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Original Research

Pesticide Usage and Comparative Analysis of Pesticide Residues in Conventionally Grown and Organic-Certified Vegetables in North Central Province, Sri Lanka

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ABSTRACT

Purpose: *The main objectives of this study were to identify the types of pesticides used by the vegetable farmers in North Central Province (NCP) of Sri Lanka and analyze the residue levels of five pesticides; Thiamethoxam, Tebuconozole, Profenofos, Chlorpyrifos, and Chlorentroniliprole on conventionally grown bitter guard, brinjal, and angled luffa (n =40×3) in NCP and in different organic certified vegetables (n=42).*

Research Method: *A standardized questionnaire was used to collect demographic information and details of pesticides used by vegetable farmers in the NCP. Pesticide residues in both conventionally grown and organic vegetables were analyzed using modified QuECHERS extraction method and GC-MS analysis.*

Findings and Values: *Among the many pesticides used by the vegetable farmers in NCP, three most commonly used insecticides were Tebufenozide (14.3%), Carbosulfan (13.7%) and Abamectin (12.4%). The GC-MS analysis data revealed that 22.5% of brinjal, 15% of angled luffa and 5% of bitter gourd samples were positive for Thiamethoxam (0.105 ±0.023 - 1.020 ±0.021 ppm) or Tebuconazole (0.090 ±0.007 - 0.180 ±0.041 ppm). Notably, 15% of brinjal samples exceeded the maximum residue limit (MRL) for Thiamethoxam (0.3 ppm) as stated by the Codex Alimentarius Commission. None of the organic certified vegetable samples had detectable levels of pesticide residue. Overall, this study suggests that vegetables produced in the NCP can contain harmful levels of pesticide residues. Therefore, providing proper training on safe pesticide handling practices to farmers and establishing a methodical screening procedure for pesticide residue in vegetables are important to ensure the safety of the vegetables produced in the NCP.*

Keywords: *Conventionally grown vegetables, Low-country vegetables, North Central Province, Organic vegetables, Pesticides, Sri Lanka*

INTRODUCTION

Fresh fruits and vegetables play an important role in a healthy diet since they deliver plenty of essential nutrients. Therefore, demand for fresh produce has increased drastically in recent years (Bandara *et al.* 2021).Also, global consumption of fresh vegetables has steadily increased due to population growth and dietary shifts, with the

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Food and Agriculture Organization (FAO) estimating a 30–40% rise in demand by 2030 (Mason *et al.* 2019). As a result, a significant gap has been created between the demand and production of fresh produce. Many developing countries struggle to meet this demand due to limited arable land, yield plateaus, and significant post-harvest losses (Kiaya 2014).

For instance, in South Asia, vegetable production meets only about 70% of per capita dietary recommendations, highlighting a critical supply gap (Dong *et al.* 2022). Therefore, farmers are increasingly adopting modern agricultural practices and advanced farming technologies, replacing traditional crop varieties with high-yielding ones. These approaches typically involve the use of mechanized equipment, synthetic fertilizers, chemical pesticides, and genetically modified or hybrid seeds (Dias & Carlos 2015).

While these innovations have remarkably improved farming efficiency and yield potential, they have also led to an increased dependence on chemical inputs, raising concerns about their long-term impact on environment and food safety (Shoeb *et al.* 2016). Several published studies documented an increasing pesticide usage in crop cultivation across the globe in recent years (Aslam *et al.* 2013, Ciscato *et al.* 2015, Shoeb *et al.* 2016). Misuse of pesticides is one of the major problems challenging the safety of food. There are many published studies revealing various types of malpractices of farmers during pesticide handling.

Pesticide misuse, including over-application, use of banned substances, and non-compliance with withdrawal periods, is a common issue in many agricultural regions (Srikrishnah *et al.* 2013, Devi *et al.* 2018). These malpractices have triggered severe health and environmental problems due to harmful levels of pesticide residues in the environment (e.g., water, soil, air, crops) and bioaccumulation in human and animal bodies (Gondo *et al.* 2021).

Therefore, it is crucial to study pesticide residues in food commodities produced for human consumption regularly and frequently, as many recent studies have discussed carcinogenic, mutagenic, immune-toxic, and geno-toxic aspects of pesticides (Ramadan *et al.* 2020; Omwenga *et al.* 2021). Because of the lack of strict legislation to control the usage of pesticides in many countries, pesticide residues in fruits and vegetables have become a significant food safety concern (Ratnamma *et al.* 2020, Pan *et al.* 2021).

As a result of increasing awareness on health issues associated with pesticide residues in food, certified organic foods are becoming more popular across the globe. However, due to high labor input, requirements to adhere to strict rules and regulations, low production rate, and the average unit price, organic foods are quite expensive compared to the conventionally grown foods. These reasons have induced some deceiving sellers to label conventionally grown foods as organic and sell at a higher price (Kazimierczak *et al.* 2022). This study was conducted to identify frequently used pesticides for vegetable cultivation by farmers in the NCP and to determine the residue levels of five selected pesticides in three commonly consumed conventional vegetable types grown in NCP and "Organic" certified vegetables sold in the Sri Lankan market.

MATERIALS AND METHODS

Survey on commonly used pesticides on vegetable cultivation by the farmers in NCP

Volunteers (n=388) who are actively engaged in conventional vegetable farming in NCP and older than 18 years of age participated in the study. A standardized questionnaire containing questions on socio-demographic factors (age, gender, education), their experience in farming and details on pesticides used (commercial names or names of active ingredients) was used to collect the necessary data.

Chemicals and reagent

Thiamethoxam (CAS- 153719-23-4), profenofos (CAS- 41198-08-7), chlorpyrifos (CAS- 2921-88-2), chlorentroniliprole (CAS- 500008-45-7), and tebuconozole (CAS 107534-96-3) were used as pesticide standards. All the pesticide standards were obtained from Sigma Aldrich. Fipronil (CAS 120068-37-3) was used as the internal standard. High performance liquid chromatography- grade acetonitrile and acetate were obtained from Sigma Aldrich. QuECHERS extraction kits (55234-U) and clean-up kits (55287-U) were purchased from Supelco. All the individual standard stock solutions (1000 mg/L and 500 mg/L) were prepared in acetonitrile and stored in -4 °C temperature.

Sample collection and preparation

Brinjals *(Solanum melongena)*, Bitter gourds *(Momordica charantia)*, and angled luffa *(Luffa acutangular)* samples (40 samples each) that were grown using conventional farming techniques were collected into polythene bags initially from 120 different places in North Central Province. A stratified random sampling approach was used to select 120 locations across the North Central Province, ensuring representation from key agricultural zones (Mahakanadarawa, Nachchaduwa, Nuwara Wewa, Tissa Wewa, Parakrama Samudra, Giritale, and Elahera) and accounting for variation in crop types and pesticide usage patterns. Forty two organic certified vegetable samples (Mukunuwenna (Alternanthera sessilis) = 10, Gotukola (Centella asiatica) = 10, Green beans (Phaseolus vulgaris) = 10, Brinjal (Solanum melongena) =12) were obtained from supermarkets and registered organic food suppliers in the Colombo district. Organic vegetables collected from markets in Colombo were verified through inspection of certification labels and supplier documentation approved under the Sri Lanka Organic Certification System (SLOCS).

Collected vegetable samples were transferred to the laboratory within 24 h and stored at minus 18 °C before analysis. Extraction was performed using the modified citrate buffered QuEChERS method. It is a quick, easy, cheap, effective, rugged, and safe method commonly used to determine pesticide residues. Vegetable samples were thoroughly homogenized with a food processor for 1 min at room temperature. Five grams of ground vegetable sample was weighed into a 15 mL QuEChERS extraction tube (Supelco #55234-U). After that 5 mL of acetonitrile was added and shaken vigorously for 1 min by vortex mixer. The sample was centrifuged for 5 min at 4500 rpm. The dispersive solid phase extraction was performed using clean up tubes (Supelco 55287-U). The remaining supernatant was transferred to a 2 mL centrifuge tube and shaken vigorously for 1 min, followed by centrifugation at 4500 rpm for 2 min. Then, the supernatant was filtered and taken into a 1.5 mL vial. All vegetable samples, regardless of source, were subjected to identical sampling, storage, and QuEChERS extraction procedures to maintain methodological consistency and comparability. The pesticide residue levels were analyzed using GC-MS system as described below.

GC-MS analysis

The Gas Chromatography system (Agilent 7890A GC-MSD, USA) coupled to a 5997B single quadrupole mass spectrometer in SIM mode was used with a Agilent J&W DB-XLB column (30 m × 250 μm × 0.25 μm), low bleed and low polarity column which offers high specific analysis of pesticides and herbicides. GC oven was programmed to heat as follows: isothermal for 1 min at 50 °C, followed by heating from 50 to 125 °C at 25 °C min^{-1}, from 125 to 230 °C at 4 °C min^{-1}, and from 230 to 280 °C at 8 °C min^{-1}. Carrier gas was He at a pressure of 60 kPa. Using a 10 μL syringe, 1 μL injections were done in split less mode at 280 °C and run time was 34 min. The Agilent 5997 B mass spectrometer operated under SIM mode with an electron impact ion source operated at 1056 V of applied EM Voltage, The ion source temperature was 230°C, and the interface temperature was 280°C.

Method validation and sensitivity analysis

The limit of detection (LOD) of the method was 0.01 mg/kg while the limit of quantification (LOQ) was 0.05 mg/kg for all the pesticides tested. These values were determined as described below. Calibration plots of five pesticides namely thiamethoxam, profenofos, chlorpyrifos, chlorentroniliprole, and tebuconozole were determined using the fripronil as the internal standard.

Series of standard solutions: 0.001 ppm, 0.005 ppm, 0.01 ppm, 0.05 ppm, 0.1 ppm, 0.5 ppm, 1.0 ppm, 2.0 ppm, 3.0 ppm, 4.0 ppm, 5.0 ppm, and 10.0 ppm were prepared using each standard. The LOD was calculated as three times the signal-to-noise ratio and LOQ was calculated as 10 times the signal-to-noise ratio.

The method validation was performed by preparing a mixture of all 4 pesticides (each concentration was 5 ppm) and it was intentionally added to the organic vegetables (Brinjal). Then, the sample was extracted using the same extraction method (QUECHERS) and ran through the same GC-MS method to determine the percent recovery. Mean recoveries of spiked samples (n=3) were within acceptable range of 91-106 % for all selected pesticides (Recovery rates between 80% and 120% were considered acceptable in accordance with the SANTE/12682/2019 guidelines for pesticide residue analysis).

Data analysis

Data obtained from the survey study was analyzed using Minitab 19 (descriptive statistics; means, medians, modes, standard deviations, minimums, maximums).

RESULTS AND DISCUSSION

Vegetables grown in Sri Lanka can be divided into two main categories, namely, Up-country vegetables and Low-country vegetables. Temperate vegetables such as beet (*Beta vulgaris*), leek (*Allium ampeloprasum*), carrot (*Daucus carota*), beans (*Phaseolus vulgaris*), and cabbage (*Brassica oleracea*) belong to the Up-country vegetables category and are mainly grown in Nuwara-Eliya, Kandy, Matale, and Badulla districts, which are located in the Central and Uva provinces of Sri Lanka.

Low-country vegetables such as eggplant (*Solanum melongena*), okra (*Abelmoschus esculentus*), pumpkin (*Cucurbita moschata*), tomato (*Solanum lycopersicum*), bitter gourd (*Momordica charantia*), snake gourd (*Trichosanthes cucumerina*), long beans (*Vigna unguiculata*), angled-luffa (*Luffa acutangula*), drumstick (*Moringa oleifera*), and capsicum (*Capsicum annuum*) are grown under tropical climatic conditions, and the North Central Province (NCP) is one of the major production areas for these vegetable types (Lakshani *et al.* 2017).

The main objective of the survey conducted during this study was to identify the types of pesticides used for vegetable farming in the NCP. Data were collected only from farmers who were actively involved in vegetable cultivation. These farmers were interviewed either at their farm sites or regional collecting centers within the NCP.

Nearly 60.5% of the participants were male, while the remainder were female. The majority of the participants (approximately 84%) were at least 31 years of age or older. Only 8.4% of the respondents were illiterate, whereas about 78% had attained education up to at least the General Certificate of Education (G.C.E.) Ordinary Level (O/L).

Regarding farming experience, about 75% of the participants had more than 10 years of experience in vegetable cultivation, while 17% and 8% had 5–10 years and less than 5 years of experience, respectively.

When collecting data about frequently and recently used pesticides, participants were allowed to write either the brand names, name of active ingredients or both. At the data processing step, for the brand names given, details of active ingredients were collected by referring to the product labels.

Most of the reported pesticides were insecticides and belonged to WHO hazard class II, III or IV. Most frequently used pesticide active ingredients by the participants were Tebufenozide (14.3%), Carbosulfan (13.7%), Abamectin (12.4%), Imidacloprid (9.9%), Acetamprid (7.0%), Thiamethoxam (4.5%), Profenofos (4.5%), Flubendimide (4.5%), Cholantronilprole (3.3%), Etofenprox by (3.1%). While the most

Table 1. Socio-demographic characteristics of vegetable farmers in NCP (N = 380).

Characteristics	% (N = 380)
Gender	
Male	60.5
Female	39.5
Age group	
Below 21 years	3.4
21 to 30 years	12.9
31 to 40 years	28.7
41 to 50 years	18.4
51 to 60 years	2.1
Over 60 years	34.5
Education	
Illiterate	8.4
Grade 1 – 5	13.2
Up to G.C.E. O/L*	64.4
Up to G.C.E. A/L**	12.7
Graduate	0.5
Post Graduate	0.8
Experience	
5 – 10 years	16.8
Below 5 years	8.4
More than 10 years	74.7

*G.C.E. O/L: General Certificate of Education Ordinary Level; **G.C.E. A/L: General Certificate of Education Advanced Level.

frequently used pesticide according to this study is Tebufenozide. Marasinghe (2009) mentioned that Chlorpyrifos is the most frequently imported OP insecticide to Sri Lanka. However, in an extraordinary gazette (no 1894/4) in 2014, Chlopyrifos was identified as a pesticide with regional restriction for sale in Sri Lanka which revoked by extraordinary Gazette (no 2255/5) in 2021. The summary of the details of commonly used pesticides by the vegetable farmers in NCP are shown in Table 2.

In this study three popular low country vegetables (40 samples per vegetable type) were analyzed for five different pesticide types. Results of the pesticide residue analysis of three types of vegetable samples grown in the NCP are summarized in Table 3.

Overall, the result revealed that 17 out of 120 conventional vegetable samples (14.2%) contain detectable levels of pesticides. About 5% of Bitter guard samples (0.112 ±0.042- 0.615±0.031 ppm) and 15% angled luffa samples (0.105 ±0.023- 0.869 ±0.082 ppm) were positive for Thiamethoxam. Among the three types of vegetable tested, only brinjal contained detectable levels of multiple pesticides (Thiamethoxam, Tebuconozole). In total, 22.5% of the brinjal samples were positive for these two pesticides where 17.5% of the samples were positive for Thiamethoxam (0.2150 ±065-

Table 2. Details of commonly used pesticides by the vegetable farmers in NCP, Sri Lanka.

Commercial name	Pesticide type	Common name and CAS number	WHO hazard class	% of respondents N = 380
Mimic	I	Tebufenozide – CAS no: 112410-23-8	IV	14.3
Marshal 20	I	Carbosulfan – CAS no: 55285-15-8	II	13.7
Zoro	I	Abamectin – CAS no: 71751-41-2	II	12.4
Admire	I	Imidacloprid – CAS no: 138261-41-3	III	9.9
Mospilan	I	Acetamprid – CAS no: 135410-20-7	III	7.0
Actara	I	Thiamethoxam – CAS no: 153719-23-4	III	4.5
Profenophos	I	Profenofos – CAS no: 41198-08-7	II	4.5
Takumi	I	Flubendiamide – CAS no: 272451-65-7	III	4.5
Vitako	I	Cholantronilprole – CAS no: 500008-45-7	III	3.3
Trebon	I	Etofenprox – CAS no: 80844-07-1	III	3.1
Acetamprid	I	Acetamiprid – CAS no: 135410-20-7	III	2.9
Captan	F	Tetrahydrophthalimide – CAS no: 85-40-5	-	2.9
Carbofuran	I	Carbofuran – CAS no: 1563-66-2	III	2.8
Delta	I	Deltamethrin – CAS no: 52918-63-5	III	2.8
Loyant	H	Florpyrauxifen-benzyl – CAS no: 1390661-72-9	IV	2.7
Moncron	I	Monocrotophos – CAS no: 6923-22-4	II	2.5
Transform	I	Sulfoxaflor – CAS no: 946578-00-3	IV	2.0
Other	-	-	-	4.2

I = Insecticide, F = Fungicide, H = Herbicide.

1.02 ±0.021 ppm) 5% were positive for Tebuconozole (0.09 ±0.007- 0.183 ±0.041 ppm). No detectable levels of Profenofos, Chlorpyrifos or Chlorentroniliprole were found in the tested vegetable samples. Noticeably, 15% of brinjal samples (5% of all conventional food samples tested) exceeded the WHO maximam Residue Level (MRL) for thaimethoxam in vegetables (0.3 ppm).

Concentrations of pesticide residues detected in vegetable samples grown in the NCP are summarized in Table 4.

The result of this study clearly suggests that vegetables available for human consumption can contain hazardous levels of pesticide. This finding is supported by recently published studies carried out in Sri Lanka. Pandipperuma *et al.* (2020) reported that 5 brinjal samples collected from various places in Batticaloa district, Sri Lanka tested positive for Profenofos. More importantly, the residue levels in all these samples exceeded the EU MRL value for profenofos (0.05 ppm). However, none of the okra samples tested in the same study were found positive for any pesticide residue. Altogether, these findings suggest that profenofos can be one of the frequently used pesticides in brinjal

Table 3. Pesticide residue analysis data on three types of vegetable samples grown in the NCP.

Vegetable	Name of pesticide									
	Thiamethoxam		Tebuconazole		Profenofos		Chlorpyrifos		Chlorantraniliprole	
	Number of + samples	%	Number of + samples	%	Number of + samples	%	Number of + samples	%	Number of + samples	%
Bitter gourd (N = 40)	2	5	ND	-	ND	-	ND	-	ND	-
Brinjal (N = 40)	7	17.5	2	5	ND	-	ND	-	ND	-
Angled luffa (N = 40)	6	15	ND	-	ND	-	ND	-	ND	-
Organic certified vegetables (N = 42)	ND	-	ND	-	ND	-	ND	-	ND	-

ND = Not Detected; (+) = Positive.

cultivation in Sri Lanka and farmers seem not to follow the safe handling practices when using this pesticide.

Even though there are only limited number of studies done on pesticide residue analysis in vegetables, the existing data provide enough evidence to suggest that wide variety of vegetables grown in Sri Lanka using conventional farming techniques can be contaminated with hazardous levels of pesticides. For example, Gamlath *et al.* (2021) reported that from 397 fruits, 199 vegetables and 85 green-leave samples collected from all over Sri Lanka, 10.08% fruit samples, 11.56% vegetable samples and 41.18% green-leave samples were positive for multiple pesticide residues exceeding their MRLs. Moreover, Aravinna *et al.* (2008) reported that from various vegetable samples collected from upcountry region of Sri Lanka, 4.4% (n = 90) of cabbage, 5.6% (n = 51) of bean samples exceeded the MRLs for Chlorpyrifos. In the same study, they have also detected various other pesticides such as Carbaryl, Fipronil, Profenofos, Permethrin, Deltamethrin, and Pirimiphos-Methyl in cabbage, leek, lettuce, and beans samples at below MRLs. Another study done by Alwis *et al.* (2006) revealed that from 144 mukunuwenna (*Alternanthera sessilis*) samples collected from various locations in Colombo district, 15.3%, 4.9%, 4.2%, 3.8%, and 0.7% samples were positive for Chlorpyrifos, Captan, Profenofos, Permethrin, Diazinon and Oxyfluorfen respectively.

When considering published data on farmers' knowledge and handling practices of pesticides, it is obvious that hazardous pesticide residue levels in vegetables is mainly due to different types of malpractices followed by farmers during handling pesticides. Over the past few years, it has been consistently reported by different researchers that farmers in Sri Lanka show a high tendency to misuse of pesticides due to various reasons. Based on a survey study among 246 upcountry vegetable farmers, Sumudumali *et al.* (2021) reported that most of the farmers tend to use pesticides as a precautionary safety measure even before any pest or disease symptoms emerge. In a similar study, Pandipperuma *et al.* (2020) reported that 90% of the farmers in Batticaloa district (n = 1200) didn't follow the recommended practices while applying pesticides. Srikrishnah *et al.* (2013) reported that around 90% of the farmers in Uwa and Central provinces (n = 387) apply more than the recommended pesticide dosage and frequency,

Table 4. Concentrations of pesticide residues detected in vegetable samples.

Vegetable type	Pesticide	Concentration (ppm)
Bitter gourd sample 1	Thiamethoxam	0.615 ± 0.031
Bitter gourd sample 2	Thiamethoxam	0.112 ± 0.042
Brinjal sample 1	Thiamethoxam	0.340 ± 0.074
Brinjal sample 2	Thiamethoxam	0.458 ± 0.021
Brinjal sample 3	Thiamethoxam	0.528 ± 0.063
Brinjal sample 4	Thiamethoxam	0.215 ± 0.065
Brinjal sample 5	Thiamethoxam	0.643 ± 0.070
Brinjal sample 6	Thiamethoxam	1.020 ± 0.021
Brinjal sample 7	Thiamethoxam	0.338 ± 0.051
Brinjal sample 8	Tebuconazole	0.091 ± 0.007
Brinjal sample 9	Tebuconazole	0.183 ± 0.041
Angled luffa sample 1	Thiamethoxam	0.128 ± 0.021
Angled luffa sample 2	Thiamethoxam	0.400 ± 0.048
Angled luffa sample 3	Thiamethoxam	0.869 ± 0.082
Angled luffa sample 4	Thiamethoxam	0.105 ± 0.023
Angled luffa sample 5	Thiamethoxam	0.225 ± 0.041
Angled luffa sample 6	Thiamethoxam	0.297 ± 0.053

while more than 89% of them harvest their produce before the recommended pesticide-free pre-harvest interval. Pathirana *et al.* (2015) reported that the majority (>90%) of Sri Lankan farmers dispose empty pesticide containers unsafely to crop land and water bodies.

In addition to hazardous levels of pesticide residues in vegetables, another dangerous consequence that can arise from such malpractice is the occurrence of high levels of pesticide residue in almost all constituents of the environment. For example, the average chlorpyrifos concentration in both fresh ground and surface water samples collected from places near agricultural lands during vegetable cultivation periods in Kandy district were 0.63 and $0.52\,\mu\mathrm{g\,L}$ respectively (Menike *et al.* 2012). Another study revealed that pesticide contaminations were higher in the wet season than the dry season in Deduru Oya river basin (Jayasiri *et al.* 2022).

Based on published research data, the global scenario with respect to pesticide residues in food commodities does not seem to be satisfactory. Many recently published studies by various countries around the world reveal that they too are facing great challenges regarding food safety due to pesticide residues (Santarelli *et al.* 2018, Xu *et al.* 2018, Park *et al.* 2022). In a study that was done using 960 vegetable samples collected from Incheon, South Korea, about 9.5% of vegetable samples contained various pesticide residues, and 16 samples (1.7%) had residues exceeding the Korean maximum residue limit (MRLs) (Park *et al.* 2022). Most frequently found pesticide residues in this study include chlorfenapyr, fludioxonil, pyridalyl, hexaconazole, and procymidone.

Another study conducted in Chile and Mexico revealed that average pesticide residue level in vegetables in Mexico is higher than that of Chile, where Chlorpyrifos and dimethoate are more prominent in vegetables grown in Mexico. In a massive study that was conducted in China during 2014 to 2016 using 20,496 food samples, it was revealed that 8.2% of the samples are positive for Carbendazim, a fungicide and a human carcinogen. Cowpeas, celery, beans with pods, lettuces, cucumbers, and leeks were among the vegetable types that were found to be positive for Carbendazim more frequently (Xu *et al.* 2018). However, Santarelli *et al.* (2018) reported that only 0.67% of the tested leafy green vegetable samples (n = 602) collected from various places in Italy were positive for pesticide exceeding their MRLs, which is a satisfactory situation compared to other countries mentioned here.

Customers are showing more interest in purchasing organic certified vegetables nowadays as such vegetables should contain no or very low levels of harmful pesticides theoretically. However, in Sri Lanka, organic food commodities are sold at relatively higher prices compared to their conventional counterpart (Ediriweera *et al.* 2007). Unfortunately, over the last few years, many cases have been reported from various parts of the world where customers have been deceived by selling conventional food as organic food (Food Fraud Advisors, 2020, Genetic Literacy Project, 2021). Recently published study data by Manuben *et al.* (2022) and Kazimierczak *et al.* (2022) also revealed that 12.2% and 7.3% of organic certified vegetable samples brought from Southern Luzon, Philippines, and vegetables marketed in Poland were positive for pesticides, while some samples exceeded MRLs for certain pesticides — suggesting that there is a high chance for organic food customers to get deceived in Sri Lanka as well.

Therefore, regular inspection of the authenticity of organic produce is extremely important at retailer level to avoid such fraudulent activities. However, the data obtained in this study revealed that none of the organic food samples tested contained detectable levels of pesticides. Hence, it can be assumed that organic vegetable farmers in Sri Lanka adhere to proper organic farming practices and organically grown vegetables are comparatively safe with respect to pesticide residues.

CONCLUSION

Based on the results of this study, it can be concluded that vegetable farmers in the NCP use many pesticides, mainly insecticides containing a wide variety of active ingredients. Further, brinjal, bitter gourd and angled luffa grown in the NCP using conventional farming methods can contain harmful levels of pesticides compared to the vegetables grown according to organic farming methods. Brinjal reported to contain harmful levels of pesticides at a higher frequency than bitter guard and angled luffa. Therefore, it can be suggested that Sri Lanka need to maintain regular and frequent inspections to examine pesticide residue levels in vegetables produced in the NCP in order to assure food safety. Training and awareness programs on pesticide handling practices and consequences of misapplication of pesticides for the farmers can be useful to improve the food safety of the vegetables produced in the NCP.

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