced to 22.05 and 30.15 per cent respectively. There was no change in the residues of ethion when dipped in KAU veggie wash 10 mLL^{-1} for five minutes and washing in water for three times.

4.4.2 Effect of Different household practices on the removal of Synthetic Pyrethroid Insecticide Residues

The results are presented in the Table 16

4.4.2.1 *Lambda cyhalothrin*

Decortication of cardamom capsules (100 %) was the promising treatment in decontaminating lambda cyhalothrin residues. Dipping the capsules in 2% synthetic vinegar solution (25.49 %) and washing followed by cooking (29.99 %) showed similar effects in removing the residues. The treatments *viz.*, 2% tamarind solution and 2% salt solution facilitated the loss of 10.91 and 11.51 per cent residues respectively. For the decontamination of lambda cyhalothrin, KAU veggie wash (10 mL L^{-1}) and washing were found to be non functional.

Table 16. Effect of decontamination practices on the extent of removal of residues of synthetic pyrethroid insecticides from dry cardamom

Treatments	Lambda cyhalothrin		Cypermethrin		Fenvalerate	
	Residues in capsules after decontamination (mg kg^{-1})	Mean per cent removal of pesticides**	Residues in capsules after decontamination (mg kg^{-1})	Mean per cent removal of pesticides**	Residues in capsules after decontamination (mg kg^{-1})	Mean per cent removal of pesticides**
Tamarind 2%*	0.76	10.91 (19.14) [c]	1.19	14.7 (22.49) [cd]	4.49	30.98 (33.82) [b]
Salt 2%*	0.75	11.53 (18.97) [c]	1.20	13.99 (20.34) [d]	4.83	25.66 (30.21) [b]
synthetic vinegar 2%*	0.63	25.49 (30.32) [b]	0.96	30.66 (33.62) [b]	4.09	37.12 (37.48) [b]
Decortication*	00	100 (89.41) [a]	00	100 (89.41) [a]	0.23	96.41 (79.13) [a]
Washing+cooking *	0.59	29.99 (33.17) [b]	1.07	23.41 (28.93) [bc]	4.30	33.87 (35.59) [b]
KAU Veggie wash*	0.85	00 (0.58) [d]	1.39	0.01 (0.78) [e]	6.10	6.14 (11.95) [c]
Washing*	0.85	00 (0.58) [d]	1.39	00 (0.58) [e]	6.50	00 (0.58) [d]
Control	0.85	-	1.39	-	6.50	-
CD(0.05)	-	(5.299)	-	(6.840)	-	(7.480)

Values shown in parentheses are $\sin^{-1}\sqrt{x/100}$ transformed values

* Subjected to dipping in treatment solutions for ten minutes followed by three normal washings

** Mean of three replications

4.4.2.2 *Cypermethrin*

The effectual treatment for discarding cypermethrin residues was decortication (100 %) which includes the removal of outer cover of cardamom capsules. The next best treatments were 2% synthetic vinegar solution (30.66 %) and washing plus cooking in closed pan (23.41 %). The percentage removal of cypermethrin residues from cardamom capsules when dipped in 2% each tamarind solution and salt solution for ten minutes were 14.70 and 13.99 per cent respectively. Only 0.01 per cent was removed by KAU veggie wash 10 mL L^{-1} which was comparable with washing in water for three times (0 %).

4.4.2.3 *Fenvalerate*

The treatment which showed significantly higher reduction of residues was decortication (96.41 %). Treatments *viz.*, dipping in 2% tamarind solution (30.98 %), 2% common salt solution (25.66 %), 2% synthetic vinegar solution (37.12%) and cooking in a closed pan (33.87%) gave comparatively lower percentage reduction of fenvalerate. Treatment with KAU veggie wash 10 mL L^{-1} gave only 6.14 per cent reduction and in the case of washing in water thrice, no change was seen.

4.4.3 Effect of Different Decontamination Practices on the removal of Neonicotinoid, Imidacloprid and Fungicide, Carbendazim

The results are presented in the Table 17

4.4.3.1 *Imidacloprid*

The extent of removal of imidacloprid residues from dry cardamom capsules by decortication was 71.14 per cent. Dipping in 2% common salt solution resulted in 40.67 per cent removal and in the case of washing plus

Table 17. Effect of decontamination practices on the extent of removal of residues of neonicotinoid, imidacloprid and fungicide, carbendazim from dry cardamom

Treatments	Imidacloprid		Carbendazim	
	Residues in capsules after decontamination (mg kg^{-1})	Mean per cent removal of pesticides**	Residues in capsules after decontamination (mg kg^{-1})	Mean per cent removal of pesticides**
Tamarind 2%*	1.26	9.90 (17.25) [c]	3.79	47.88 (43.78) [cd]
Salt 2%*	0.83	40.67 (39.58) [b]	3.57	51.00 (45.57) [c]
synthetic vinegar 2%*	1.14	18.441(25.35) [c]	4.19	42.44 (40.64) [d]
Decortication*	0.40	71.14 (57.50) [a]	2.12	70.90 (57.35) [b]
Washing+cooking*	0.83	40.27 (39.26) [b]	1.47	79.77 (63.28) [a]
KAU Veggie wash*	1.29	11.19 (15.99) [c]	5.39	26.02 (30.63) [e]
Washing*	1.07	23.37 (28.30) [bc]	5.41	25.65 (30.41) [e]
Control	1.40	-	7.28	-
CD(0.05)	-	(12.610)	-	(4.224)

Values shown in parentheses are $\sin^{-1}\sqrt{x/100}$ transformed values

* Subjected to dipping in treatment solutions for ten minutes followed by three normal washings

** Mean of three replications

cooking in a closed pan it was 40.27 per cent. These treatments were statistically on par. A considerable decrease in residue was observed for all decontaminating treatments except2% synthetic vinegar solution (18.44 %) , 2% tamarind solution (9.90 %) and KAU Veggie wash 10 mL L^{-1} (11.19 %) when compared with washing in water for three times (23.37 %).

4.4.3.2 *Carbendazim*

Washing in tap water for three times followed by cooking and decortication reduced more than 70 per cent of carbendazim residues. The next leading treatment was 2% common salt solution (51 %) followed by 2% tamarind solution (47.88 per cent) and 2% synthetic vinegar solution (42.44 %). However, the percentage residue removal by treatment with KAU Veggie wash 10 mL L^{-1} (26.02 %) and water (25.65 %) were less compared to other treatments.

Discussion

5. DISCUSSION

Small cardamom is one of the highly prized spices of the world after saffron and vanilla. India is the second largest producer of cardamom and Indian cardamom is considered a superior quality in the international markets (Chempakam and Sindhu, 2008). Cardamom like other spices is vulnerable to damage by a wide variety of insect pests and diseases. In a desperate bid to control them, farmers resort to frequent application of pesticides either as foliar or soil treatment at 15-20 days interval (Nath and George, 2013).

Residues in cardamom have been reported by various researchers in India (Chozhan and Regupathy, 1989; Kathpal and Kumari, 1993; Singhal, 2000; Shetty, 2006; Nair *et al.* 2013; Nair 2013; Seena 2013). Use of chemicals was promiscuous which resulted in pesticide residues far from acceptable limits and became a reason for the rejection of spices from India (Bharadwaj *et al.*, 2011). After the formation of WTO, the presence of residues above the permissible level is also a major bottleneck in the acceptance of food commodities by the importing countries under WTO agreement on the application of sanitary and phytosanitary measures (SPS agreement). Adoption of Good Agricultural Practices (GAP) for raising cardamom is a viable method for the management of pest; however, quick implementation is not feasible since it affect the production badly. In the meanwhile, decontamination techniques could be developed to remove pesticide residues from fresh and dry cardamom before export or domestic use

Studies on the deletion of residues from cardamom are very less compared to other agricultural commodities. Thus the present study entitled "Management of pesticide residues in small cardamom, *Elettaria cardamomum* Maton was undertaken to standardize various commercial and household techniques to remove residues from cardamom. The results obtained are discussed here under.

5.1 DOCUMENTATION OF PESTICIDE USE PATTERN IN CARDAMOM

Twenty five farmers were chosen randomly from different regions of Idukki district. A thorough survey was carried out with the help of a questionnaire.

Data on the landholding size of respondents shows that 36 per cent farmers having an area of two to five acres, 29 per cent own one to two acres, and 14 per cent each have less than one and more than five acres of land whereas seven per cent possessed more than 10 acres of land. Among these farmers, 64 per cent were adopting irrigation practices in cardamom while the rest grew cardamom as a rainfed crop. Non adoption of irrigation is mainly due to the inability to afford the high cost of equipments.

Out of the 25 farmers interviewed 92 per cent practiced prophylactic spraying of pesticides rather than the curative measures. Since cardamom is cultivated in Idukki for several years continuously the chances of pest outbreak is very high, which is the reason why farmers are following prophylactic spraying of pesticides. Only eight per cent of farmers practiced integrated pest management practices and none of them used biocontrol measures and botanicals. Farmers expected a sudden control of pests and diseases which led to the adoption of chemicals rather than biocontrol and botanicals.

Organophosphates, synthetic pyrethroids and carbamates were the commonly used groups to control different pests. Among organophosphates, quinalphos, dimethoate, chlorpyriphos, profenophos, ethion, monocrotophos were the commonly used ones. They used synthetic pyrethroids like lambda cyhalothrin, cypermethrin, fenvalerate and bifenthrin. Thiodicarb and carbosulfan were the carbamate group pesticide used. Imidacolprid and thiamethoxam were the most widely used new generation molecule. To control different diseases, the farmers used fungicide mainly bordeaux mixture, copper oxy chloride, carbendazim, mancozeb and fosetyl-Al. Even though several green labeled new generation molecules are available in the market farmers tend to rely on the older ones since they are unaware of their availability and effectiveness. The low dosage and high cost of newer molecules act as another barrier for their non adoption. Most of the respondents are not ready for a change in the use of chemicals which they have been practicing for several years. In severe infestation to get a good result, the farmers were found to have been mixing more than one pesticides either with same mode of action or different. This method may produce a more dangerous mix, since mixing of pesticides modify the chemical properties which eventually lead to potentiation and thereby increase detrimental effects (Salameh *et al.* 2004).

The study has revealed that majority of the farmers collect technical information from pesticide dealers rather than agricultural officers. 80 per cent farmers utilize the power sprayer and the rest depended upon motorized sprayer for the pesticide spraying. Within short period of time, the farmers were able to complete the pesticide application by using power sprayer. Pesticides were applied in 30 days interval by 80 per cent of the farmers regardless of the infestation. Ten per cent each applied pesticides at fortnightly intervals and forty days interval. Majority of the farmers (60 %) knew the adverse effects of pesticides to certain extent. As regards use of safety measures while spraying, 80 per cent farmers were using gloves as a safety measure during pesticide application. Mask was adopted by 10 per cent farmers and 10 per cent farmers were not using any safety measures. The main reason for the non adoption of safety measures during pesticide application is due to the inconvenience which agrees with that of Kesavachandran *et al.* (2009). Expenditure incurred and the difficulty in wearing protective measures was the reasons given for not using such devices.

Dizziness and headache was experienced by 90 per cent of respondents during pesticide application and ten per cent farmers experienced dermal diseases after the application of pesticides. Similar studies done by Seena (2013), explains that headache and dizziness were the main health hazard faced by majority (60 %) of the respondents in Idukki.

From the survey, it was clear that both chewing and sucking pests infested cardamom. The main sucking pests observed were cardamom thrips *Sciothrips cardamomi*, lacewing bug *Stephanitis typicus*, cardamom scale *Aulacaspis* sp. and cowpea pod bug *Riptortus pedestris.* The chewing insect pests recorded were shoot/capsule borer *Conogethes punctiferalis*, hairy caterpillars *Eupterote* spp. and cardamom root grub *Basilepta fulvicorne*. The results are in agreement with the findings of Narasimham (1987), Thomas (2001) and Sathyan *et al.* (2017).

5.2 VALIDATION OF MULTI RESIDUE METHODS (MRM) FOR PESTICIDE RESIDUE ANALYSIS IN CARDAMOM

In the present study, a multi-residue analytical method was validated for the analysis of residues of different pesticides in cardamom capsules. Limit of Detection, Limit of Quantification, Linearity, Recovery and Repeatability were taken as the method satisfying requirements. The mean percentage recovery ranged from 72.57 to 118.86 per cent and it remained within the internationally accepted range of 70 to 120 per cent . In the case of Relative Standard .Deviation (RSD) for all pesticides it was less than 20 per cent. This agreed with the results of Aaruni (2016) with 74.75 to 117.33 mean percentage recovery for the chemicals evaluated and it confined within the acceptable range. It showed that, the method adopted was sufficiently reliable for pesticide residue analysis in cardamom.

5.3 EFFECT OF DIFFERENT DECONTAMINATION PRACTICES ON THE REMOVAL OF PESTICIDE RESIDUES FROM FRESH CARDAMOM AT HARVEST

Based on the percentage removal, a significant reduction of pesticides was observed from fresh cardamom by using different washing solutions. The result indicated that 2% sodium bicarbonate solution, 2% sodium carbonate solution showed significant effect in reducing all the pesticides when compared to 2% alum solution and water.

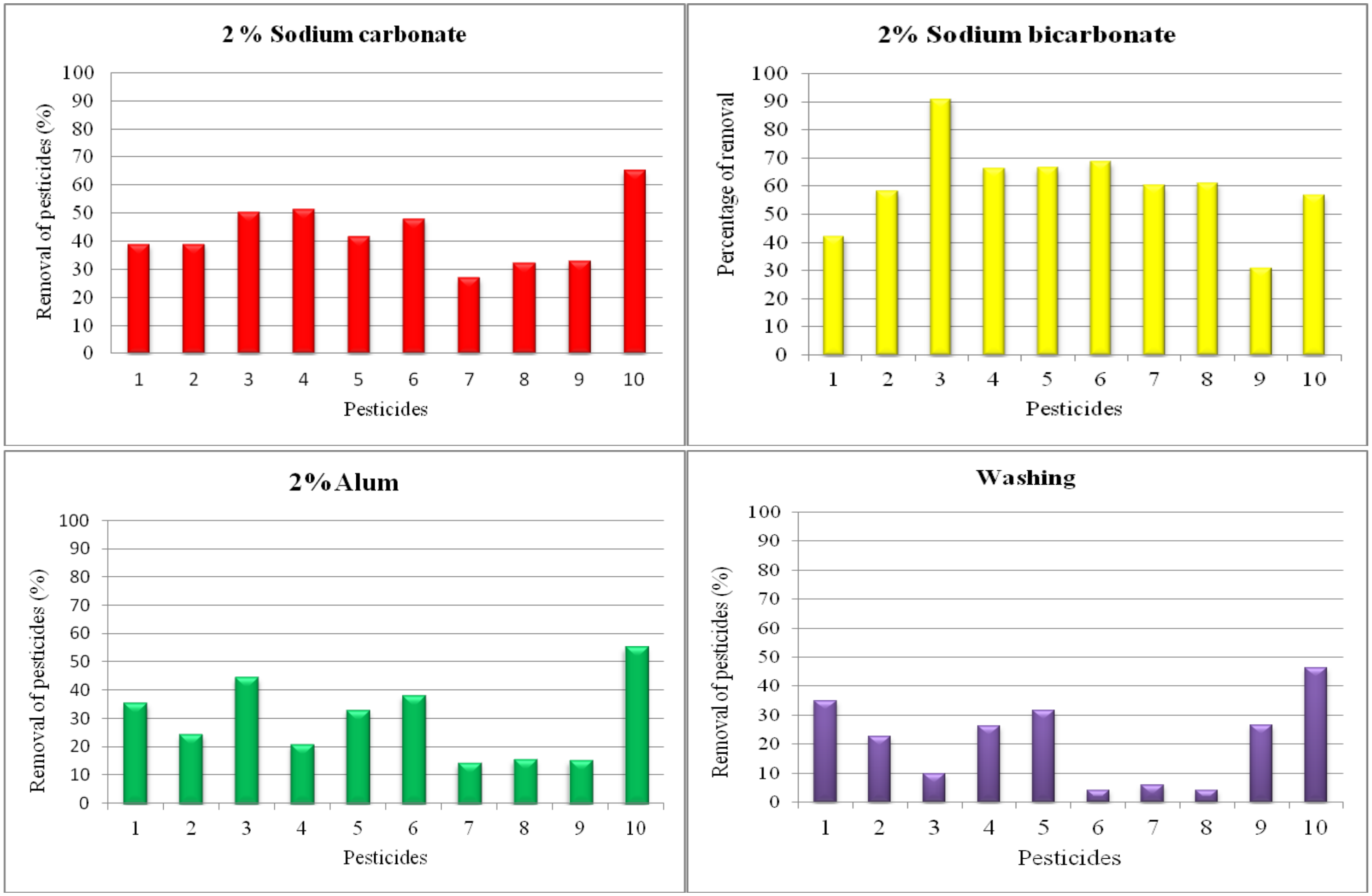
In the present study, the highest removal of organophosphate and synthetic pyrethroid pesticides was observed when the capsules were treated in 2% sodium bicarbonate solution for ten minutes (Figure 1). This treatment removed fairly a good amount of dimethoate (41.80%), chlorpyriphos (58.04%), quinalphos (90.70%), profenophos (66.27%), ethion (66.42%), lambda cyhalothrin (68.43%), cypermethrin (60.10%) and fenvalerate (60.92%). This is in agreement with the findings of Chandra *et al.* (2015) who reported the removal of chlorpyriphos (59.80-61.80%) and cypermethrin (61.90-62.80) residues from brinjal. According to Yang *et al.* (2017) pesticides can degrade in the presence of $NaHCO_3$, which assists the physical removal force of washing. Alkaline nature of the solution may affect the stability of pesticides and that could be the reason for the depletion of organophosphate and synthetic pyrethroid pesticides.

Among organophosphate insecticides, the highest removal was observed in quinalphos and the lowest removal was observed with dimethoate. The systemic nature of dimethoate might be the reason for its least removal when compared to other pesticides. According to Holland *et al.* (1994) surface residues are amenable to simple washing operations where as systemic residues present in tissues will be little affected. Liang *et al*. (2012) reported that 77.80 per cent reduction in the residues of chlorpyriphos was observed in cucumber by treating with 2% sodium bicarbonate solution.

Washing of cardamom capsules in water for three times followed by shaking in 2% sodium carbonate solution for ten minutes removed the highest quantity of pesticide residues imidaclprid and carbendazim (32.75 and 65.15 % respectively) (Figure 1). In the case of organophosphate and synthetic pyrethroid pesticides, sodium carbonate solution stood next in performance after sodium bicarbonate solution. It removed 38.69-50.99 and 26.77-47.77 per cent organophosphates and synthetic pyrethroids respectively. The highest removal was observed in carbendazim and the lowest in the case of cypermethrin. Sodium carbonate solution has an efficient role in the elimination of total DDT, pirimphos methyl, malathion and profenophos pesticides from contaminated potatoes (Zohair, 2001). Amir *et al.* (2019) reported that sodium carbonate showed a greater reduction power when it combines with simple water to reduce toxic residues.

Washing in 2% alum solution eliminated 20.31-43.89 per cent organophosphate, 13.80-37.53 synthetic pyretroids, 14.58 per cent imidacloprid and 54.70 per cent carbendazim. There was no significant difference between washing in alum and water in the case of dimethoate, chlorpyriphos, ethion and imidacloprid. In the case of profenophos the treatment was less effective than washing in water.

Washing in water proved the least effective showing 34.77, 22.47, 9.76, 31.55, 3.98, 5.88, 4.14, 26.54 and 46.29 per cent reduction in dimethoate, chlorpyriphos, quinalphos, ethion, lambda cyhalothrin, cypermethrin, fenvalerate, imidacloprid and carbendazim respectively. Generally washing is found to be more effective for contact pesticides than systemic pesticides but the solubility or polarity of pesticides also decide the amount of removal. This result is not in accordance with that of Radwan *et al.* (2005) who reported that 81.06, 85.16, 99.26 per cent profenophos residues was reduced from hot pepper, sweet pepper and egg plant respectively but it agrees with that of Satpathy *et al.* (2012), who reported that the washes from the chemical solutions were more powerful in reducing pesticides than water alone.



1: Dimethoate, 2:Chlorpyriphos, 3: Quinalphos, 4: Profenophos , 5: Ethion, 6: Lambda cyhalothrin, 7: Cypermethrin, 8: Fenvalerate, 9: Imidacloprid, 10: Carbendazim

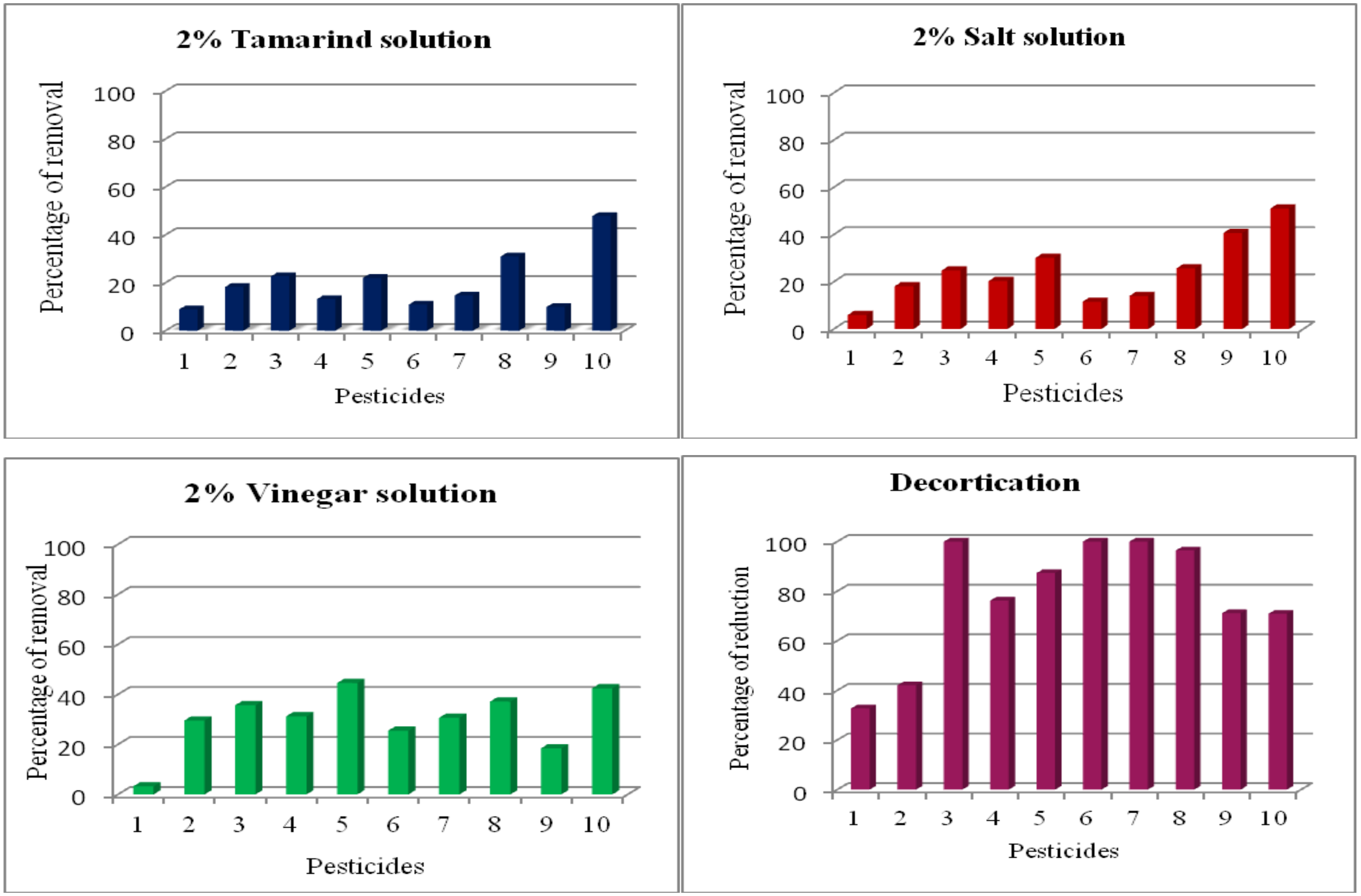
Fig. 1. Effect of washing with different chemicals in the removal of pesticide residues in fresh cardamom

5.4 EFFECT OF DIFFERENT HOUSEHOLD PRACTICES ON THE REMOVAL OF PESTICIDE RESIDUES IN DRY CARDAMOM CAPSULES

Among the different treatments, decortication showed maximum removal of organophosphates (32.75-100%), synthetic pyrethroids (96.41-100%) and new molecule imidacloprid (71.14%) (Figure 2). 100 per cent removal of quinalphos, cypermethrin and lambda cyhalothrin was observed by decortication method. Nair (2013) reported that decortication of cardamom capsules removed organophosphate (48.19 to 93.41 %) and synthetic pyrethroid residues (66.61-100 %). Among organophosphate pesticides, dimethoate (32.75%) and chlorpyriphos (42.00%) were present in cardamom seeds even after decortications. This may be due to the high penetrating power of these molecules where, the residues moved to seeds. Decortication removed 70.90 per cent residues of the fungicide carbendazim.

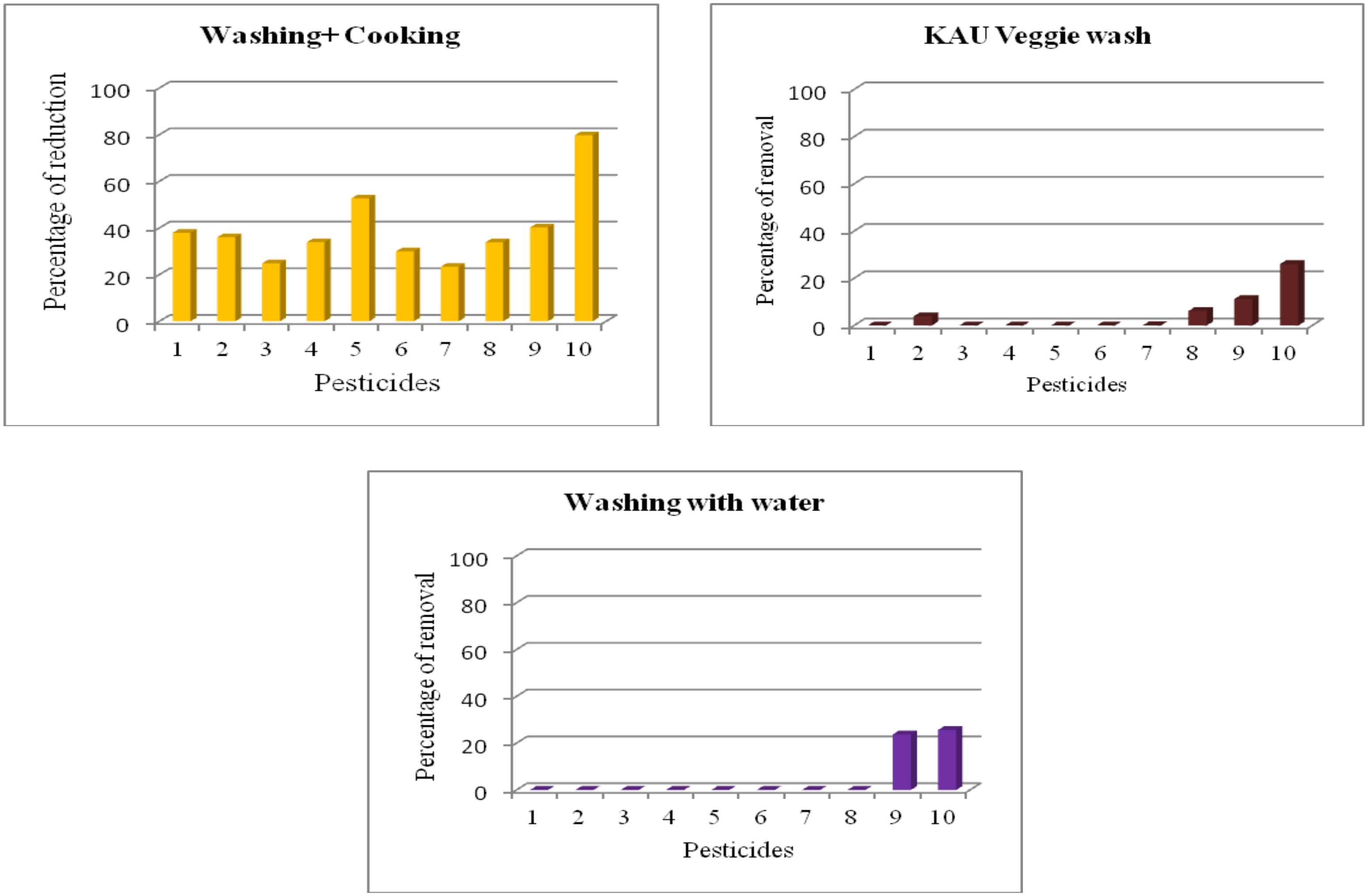
According to Holland *et al.* (1994), the major portion of the pesticides sprayed to the crops undergo very restricted movement through the outer wall and residues remain on the outer regions. This result shows that by removing the capsule cover, most of the pesticide residues present could be removed very easily. It is very cheap and easy when compared to other methods. Cardamom farmers can easily adopt this method and produce pesticide free cardamom seeds and cardamom powder for export and domestic use and to gather attractive income.

Washing in water for three times followed by cooking in a closed pan resulted in considerable removal of pesticide residues. It removed 24.83 to 52.69 per cent of organophosphates, 23.41 to 33-87 per cent of synthetic pyrethroids, 40.27 per cent imidacloprid and 79.77 per cent of carbendazim residues. The highest removal was observed in carbendazim and it was the best treatment for dimethoate (Figure 3). Heating process would cause degradation and volatilization of systemic pesticides and this might be the reason for the removal of dimethoate residues.



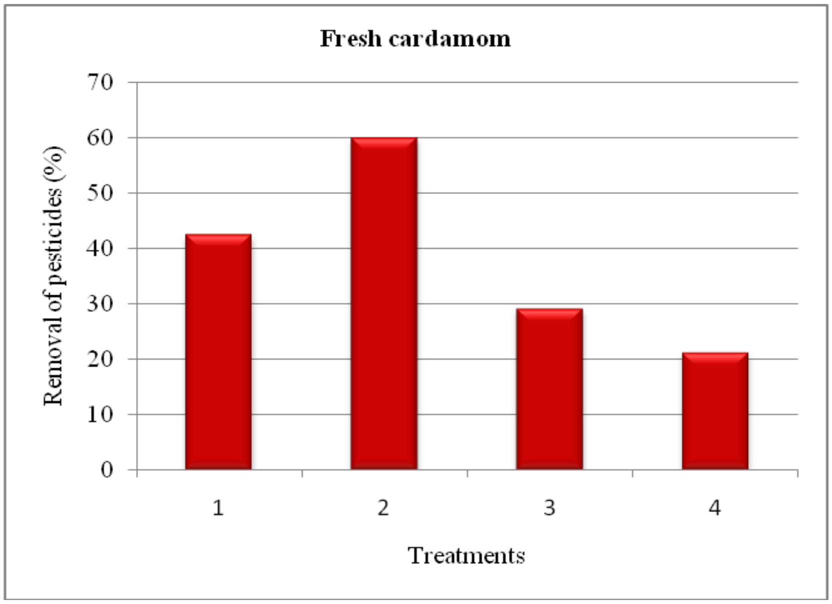
1: Dimethoate, 2:Chlorpyriphos, 3: Quinalphos, 4: Profenophos , 5: Ethion, 6: Lambda cyhalothrin, 7: Cypermethrin, 8: Fenvalerate, 9: Imidacloprid, 10: Carbendazim

Fig. 2. Effect of different household practices in the removal of pesticide residues from dry cardamom



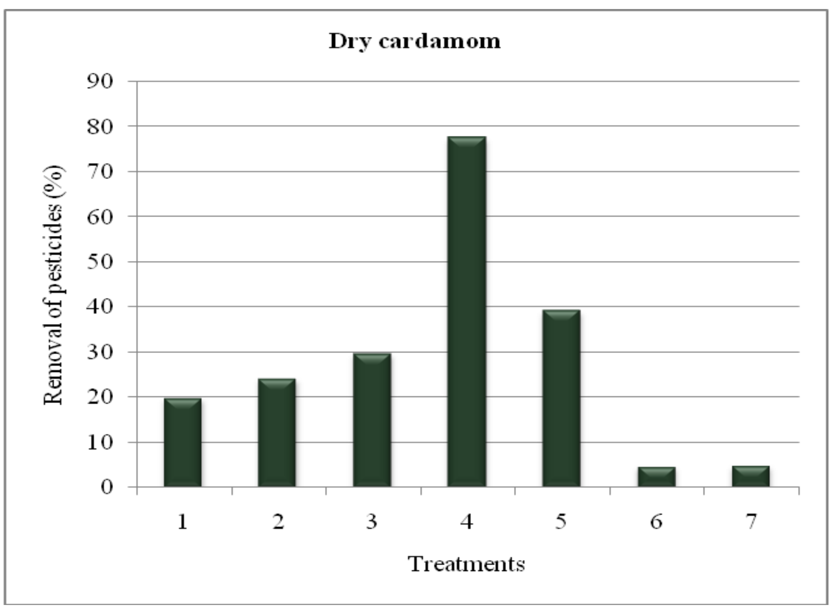
1: Dimethoate, 2:Chlorpyriphos, 3: Quinalphos, 4: Profenophos , 5: Ethion, 6: Lambda cyhalothrin, 7: Cypermethrin, 8: Fenvalerate, 9: Imidacloprid, 10: Carbendazim

Fig. 3. Effect of different household practices in the removal of pesticide residues from dry cardamom



1: 2% Sodium carbonate, 2: 2% Sodium bicarbonate, 3: 2% Alum, 4: Washing in water

Fig. 4. Effects of different treatments on fresh cardamom



1: 2% Tamarind, 2: 2% Salt, 3: 2% Vinegar, 4: Decortication, 5: Washing + cooking, 6: KAU Veggie wash, 7: Washing with water

Fig. 5. Effects of different treatments on dry cardamom

Dipping the capsules in 2% synthetic vinegar solution followed by washing removed ethion (44.55%), carbendazim (42.44%), fenvalerate (37.12%), quinalphos (35.67%), profenophos (31.24%) and cypermethrin (30.66%). Removal of other pesticides did not exceed more than 30 per cent. The lowest reduction was seen in the case of dimethoate. A study conducted by Kin and Huat (2010) reported that acidic solution was more powerful in the decontamination of the organocarbamate and organophosphate pesticides compared to other solutions.

Abou-Arab, (1999) reported that washing with 10% acetic acid removed 91.50 and 86.80 per cent residues of dimethoate and profenophos respectively from tomato. The reason for the removal of pesticides might be due to its more power as a chelating agent which force and make the residues unavailable (Amir *et al.*, 2019).

Dipping the capsules in 2% salt solution for ten minutes followed by three washing in water was found to be effective for the removal of imidacloprid (40.67%) and carbendazim (51.00%). In organophosphates, the highest percentage reduction was recorded in quinalphos with 22.73 per cent and the lowest in the case of dimethoate with 5.98 per cent. In the case of synthetic pyrethroids, 25.66 per cent was the highest percentage removal which was in the case of fenvalerate and lambda cyhalothrin showed the lowest removal with 11.53 per cent. These observations are not in agreement with that of Vemuri *et al.* (2015) who stated that by washing with 2% salt water 78, 91 and 88.20 per cent residues of dimethoate, quinolphos and profenophos could be removed respectively from brinjal.

About 8.90-47.88 per cent of pesticide residues were removed by 2% tamarind solution. The removal occurred due to the slight emulsifying property and acidic nature of tamarind. Effectiveness of this treatment is almost similar to that of 2% salt solution except imidacloprid. These results are not in line with that of Nair (2013) who reported that dipping in 2% tamarind resulted in the removal of 47.64-70.53 per cent reduction of organophosphate and synthetic pyrethroid pesticide residues from okra. According to Vijayasree *et al.* (2013), 2% tamarind solution removed 47.78 per cent chlorantraniliprole residues from cowpea.

Dipping in KAU veggie wash 10 mL L^{-1} for five minutes followed by washing in water and washing in water for three times showed less effectiveness in removing pesticide residues except residues of imidaclprid and carbendazim. The result was not in an agreement with that of Muralikrishna (2015) who reported that KAU Veggie wash removed 73.75 per cent quinalphos, 73.45 per cent profenophos and 61.08 per cent dimethoate from amaranth but it agrees with that of Aaruni (2016) who reported that for synthetic pyrethroids, the effects of KAU Veggie wash was as analogous to that of tap water. This showed that Veggie wash developed by KAU for removing residues of vegetables and fruits was not effective in removing residues from spices.

The present study "Management of pesticide residues in small cardamom, *Elettaria cardamomum* Maton" portrays the pesticide use pattern in cardamom in Idukki district and efficiency of different commercial and household practices in decontaminating both fresh and dry cardamom capsules. Data on pesticide use pattern showed the indiscriminate use of pesticides in cardamom field, which led to the high amount of pesticide residues in capsules. In every importing country, the consumers are more concerned about the good quality foods. The presence of pesticides above the limit leads to immediate rejection of the exporting goods. Even though India lead second in cardamom production the competition are increasing day by day in the world market. Quality takes over the position than quantity in the case of agricultural produce. Hence production of good quality pesticide free cardamom is very essential to maintain top position in the market. Giving awareness among farmers and continuous monitoring should be done to improve the quality of cardamom capsules. The main objective of this study was to develop a decontaminating strategy to remove pesticides at harvest time and also at house hold level.

Summary

6. SUMMARY

Among Indian states, Kerala is the largest producer of cardamom. Premium price of cardamom has motivated cardamom planters to adopt year round spray with the synthetic insecticides in order to avoid any chance of pest infestation. This turned cardamom as one of the highest pesticide consuming crop. Presence of pesticide residue in cardamom capsules which is exported from India became a serious problem. Several importing countries rejected cardamom capsules from India due its low quality in terms of pesticide residues. Though different decontamination studies were conducted in India for the removal of pesticide residue from food commodities *viz*., fruits, vegetables etc., however, studies in cardamom are less. In this context, the present study entitled "Pesticide residue management in harvested capsules of small cardamom, *Elettaria cardamomum* Maton." was undertaken to standardize commercial and household techniques to decontaminate pesticide residues from fresh and dry cardamom capsules. The results of the studies are summarized here under.

- Studies on documentation of pesticide use pattern in cardamom revealed that most of the cardamom farmers used pesticides as a prophylactic measure at 20 to 30 days interval. Adoption of integrated pest management practices was very less and none of them applied botanicals and biocontrol agents. The major pesticide used were quinalphos, dimethoate, chlorpyriphos, profenophos, ethion, monocrotophos under organophosphorous group, lambda cyhalothrin, cypermethrin, fenvalerate and bifenthrin under synthetic pyrethroids, thiodicarb and carbosulfan as carbamate. Imidacolprid was the most commonly used new generation molecule followed by thiamethoxam. Among fungicides the commonly used were bordeaux mixture, copper oxy chloride, carbendazim, mancozeb and fosetyl-Al.
- The main sucking pests recorded were cardamom thrips *Sciothrips cardamomi*, lacewing bug, *Stephanitis typicus*, cardamom scale, *Aulacaspis* sp. and cowpea pod bug *Riptortus pedestris*).

The chewing insect pests recorded were shoot/capsule borer *Conogethes punctiferalis*, cardamom root grub *Basilepta fulvicorne* and hairy caterpillar, *Eupterote* sp.

- Multi-residue analytical method was validated for the analysis of residues of different pesticides in cardamom capsules. Limit of Detection, Limit of Quantification, Linearity, Recovery and Repeatability were the validation parameters taken for the ten pesticides. Of the ten pesticides evaluated, the mean percentage recovery ranged within the internationally accepted mean recovery range of 70 to 120 per cent. The Relative Standard Deviation (RSD) was less than 20 per cent. Therefore it is confirmed that the method is suitable for pesticide residue analysis in cardamom. The estimation of residues were performed by using Gas Chromatograph and LC-MS/MS
- Studies conducted to evaluate the effect of different chemical solutions on removal of pesticide residues in fresh cardamom showed that among the different washing methods adopted, 2% sodium bicarbonate solution and 2% sodium carbonate solution showed significant effect in reducing all the pesticides when compared to 2% alum solution and water. Washing of cardamom capsules in water for three times followed by shaking in 2% sodium bicarbonate solution for ten minutes removed 41.81-90.70 and 60.10- 68.43 per cent organophosphate and synthetic pyrethroid pesticides respectively. Imidacloprid was removed by 30.83 per cent and carbendazim to the extent of 56.55 per cent. Maximum removal was observed in quinalphos (90. 70%)
- In the case of dry cardamom, decortication and washing and cooking in closed pan for ten minutes showed maximum reduction in pesticide residues. Decortication removed 100 per cent residues of quinalphos, lambda cyhalothrin and cypermethrin. The lowest removal was observed in the case of dimethoate. In dry cardamom, washing and cooking in closed pan for ten minutes showed maximum reduction of pesticide residues of imidacloprid. This treatment removed 79.77 per cent residues. The next best treatment was dipping the

capsules in 2% vinegar solution for ten minutes followed by three washing in water. It removed up to 44.55 per cent pesticide residues.

- The present study revealed that washing the fresh cardamom capsules in water for three times followed by shaking in 2% sodium bicarbonate solution for ten minutes was the best treatment in removing pesticide residues from cardamom capsules followed by 2% sodium carbonate. Decortication of cardamom capsules has showed maximum removal of pesticides in the case of dry cardamom which was followed by washing and cooking in closed pan for ten minutes

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Appendix

APPENDIX I

PROFORMA FOR SURVEY ON PESTICIDE USE PATTERN AMONG CARDAMOM FARMERS IN IDUKKI DISTRICT

Sl no.	Particulars	Response of farmers
1	Location	
	Block	
	Taluk	
	Panchayat	
2	Name and address of Farmer	
3	Age	
4	Education	
5	Size of holding (ha)	
6	Land status	
A	Own land	
B	Leased land	
7	Cropping pattern	
8	Irrigation status	
A	Irrigation	
B	Rainfed	

9	Average yield (kg/ha)	
10	Annual income	
11	Soil type	
12	Source of technical information regarding crop protection	
A	Agriculture officers	
B	Company representatives	
C	Other progressive farmers	
D	Own decisions	
E	Media	
13	Source of plant protection chemicals	
14	Cost of plant protection measures	
A	Cost of chemicals	
B	Cost of labour	
C	Total cost	
15	Is there any practice of manual mixing of pesticides and spraying?	
16	Is there any prophylactic application of PP chemicals	
17	Type of sprayer used	
18	Whether it is possible to avoid pesticide	
19	Whether following integrated pest management strategies	

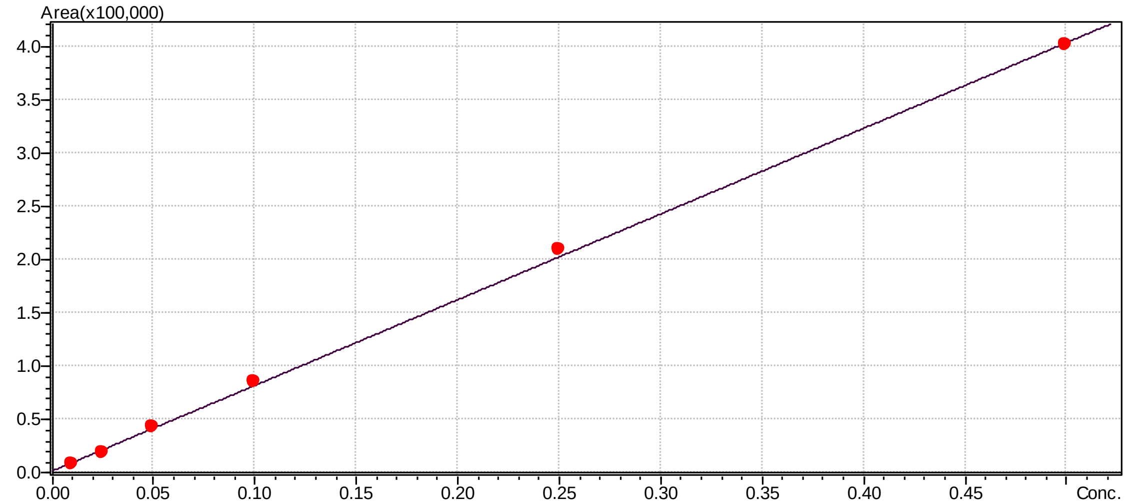
20	Practicing any biological control measures	
21	Application of plant protection chemicals as per the recommendations of KAU or not.	
22	Whether following the directions in the pesticide label during handling and application of pesticides?	
23	Most frequently used pesticides	
A	Insecticide	
B	Fungicide	
C	Herbicide	
24	Rate of application	
25	Time of application of pesticides	
A	Early morning	
B	Morning	
C	Afternoon	
D	Evening	
26	Frequency of application	
27	Method of application	
28	Any control failures noticed after the application of any pesticides	
29	Name of pest which is very difficult to control	
30	Aware of the direction of wind while spraying effects of pesticides	

31	Degree of awareness regarding the adverse health effects of pesticides	
A	Well aware	
B	Aware of some adverse health effects	
C	Totally ignorant	
32	Pesticide application by	
A	Himself	
B	Labour	
33	Type of clothing while spraying	
34	Safety precautions taken while spraying	
A	Use of gloves	
B	Wearing mask	
C	Wearing boots	
D	Nothing adopted	
35	Reasons for non-adoption of safety measures	
36	Method of disposal of pesticide containers	
A	Dumping in the field	
B	Putting in drainage channels	
c	Burning	

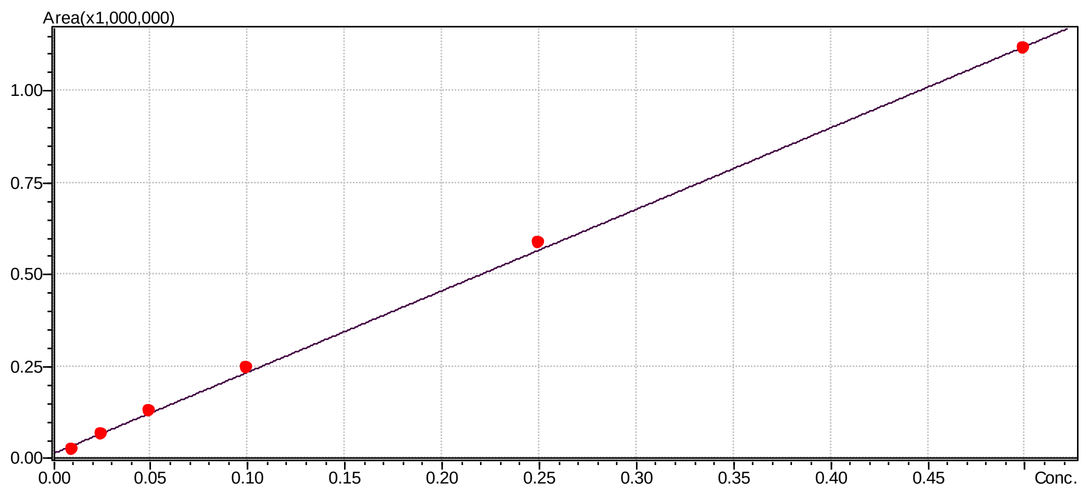
d	Burrying deep in soil	
37	Type of health hazard due to pesticide application	
A	Some irritation during the time of spraying	
B	Continuous coughing, difficulty to breathe, skin diseases etc.	
38	Cases of poisoning/death due to pesticide use	
39	Percentage increase in crop yield due to pesticide application	
40	Awareness about new generation insecticides	
41	Are you aware about the presence of pesticide residues in cardamom (yes /no)	
42	Are you concern about the reject of consignment of cardamom from foreign countries due to the presence of pesticide residues (yes/no)	

APPENDIX II

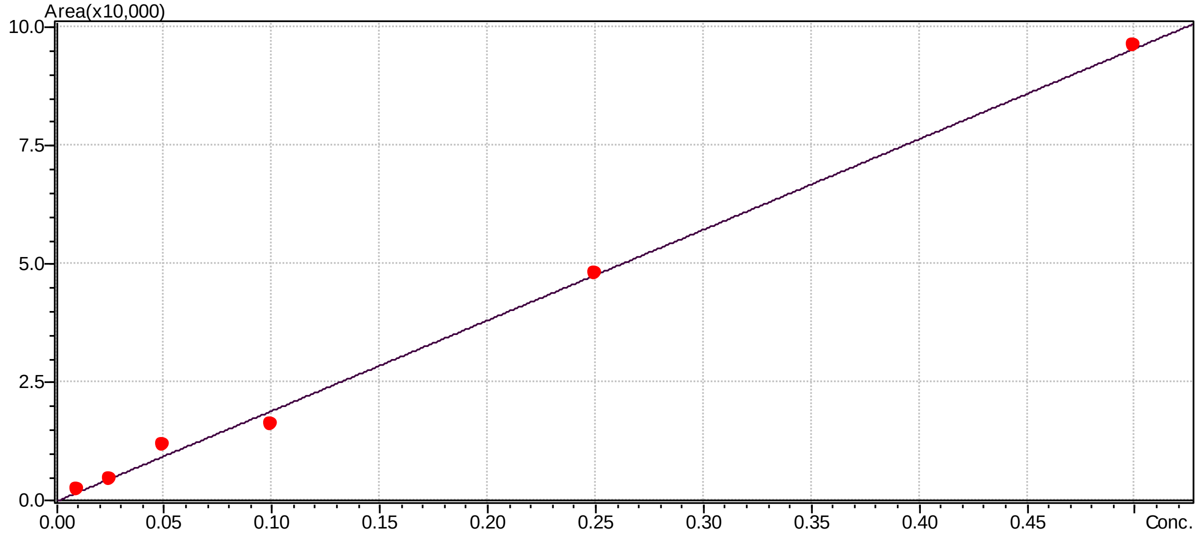
Calibration curve of dimethoate



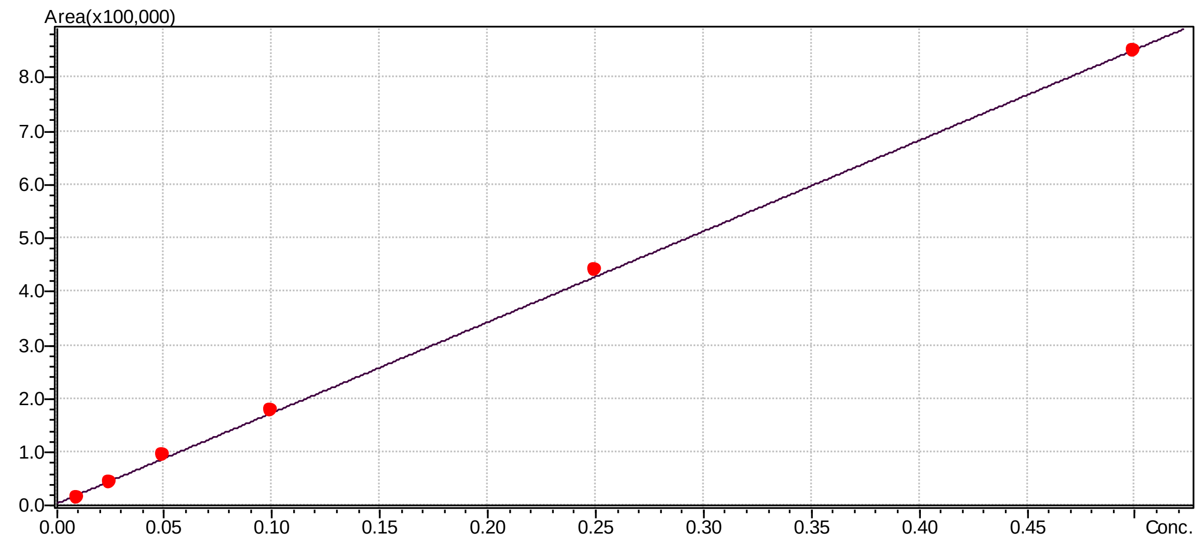
Calibration curve of chlorpyriphos



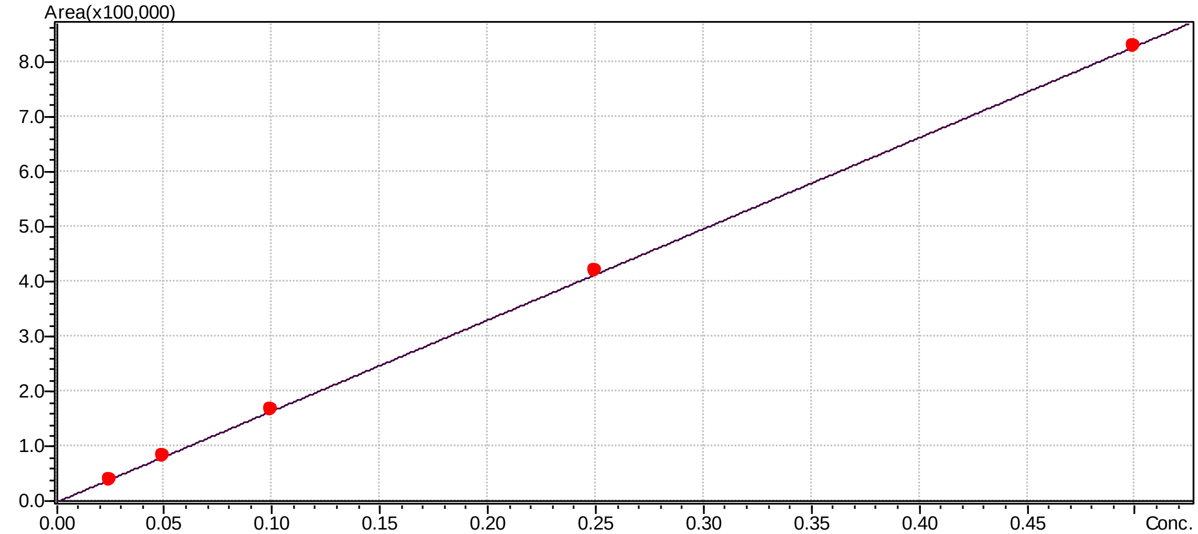
Calibration curve of quinalphos



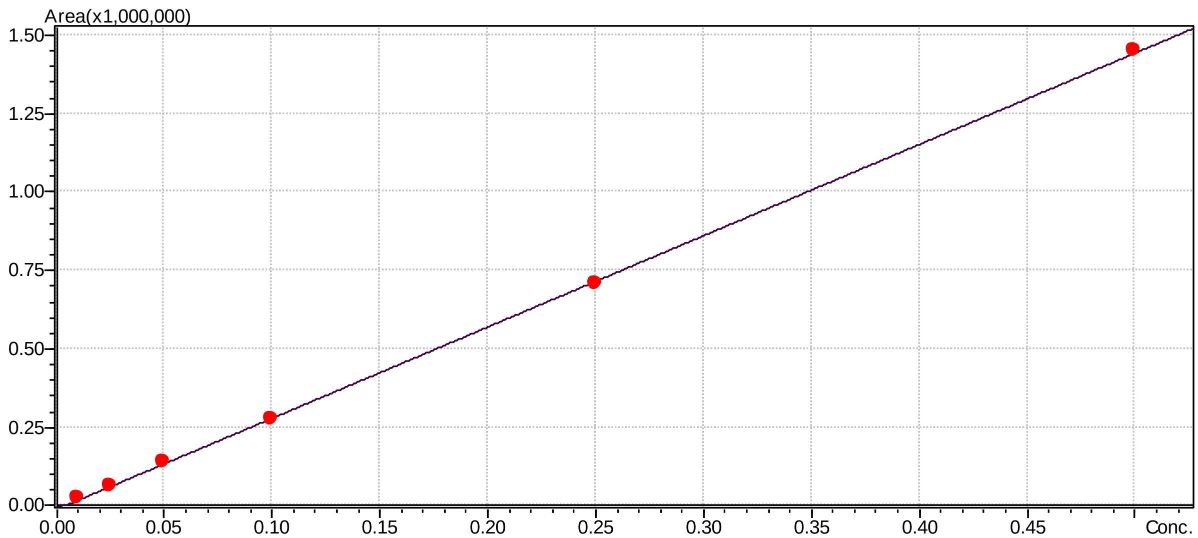
Calibration curve of Profenophos



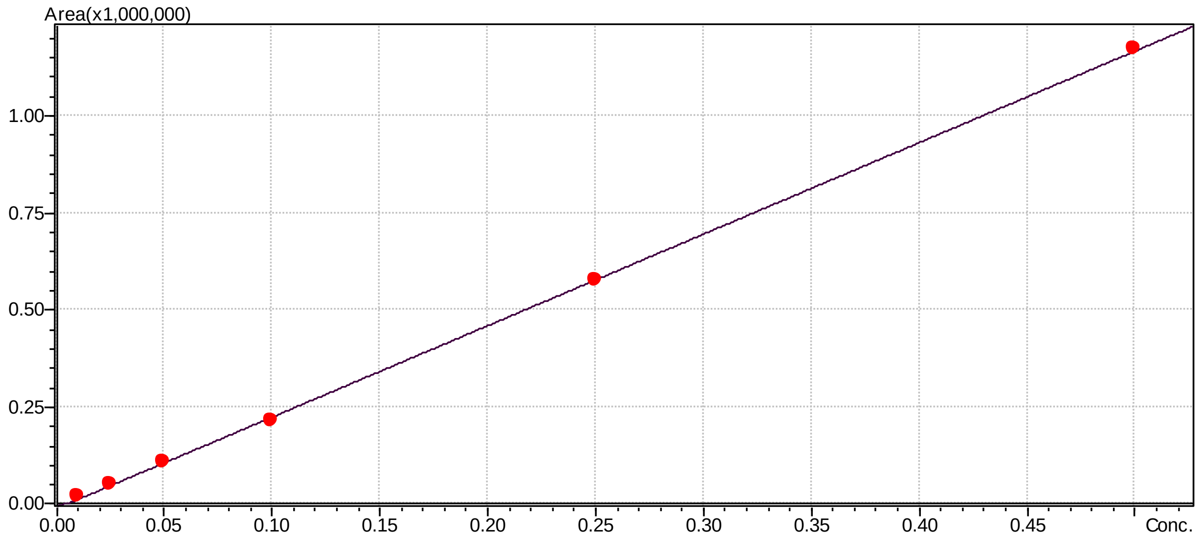
Calibration curve of ethion



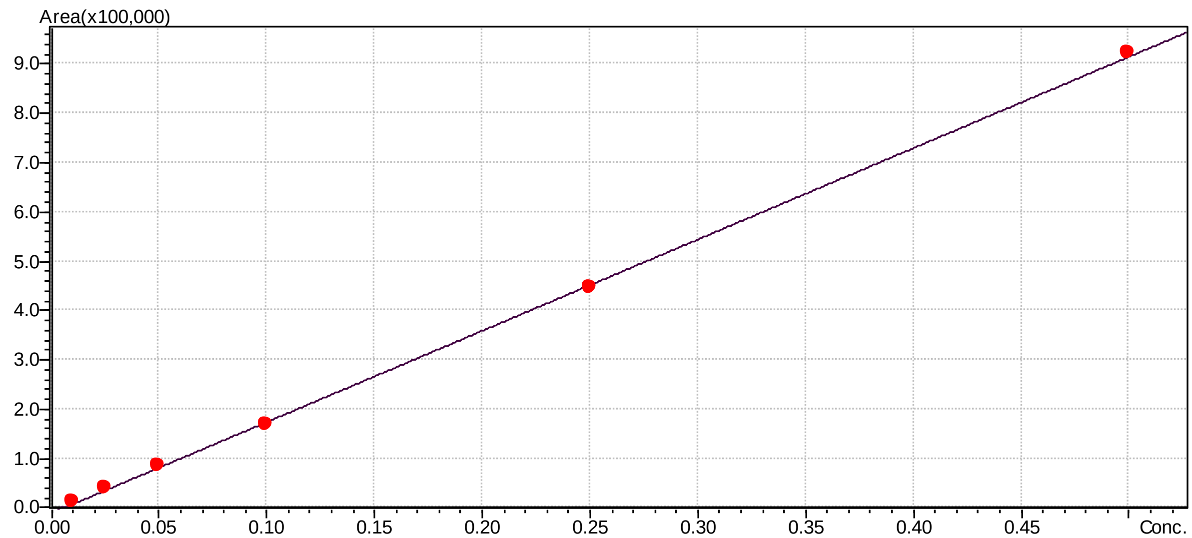
Calibration curve of lambda cyhalothrin



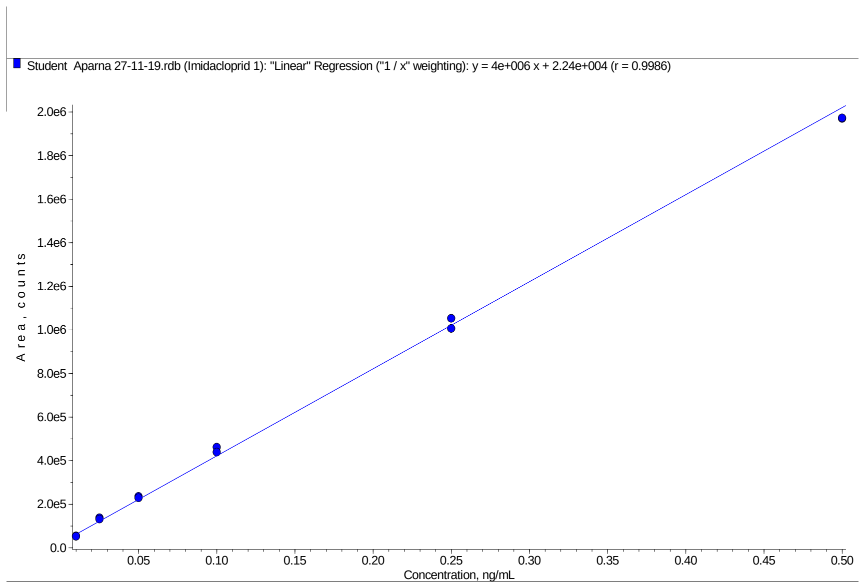
Calibration curve of alpha cypermethrin



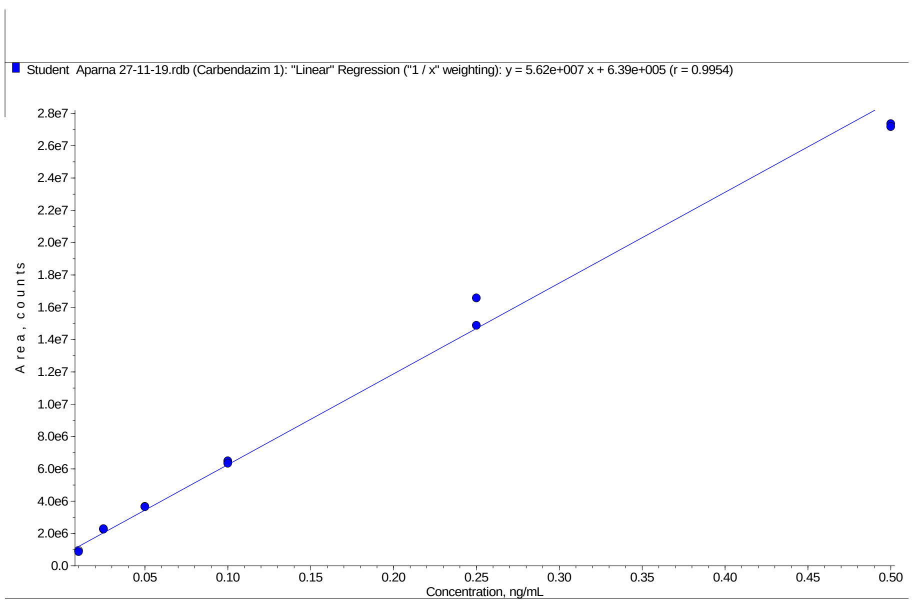
Calibration curve of fenvalerate



Calibration curve of imidacloprid



Calibration curve of carbendazim



PESTICIDE RESIDUE MANAGEMENT IN HARVESTED CAPSULES OF SMALL CARDAMOM, *Elettaria cardamomum* Maton.

by

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Abstract of the thesis
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ABSTRACT

A study on "Pesticide residue management in harvested capsules of small cardamom, *Elettaria cardamomum* Maton." was undertaken at College of Agriculture, Vellayani and Cardamom Research Station, Pampadumpara during June 2019 to February 2020. The objectives were to document the pesticide use pattern in cardamom in Idukki district and to evaluate the effect of different decontamination methods for the removal of pesticide residues from fresh and dry cardamom capsules.

Field survey conducted among the farmers of Idukki district revealed that quinalphos, dimethoate, chlorpyriphos, ethion, profenophos, monocrotophos, lambda cyhalothrin, cypermethrin, fenvalerate, thiodicarb, carbosulfan, imidacloprid thiamethoxam, bordeaux mixture, copper oxy chloride, carbendazim, mancozeb were the most commonly used pesticides.

The pests recorded during the study include shoot/capsule borer *Conogethes punctiferalis,* cardamom thrips *Sciothrips cardamomi,* cardamom root grub, *Basilepta fulvicorne,* hairy caterpillar, *Eupterote s*p., lacewing bug, *Stephanitis typicus,* cardamom scale *Aulacaspis* sp. and cowpea pod bug, *Riptortus pedestris.* For the timely management of these pests farmers were using a prophylactic spraying of plant protection chemicals at 20 to 30 days interval. Most of the farmers depended on pesticide retailers as a source of technical information.

The laboratory experiment was laid out in CRD to study the efficacy of different decontamination techniques in removing pesticide residues from fresh and dry cardamom capsules. In fresh cardamom, washing with water for three times followed by shaking in 2 % sodium bicarbonate solution for ten minutes showed superiority over other treatments in the removal of pesticide residues (30.83 to 90.70 %) except carbendazim. The highest removal was observed in quinalphos (90.70 %) and the lowest removal was observed in imidacloprid (30.83%). Sodium

bicarbonate solution removed residues of dimethoate, chlorpyriphos, profenophos, ethion, lambda cyhalothrin, cypermethrin, fenvalerate and carbendazim by 41.82, 58.04, 66.27, 66.42, 68.43, 60.10, 60.92 and 56.55 per cent respectively. The next best decontaminating agent was 2 % sodium carbonate, which removed 26.77-65.15 per cent pesticide residues from fresh cardamom.

In dry cardamom capsules, the highest removal of residues was obtained by removing the outer covering of dry cardamom (Decortication) which removed 32.75 to 100 per cent residues. No residues of quinalphos, lambda cyhalothrin and cypermethrin were detected in seeds after decortication. Washing and cooking of dry capsules for ten minutes showed a significant reduction in residues of dimethoate (37.95 %) and carbendazim (79.77 %). The removal of residues ranged from 23.41 to 79.77 per cent. The third best treatment was washing in 2 % vinegar which removed 44.55 per cent residues of ethion.

The study could be concluded that washing of fresh cardamom with water for three times followed by shaking in 2 % sodium bicarbonate solution for ten minutes showed the maximum removal of pesticide residues. Decortication was the effective treatment for removing pesticide residues from dry cardamom.