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Pesticide Use in Market Gardening and Perceived Risk of Consumers Exposed to Pesticide Residues

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A B S T R A C T

Pesticides are commonly applied in market gardening to improve productivity and pest control. Pesticide residues could be persistent in vegetables and generate a potential health hazard for consumers. This study has been carried out in Tunisia to assess the perceived risk of consumers exposed to pesticide residues remaining in vegetables. Two surveys with different questionnaires were conducted among 30 market gardeners and 50 households located in the Djebeniana delegation (Sfax governorate, Tunisia) in order to analyze the phytosanitary practices of farmers on the one hand, and to better understand the attitude related to vegetable consumption and awareness on pesticide residues, on the other hand. The results revealed that various phytosanitary products have been used by market gardeners (43 commercial products containing 39 different active substances (AS)). Among these AS, abamectin and methomyl are considered as highly hazardous according the WHO classification. According to the behavior of pesticides in plants, more than half of the AS. (54%) are systemic and can be absorbed by the plant and moved around in its tissues. Furthermore, the majority of the surveyed farmers had never undergone agricultural training, which is a real handicap with respect to good phytosanitary practices. After applying pesticides, the pre-harvest interval was regularly not respected by almost half of the interviewed market gardeners. In addition, the study showed that all consumers washed their vegetables before consumption, but more than half of the respondents (54%) wash their vegetables for less than a minute (simply passing them under running water). In the light of these results, it appears that consumers may be exposed to pesticide residues from vegetables on the Tunisian market, with potential effects on their health.

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Introduction

In Tunisia, market gardening plays a strategic role in providing food security and meeting the demands of consumer markets. Tunisia's market gardening accounts for 15.3% of the total agricultural production (excluding fisheries) (Chebbi et al., 2019). It is mainly located in coastal areas and extends towards the centre of Tunisia where water reserves (dams, artificial lakes and wells) are located. The vegetable sector exceeded 151 thousand hectares, with a national production of around 3.6 million tons (Chebbi et al., 2019). The main vegetables produced are tomato (39%), watermelon (15%), onion (12%), potato (11.5%) and chili pepper (10%) (GIL 2015). Most of these vegetables are intended to supply the local market and generate a surplus for export.

However, vegetable crops are subject to various pests and diseases that can cause yield loss. Therefore, Tunisian farmers more commonly use phytosanitary products in order to increase production and reduce pest pressure. They considered that these products plays irreplaceable role to achieve an economically viable production levels, to meet consumer market demands and to guarantee quality and quantity of commodities. Despite their popularity and their extensive use, pesticides can pose major health risks (Upadhayay et al., 2020) to farmers (operators and workers), consumers, bystanders and residents. In this regard, several studies have reported the relation between pesticide use and several health effects and diseases (Mostafalou and Abdallahi, 2013; Sabarwal et al., 2018;

Ahouangninou et al., 2019), such as the development of certain types of cancer (Thongprakaisang et al., 2013; Mehmood et al., 2020), neurological diseases (Brouwer et al., 2017; Li et al., 2014), reproductive disorders (Anifandis et al., 2018), respiratory problems (Mamane et al., 2015), etc.

Similar to other developing countries, the pesticide sector is very poorly regulated in Tunisia. Only the terms and conditions are set for obtaining approval and authorization to sell commercial pest control products. Concerning the protection of humans and the environment against pesticides during and after their application on crops, there are no explicit laws yet (Phytosanitary Index, 2020). Moreover, the monitoring of residues in foodstuffs is not yet carried out on a regular basis. This explains why vegetable crops are regularly treated until harvest. Vegetables are marketed without respecting the pre-harvest interval (PHI). As a result, pesticide residues present in vegetables can generate a potential health risk for consumers (Chourasiya et al., 2015; Darko and Akoto 2008; Elgueta et al., 2017; Nougadère et al., 2012). Nevertheless, food processing and household food manipulation such as peeling, washing, blanching, and cooking could be effective in removing most of the pesticide residues that are found on vegetable surfaces or that have penetrated into raw crops (Chavarri and Herrera, 2005 ; Fenoll et al., 2007 ; Keikotlhaile et al., 2011 ; Ramezani and Shahriari, 2014 ; Leili et al., 2016; Kumari and John, 2019).

This study aimed to analyze the phytosanitary practices of farmers and the different risks related originating from exposure to pesticide residues present in vegetables in Tunisia.

Materials and Methods

Study Area

The study was carried out in Djebeniana Delegation, more precisely in seven localities (Djebeniana Center, El Ajenga, Ellouza, Mjedba, Msetriya, Nwayel, and Ouled Bousmir). Djebeniana is a commune in the Sfax Governorate, Tunisia (Figure 1). Located between 35°01′51″N and 10°54′14″E, it is 35 km north of Sfax on the Mediterranean coastal plain. In 2014, the number of people living in this commune was 49678 (INS, 2015). Governorate of Sfax is the economic center of Tunisia and the second most populated city after the capital. Delegation of Djebenianan was selected as it represents a town with an agronomic vocation, knowing to be the main vegetables supplier of the Sfax governorate.

Study Design

In order to evaluate phytosanitary practices and to perceive the risk of the consumers, two original questionnaires were developed separately, one for the market gardeners and one for the consumers located in Djebeniana delegation. The study was conducted between January and June 2020. It was administered by the same investigator and consisted of face-to-face interviews with participants. The interview has always begun with the presentation of the framework of the visit. The local language (Arabic Tunisian) was used for respondents and the questionnaire was completed in real live on site in French by the investigator. For each interview, a period of 10 to 15 minutes was devoted for consumers and of 20 to 30 minutes for farmers depending on the number of questions in the questionnaire.

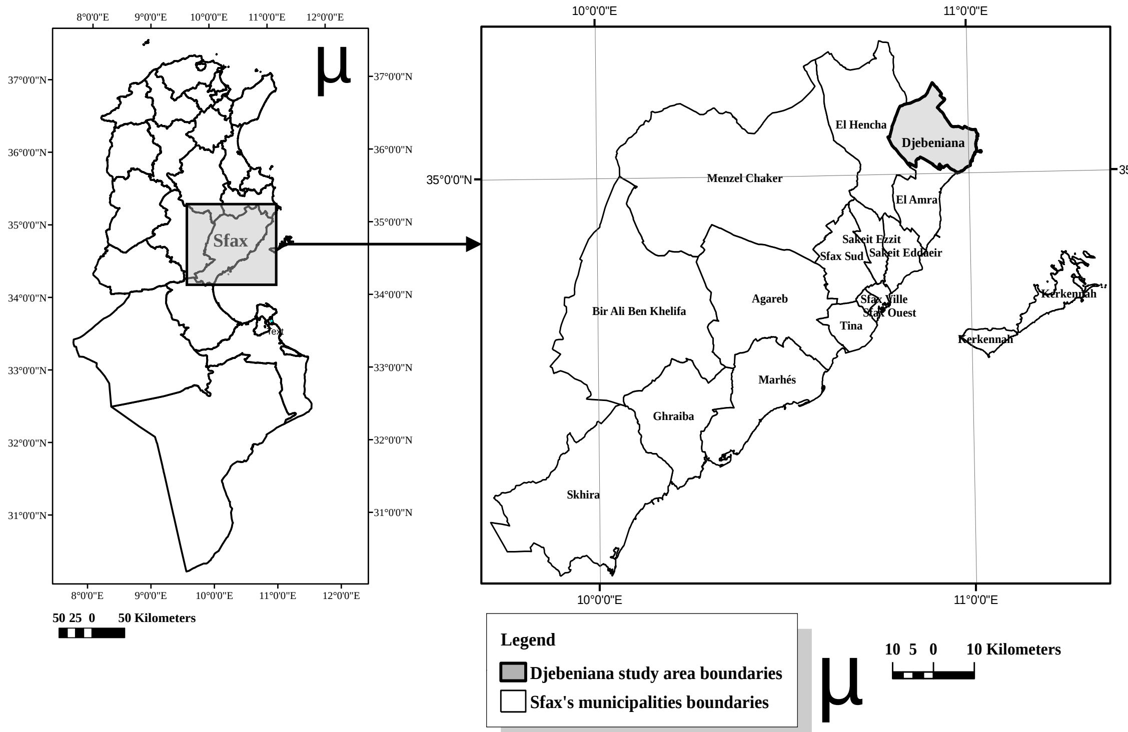


Figure 1. Location of the study area: Djebeniana Delegation, Sfax Gouvernorate, Tunisia. These maps were produced using ArcMap Version 10.6.1 (ESRI, 2018)

A first survey was conducted among 30 market gardeners, which were randomly chosen from professionals located in Djebeniana delegation with the aim to investigate the professional practices and pesticide uses. Farmers were contacted with the help of the heads of Extension Territorial Cells (ETC) and were met individually. Only market gardeners present during our visit and having freely accepted to participate in our study were included. The size of the group was considered large enough to be representative as all of the market gardeners had the same type of activities. They were asked to answer a detailed questionnaire on their socio-demographic data of their vegetables crops, and their management of plant protection products (PPP).

To have a better understanding of vegetable consumption and the attitudes towards pesticide residues, a total of 50 consumers participated voluntarily in the second They were randomly selected from the inhabitants living in the Djebeniana delegation. The 50 participants were invited to answer questions related to (i) socio-demographic data (identity, age, sex, level of education, etc.), (ii) vegetable consumption (purchase of vegetables, origin of vegetables consumed, frequency of consumption, etc.) and (iii) consumer attitude (purchase of organic and / or conventional products, factors explaining purchasing and consumption behavior, washing and peeling of vegetables, etc.).

Data Processing and Analysis

The data collected was entered and tabulated manually in the EXCEL 2016 spreadsheet according to the variables collected. SPSS software version.24 was used for statistical analysis of the data. Statistical parameters such as means and percentages were calculated and used to construct histograms and frequency distribution tables.

The list of the used plant protection products used was completed by examining the packaging and consulting the 2018 phytosanitary index. The data collected on the various AS, their physicochemical and toxicological properties are compiled from various databases (EU pesticide data base, 2021; PPDB data base, 2021).

Results and Discussion

Hazard Identification and Characterization

Phytosanitary practices used by market gardeners

According to the survey, the majority of the 30 interviewed market gardeners were predominantly owners of plots (70%), adult males (93%) aged from 25 to 58 years (mean age: 42 ± 9 years). Regarding their level of education, 7% of the farmers surveyed are illiterate. The level of education attained by the majority of respondents is limited to primary education (53%). This is explained by the fact that they have been in an agricultural environment since birth and have inherited this profession from their ancestors. Thirty percent of them have completed their secondary education, while only 3 people have graduated from higher agricultural education (one respondent) and non-agricultural education (2 respondents). Almost all of the interviewed market gardeners had no agricultural training, but their average work experience was about 20 years. The low level of education of the agricultural workforce has also been reported in Tunisia (Toumi et al., 2018) and by many studies in other developing countries, such as Algeria (Soudani et al., 2020) and Burkina Faso (Naré et al., 2015; Son et al., 2016).

The average farm size was approximately 6 ± 4 ha. The main crops in the study area were chili peppers (100%), cucumbers (70%), and tomatoes (43%). Chili peppers were grown in greenhouses (70%), open fields (10%), or both (20%). Cucumbers and tomatoes are grown in the open field. Other crops included watermelon (27%), melon (7%), potato (7%), zucchini (3%) and parsley (3%).

Generally, these vegetables are sold on the spot in the plots and then distributed towards local markets. If the pesticides are used in accordance with the recommendations on the commercial product label, their residues should not exceed the maximum residue levels (MRLs) (EFSA, 2021).

The obtained results showed that most of the vegetable farmers (73%) have the habit of reading the labels before using pesticides, but all of them declared that they not always understand the content. Almost 27% of the farmers have never read the labels before using PPPs because they cannot understand the pictograms and instructions mentioned on the PPP packages due to their low level of education. Ríos-González et al. (2013) showed the importance of the level of education on farmers' behaviors and attitudes towards these toxic products. Although all farmers (93%) stated that they follow the recommended dose, two-thirds (67%) decide the amount to use based on their experience or by asking other farmers (20%), and only half asking advice from a supplier (50%), or following the advice of an agriculture agent (3%). More than 56% of farmers sometimes mix PPPs to save time and especially to reduce the cost of tractor rent even if it is not authorized by the authority. To quantify the dose of pesticides to be applied, farmers use a cap (53%) or a graduated dosing device (47%).

Regarding the pre-harvest interval, almost half of the interviewed market gardeners do not respect it and they harvest about 3 days of treatment instead of the recommended days mentioned in the labels. According to the farmers, the main reasons for not respecting the pre-harvest interval are that the vegetables are harvested every 2 days and they have to treat them to avoid quality deterioration. Farmers are always exposed to the instability of market prices for vegetable because the higher the market price, the more the farmer rush to sell his products, even if they already did the treatment the day before or a few days before harvest. Therefore, pesticide residues remaining on vegetables can create potential health risks for workers entering previously treated areas to perform harvesting tasks (Toumi et al., 2019) and for consumer health (Darko et al., 2008; Nougadère et al., 2012; Chourasiya et al., 2015; Elgueta et al., 2017)

The survey revealed that more than 94% of farmers did not receive any training about the proper use of pesticides and information on pesticide residues in vegetable products. Only 6% of them received information on pesticide residues in vegetable products through the media and contacts with authorities by an agent of Extension Territorial Cells (ETC).

Pesticides Applied on Vegetables

The survey conducted among market gardeners revealed the use of various phytosanitary products (43 commercial formulations) in order to control harmful pests and prevent crop yield or product damage. These products are composed of 39 different AS, of which 7 are not approved (carbendazim, chlorpyriphos-methyl, chlorothalonil, diafenthiuron, methomyl, thiamethoxam, thiocyclamhydrogen oxalate) to be used in the European Union, while the products based on these AS are still authorized in Tunisia.

Biological Activities

Pesticides commonly used were insecticides (50%), followed by fungicides (33%), acaricides (5%), and herbicides (2%). The rest of the commercial products have two biological activities (insecticide+acaricide), fungicide+acaricide) or (fungicide+acaricide). More than 70% of the market gardeners use the insecticide Vertimec (AS: abamectin), 50% of them use Mospilan (AS: acetamiprid) and Pegasus (AS: diafenthiuron). While, Systhane (AS: myclobutanil) (50%) and Microcrops (AS: sulphur) (67%) are the most used fungicides (Table 1).

Toxicological Properties

The AS can be classified according to their toxicity. The obtained results showed that 15 AS (azoxystrobin, propiconazole, chlorothalonil, etc.) cause acute toxicity (Table 1). Moreover, different AS have chronic effects, such as fertility problems and cancer, etc.

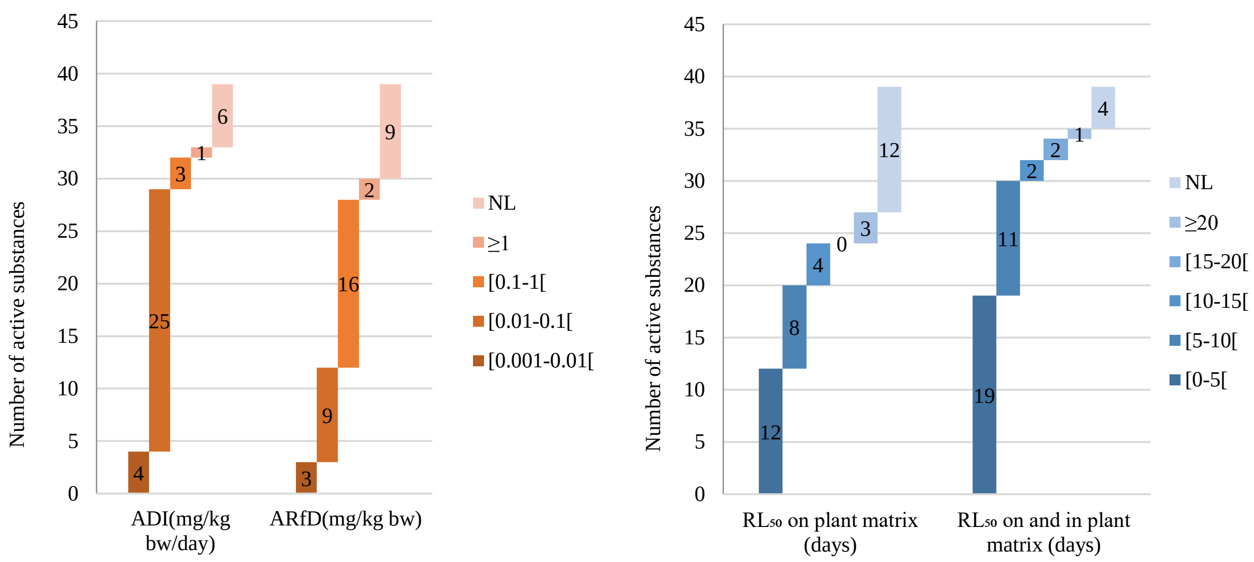
Regarding the WHO classification, abamectin and methomyl are considered as highly hazardous (WHO class Ib). Whereas, 31% of AS have an acute hazard in normal use (WHO class U) and 28% are classified as slightly hazardous (WHO class III), 26% are considered as moderately hazardous (WHO class II).

In order to assess whether the residue level expected to occur in vegetables does not lead to unacceptable consumer risk, cultural dietary information (consumed vegetables, quantity, frequency, etc.) is combined with available residue data to assess potential residue intake by consumers, which is compared to toxicological reference values. The toxicological reference values used in dietary risk assessment are the Acceptable Daily Intake (ADI) and the Acute Reference Dose (ARfD). The more this toxicological reference value is lower, the more the AS is toxic. Three and 4 AS have an ARfD and ADI values below 0.01 mg kg^{-1} bw and 0.01 mg kg^{-1} bw day^{-1} respectively (Table 1, Figure 2a).

Physicochemical Proprieties

Understanding the behavior of pesticides used during vegetable cultivation is important for effective and safe application in order to minimize the risk for consumers (Łozowicka et al., 2020). According to the obtained results, more than half of AS (54%) are systemic that can be absorbed by the plant and moved around in its tissues. Therefore, consumers exposed to these types of pesticides present in vegetables may be at increased risk with possible effects on their health.

Data on dissipation rates tend to be highly variable, depending on the physicochemical behavior of the AS, the type of plant matrix, the overall plant architecture (e.g., leaf shape, fruiting habits), its texture (e.g., presence of waxes or surface hairs), and if the dissipation rate is measured on the crop surface or if it has been absorbed into its flesh (Lewis and Tzilivakis, 2017). Concerning dissipation rate RL_{50} on and in plant matrix, the majority of AS (77%) have values below 10 days while 5 pesticides (mefenoxam, cyproconazole, tebuconazole, chlorpyrifos-methyl, pyriproxyfen) have values equal or greater than 10 days with a maximum reaching 65.5 days for the insecticide pyriproxyfen. While, according to the dissipation rate RL_{50} on plant matrix only, almost half of AS (51%) have RL_{50} values below 10 days. The AS thiophanate methyl, spinosad and penconazole have the highest value (30, 49 and 65.6 days, respectively) (Table 1, Figure 2b). The dissipation rate of a pesticide after application provides valuable information to assess the behavior of residues and estimate the preharvest interval (PHI) (Malhat et al. 2016).



(a) (b)

Figure 2. Ordering of 39 AS used by the 30 surveyed market gardeners according to their (a) toxicological reference values (ADI and ARfD) and (b) to their dissipation rate RL_{50} values on plant and on and in plant. NL = Not listed

Table 1. List of active substances used by the 30 market gardeners in studied locations, classified using their biological activity, commercial product, their behavior in plants (systemic (S) or non-systemic (NS)), their dissipation rate RL_{50} values (PPDB, 2021), toxicological properties (according to CLP Classification (EU pesticide data base, 2021) and WHO classification (PPDB, 2021), their ADI and ARfD values (EU pesticide data base, 2021), and the number of farmers use this active substance

Commercial product	Active substances	T	D1	D2	Toxicity		ADI	ARD	N
					CLP	WHO			
Acaricide									
Apollo 50	Clofentezine	NS	-	-	-	III	0.02	0.01	1
Jalisco	Hexythiazox	NS	12	4.8	-	U	0.03	0.009	1
Fungicide									
Amistar Xtra	Azoxystrobin	S	7.6	8.0	H331	U	0.2	0.2	1
	Cyproconazole	S	13.9	11.5	H301, H360D, H373	II	0.02	0.02	1
Avantage CT	Chlorothalonil	NS	5.5	5.0	H317, H318, H330, H335, H351	U	0.015	0.05	1
	Dimethomorph	S	-	5.4	-	III	0.05	0.6	1
Clip	Famoxadone	NS	12.3	9.8	H373	U	0.006	0.1	1
	Mancozeb	NS	5.6	5.3	H317, H361d	U	0.023	0.15	1
Dithane M 45	Mancozeb	NS	5.6	5.3	H317, H361d	U	0.023	0.15	1
Galben M	Benalaxyl	S	-	3.2	-	III	0.04	0.5	1
	Mancozeb	NS	5.6	5.3	H317, H361d	U	0.023	0.15	1
Luna experience 400 SC	Fluopyram**	S	-	7.1	-	NL	0.012	0.5	1
	Tebuconazole	S	2.7	16.1	H302, H361d	II	0.03	0.03	1
Mandarin	Carbendazim	S	5.6	8.4	H360fd	U	0.02	0.02	1
Methyl-T	Thiophanate-methyl	S	29.6	4.2	H317, H332, H341	U	0.08	0.2	3
Microcrops	Sulphur***	NS	-	-	H315	III	-	-	16
Milor M	Metalaxyl	S	9.2	5.7	H302 ; H317	II	0.08	0.5	1
	Mancozeb	NS	5.6	5.3	H317, H361d	U	0.023	0.15	
Nimrod	Bupirimate	S	3.5	-	H317, H351	III	0.05	-	2
Previcur 607	Propamocarb	S	4.75	8.5	-	U	0.29	1.0	3
Promess									4
Ridomil GOLD MZ 68 WG	Mancozeb	NS	5.6	5.3	H317, H361d	U	0.023	0.15	1
	Mefenoxam	S	-	10.8	-	-	-	-	1
Systhane 240 EC	Myclobutanil	S	-	4.1	H302, H319, H361d	II	0.025	0.31	20
Topaze 100	Penconazole	S	65.6	6.6	H302,H361d	III	0.03	0.5	1
Herbicide									
Fusilade Max	Fluazifop-P- Butyl	S	-	3.9	-	III	-	-	1
Insecticide									
Aakomectine	Abamectin*	S	12.7	3.0	H300, H330, H361d, H372	Ib	0.0025	0.005	5
Amiral	Indoxacarb	NS	3.4	1.6	H301, H317, H332, H372	II	0.006	0.125	6
Azar	Azadirachtin*	S	3.8	3.6	-	NL	0.1	0.75	1
Confidor	Imidacloprid	S	2.5	4.9	H302	II	0.06	0.08	1
Cypercal 250 EC	Cypermethrin	NS	5.1	4.7	H302, H332. H335	II	0.05	0.2	4
Delta	Deltamethrin	NS	6.5	3.0	H301, H331	II	0.01	0.01	2
Deltacal									1
Evisect	Thiocyclam hydrogen oxalate	NS	-	-	-	II	-	-	1
Kuik 400 SP	Methomyl	S	3.0	4.0	H300	Ib	0.0025	0.0025	2
Lannate 20 L									1
Lannate 25									1
Laser 240 SC	Spinosad*	NS	49	2.5	-	III	0.024	-	1
Mospilan 20 SL	Acetamiprid	S	6.3	6.2	H302	II	0.025	0.025	15
Pegasus 500 SC	Diafenthiuron****	NS	3.1	3.0	-	III	-	-	15
Potenza 1.8	Abamectin*	S	12.7	3.0	H300, H330, H361d, H372	Ib	0.0025	0.005	3
Proximo EC	Pyriproxyfen	NS	-	65.5	-	U	0.05	1	1
Radiant 120 SC	Spinetoram	NS	-	2.62	-	U	0.025	0.1	1
Reldan 40 EC	Chlorpyrifos-methyl****	NS	2.4	19.1	H317	III	-	-	1
Renova	Thiamethoxam	S	3.2	4.4	H302	NL	0.026	0.5	2
Rufast 7.5 EW	Acrinathrin****	NS	-	2.6	-	U	0.01	0.01	3
Takumi 20 WG	Flubendiamide	NS	2.9	2.9	-	III	0.017	0.1	7
Tracer 240 SC	Spinosad*	NS	49	2.5	-	III	0.024	-	1
Vertimec	Abamectin*	S	12.7	3.0	H300, H330, H361d, H372	Ib	0.0025	0.005	22 6
Voliam Targo 063 SC	Chlorantraniliprole	NS	1.3	4.3	-	U	1.56	-	6

T: Type; D1: Dissipation rate RL_{50} on plant matrix; D2: Dissipation rate RL_{50} on and in plant matrix; CLP: CLP classification; WHO: WHO Classification; ADI: ADI (mg/kg bw/day); ARD: ARfD (mg/kg bw); N: Number of farmers citations

Consumers Attitudes and Their Eating Habits

Socio-demographic data of surveyed consumers

The survey revealed that the majority of the 50 interviewed consumers were predominantly adult females (86%) aging 20 to 87 years (mean age: 45 ± 16 years). The majority of respondents live in families (92%) with an average of 4 people per household. Only 8% live alone and the majority of them are male. Assessment of literacy status showed that more than half of the consumers were illiterate (30%) or had obtained a primary (14%) or secondary (22%) level. Only 34% of them were graduates (Figure 3).

Consumers' behaviors and concerns on fresh vegetable

Concerning purchasing vegetables, 40% of respondents declared to do the shopping themselves; while 60% reported that another family member (daughter, son, husband, or father) is responsible for this task (Table 2).

The majority of the surveyed consumers bought vegetables at the Souk (96%) or at a local store (fruit and vegetable shop) (74%) which is consistent with Tunisian traditions since the majority of Tunisians live in delegations. Only 11 consumers reported to buy their vegetables from supermarkets, which is explained by the fact that there are only two supermarkets in Djebeniena (Monoprix and Aziza) and the vegetables purchased by respondents are generally from supermarkets located in Sfax (downtown).

Regarding purchasing and consumption behavior, 80% of the surveyed consumers did not buy vegetables as often as they would like because of the high price. The latter is considered to be the main obstacle to vegetable consumption. Product quality is a primary criterion for choosing vegetables by 42% of respondents. A quarter of the consumers did not buy vegetables because of bad taste. Other factors that can also limit the purchase of vegetables are lack of time and know-how needed to prepare them (18%) and the perishable nature of products (10%). Nevertheless, none of the participants was interested in the origin of the purchased vegetables and the traceability of the products from the production chain to the distribution chain.

Regarding the origin of vegetables, 70% of the surveyed consumers responded that they never know the origin of the vegetables while only 30% declared that they sometimes know it. This is due to the absence of a label indicating the vegetable origin in the Souk or in the local stores.

Of the 50 surveyed consumers, 70% had never purchased organic products, while 94% of the participants indicated that they mostly consume conventional vegetables. These results can be explained by the high cost and the absence of a market for organic products in the delegation of Djbeniana.

Table 3 represents the frequency of consumption of vegetables. More than 80 % of the respondents eat 4 vegetables (garlic (92%), tomatoes (90%), chili peppers (88%), and onions (82%) every day in agreement with the last National Institute of Statistics (INS) study which reported potatoes, tomatoes, chili peppers, and onions as the most consumed vegetables in Tunisia in 2015 (INS, 2018). These most consumed vegetables are the basis of Tunisian dishes and are part of culinary habits (Khaldi et al., 2009). The regular supply of these products is linked to the development of crops under shelter and may explain these trends, especially tomatoes and chili peppers. In addition, carrots, cucumbers, and potatoes are consumed daily by 46%, 60%, and 62% of respondents. The diet of the studied population is healthy from a nutritional point of view since, according to WHO recommendations, the consumption of at least 400 g, or five portions, of fruits and vegetables per day reduce the risk of disease non-transmissible and helps to ensure a sufficient daily intake of dietary fiber (WHO, 2018).

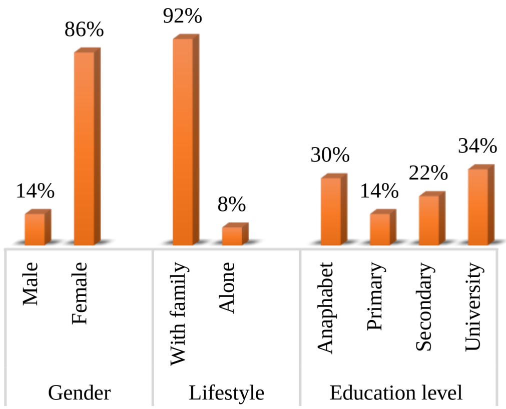


Figure 3. Social and demographic characteristics of 50 surveyed consumers

Table 2. Behaviors and concerns on fresh vegetable of 50 surveyed consumers

Questions	Multiple choice answers		Frequency (%)
Who is going shopping?			
	You		40
	Someone else		60
Where do you buy your vegetables?*			
	Central market		2
	Directly to producers		10
	Market (Souk)		96
	Convenience stores		74
	Supermarket / Hypermarket		22
What limits your intake of vegetables?*			
	The price		80
	The perishable nature of fresh products		10
	The time and know-how necessary for their preparation		18
	The taste		24
	The quality		42
	The origin		0
Do you know the origin of bought vegetables?			
	Yes		30
	No		70
Do you usually buy organic or conventional products?			
	Organic products	Never	70
		Sometimes	30
		Always	0
	Conventional products	Never	0
		Sometimes	6
		Always	94

* answer with multiple choices

Table 3. Frequency of vegetable consumption (daily, weekly, monthly or never) by the 50 surveyed consumers

Vegetables	Frequency of consumption (%)			
	Daily	Weekly	Monthly	Never
Garlic	92	8	0	0
Tomatoes	90	10	0	0
Chilli Peppers	88	12	0	0
Onions	82	18	0	0
Potatoes	62	38	0	0
Cucumber	60	28	12	0
Carrots	46	54	0	0
Parsley	30	66	2	2
Turnips	28	68	4	0
Chard	18	74	4	4
Fennel	14	66	16	4
Lettuce	10	44	28	18
Squash	4	78	14	4
Zucchini	4	78	12	6
Celery	4	8	44	44
Broccoli	2	2	4	92
Cauliflower	0	34	54	12
Spinach	0	6	10	84
Eggplants	0	4	40	56
Artichokes	0	0	44	56

Other vegetables (squash (78%), zucchini (78%), turnips (68%), fennel (66%) and parsley (66%)) are consumed weekly. The frequency of consumption of these vegetables is considered average, while consumption is considered to be very low for other vegetables, notably artichokes, eggplants, broccoli, and spinach since more than half of the participants stated to never consume them.

Perception and Mitigation of the Risk of Exposure by Consumers

Household methods such as peeling, washing, and cooking of vegetables were found to possibly decrease the concentration of pesticides residue (Claeys et al., 2011; Bonnechère et al., 2012a and 2012b; Sinha et al., 2012; Kim et al., 2016; Kumari and John, 2019; Ramadan et al., 2020; Hendriadi et al., 2021). The behavior of residues during processing depends on terms of the physicochemical properties of the pesticide and the nature of the process (Chung, 2018).

Peeling of vegetables

Peeling vegetables helps to remove the pesticides present on the surface, but also of the fiber, vitamins, and minerals. Peeling is a very effective technique for removing some of the pesticide residues, although some of this toxic has seeped into the flesh under the skin. The disadvantage of this technique is the loss of bioactive compounds (Yang et al., 2017).

The survey showed that 56% of the participants sometimes peeled their vegetables, while 44% reported to always peel or strip the vegetables before consumption. Some people usually peel vegetables in order to avoid ingesting traces of impurities (pesticides, waxes, preservatives, etc.). But for others, peeling is also a matter of taste, in the sense that some do not appreciate the flavor or texture of the skin of certain vegetables, but also because some skins are simply inedible (garlic, onion, potato, etc.). Nevertheless, some people think that certain vegetables should not be peeled in order to preserve the vitamins and minerals they contain and therefore they keep the skins with simple washing. In this context, a study reported that the peeling procedure reduced the amount of imidacloprid residues by 65 % from cucumber samples (Leili et al., 2016). In addition, Rawn et al. (2008) showed that captan residues decreased in apples through rinsing and peeling. Bonnechère et al. (2012b) reported that peeling of melons decreased the concentration of pesticide residues for cyromazin, carbendazim, and thiamethoxam by approximately 50% and for maneb, imazalil, and acetamiprid by more than 90%.

Washing of vegetables

Washing of vegetables serves to eliminate dust, microbes, bacteria, pesticide residues, etc., and prevents possible food poisoning. All of the interviewed consumers declared that they washed the vegetables before consumption. Only a few consumers of broccoli and garlic did not wash these vegetables before consumption.

Washing time: Pesticide residues could be greatly reduced by increasing the frequency of washing (Kim et al., 2016). All consumers washed their vegetables before consumption, but washing time varies from person to person. More than half of the respondents (54%) washed vegetables for less than one minute (just running water) while32% washed them between 1 and 5 minutes and only 7 respondents washed them for more than 5 minutes. In this context, a study demonstrated that up to 89% of pesticide residues could be removed from carrot samples by 5 min washing (Bonnechère et al., 2012c).

Washing methods: Traditional washing methods to remove debris and dirt prior to consumption have been assumed to reduce the pesticide residues. Many washing solutions such as chlorine solution, ozonated water and strong acid have been proven successful in removal of pesticide residues during commercial crop process (Ong et al., 1996; Zohair, 2001; Pugliese et al., 2004). The chemicals recommended for the purpose of removing residues are salt, baking soda, distilled vinegar and potassium permagnate (Satpathy et al., 2012). The Figure 4 shows the washing procedures of vegetables which was adopted by the 50 consumers.

The type of washing varies from one household to another: of the 50 participants, 90% washed the vegetables by rubbing with their hands. More than half of the participants soaked the vegetables and 44% of the respondents declared to add bleach. Nevertheless, the percentage of people who use vinegar and salt is very low.

Washing with water is the most common method in every household since it is considered the cheapest and simplest (Krol et al., 2000). A recent study was conducted in Iran demonstrating that washing with drinking water for 2 min led to about 51 and 43 % loss of ethion and imidacloprid residues present in cucumbers samples, respectively (Leili et al., 2016).

Reducing residue levels from vegetables is very variable depending on the surface area, thickness, the amount of wax on the cuticle, age of the residue, physicochemical properties of pesticide, and washing conditions (Tomer and Sangha, 2013; Kim et al., 2016).

Vegetable cooking

Exposure to pesticides in foodstuffs can be influenced by the cooking method or direct consumption in a fresh or raw state. Figure 5 shows the type of vegetable consumption (fresh/cooked, boiled, fried, or steamed) by the surveyed consumers for each type of vegetable. In this section, the percentage was calculated by considering only those who reported consuming these vegetables.

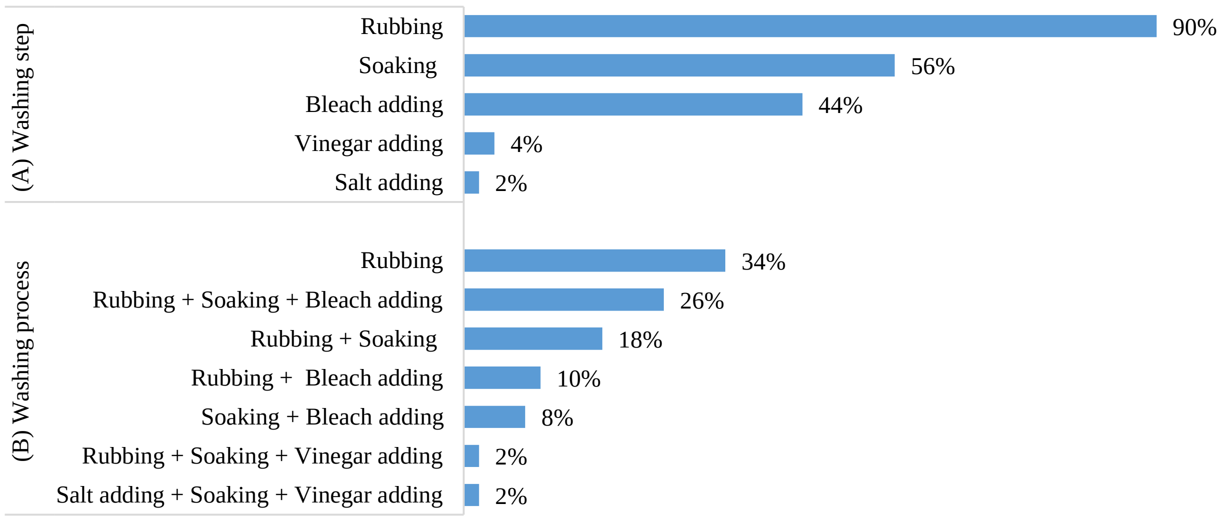


Figure 4. (A) Washing step and (B) washing process of vegetables adopted by the 50 surveyed consumers

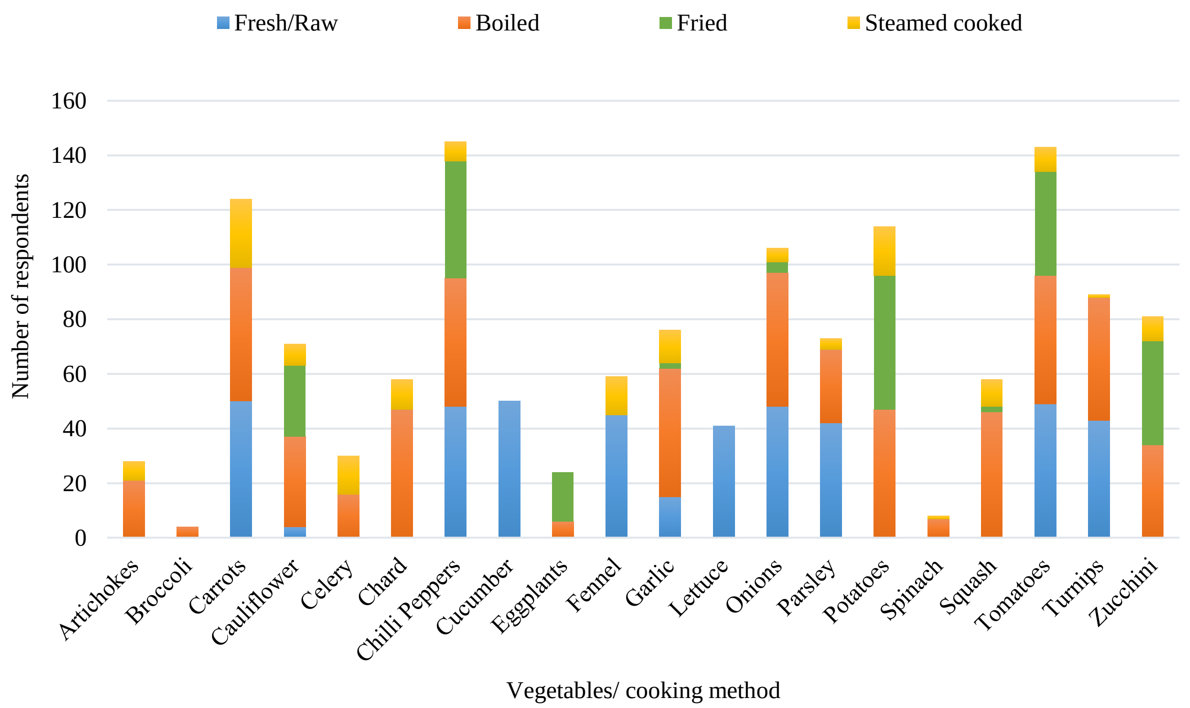


Figure 5. Cooking method (fresh/raw (blue), boiled (orange), fried (green) or steamed cooked (yellow) used for each type of vegetable by the surveyed consumers. Multiple answers were possible

The obtained results showed that vegetables mostly consumed in their fresh and/or raw state are tomatoes, chili peppers, parsley, onions, fennel, cucumbers and carrots. According farmers' surveys, vegetables are sprayed several times and up to the final harvest and are often put onto the markets without consideration of the PHI. Therefore, consuming vegetables raw (or even washed) with large amounts of pesticide residue could be unsafe (Park et al., 2016).

Nevertheless, cooking serves to decrease the amounts of pesticides present in vegetables (Keikotlhaile and Spanoghe, 2011). Several studies have reported the importance of cooking in removing pesticides from vegetables. Boiling of vegetables was found to be more effective than washing in dislodging the residues (Satpathy et al., 2012). Kaushik et al, 2009 showed that hot water blanching generally increases residue removal compared to washing and can hydrolyze substantial fractions of non-persistent compounds. Chlorpyrifos and dithiocarbamate residues on asparagus are removed at 83% and 100%, respectively, following bleaching (Chavarri et al., 2005). Other studies have shown that the washing and blanching of peppers allow removing about 90% and 88% of λ-cyhalothrin and iprodione residues, respectively (Lee and Jung, 2009). Moreover, boiling apples results in the removal of iprodione residues (Rasmusssen et al., 2003). However, the majority of studies investigated only parent pesticides and did not consider metabolites. After this household process, pesticides could be metabolised and the metabolites may be more toxic than the parent pesticides.

In contrast, another study observed that the level of pesticide residues was not reduced by microwave cooking (Bonnechère et al., 2012c).

Conclusion

In conclusion, market gardeners use a wide range of pesticides to control pests and diseases. Pesticide residues present on vegetables can constitute a potential risk to consumers and could be considered as a human health concern. The poor phytosanitary practices, the low level of farmers' educations, the lack of information on the pesticide hazard appears clearly during the interviews with market gardeners. Some home preparation procedures such as washing, peeling, and cooking could reduce residues of pesticides remaining on vegetables. According to this study, more than half of the respondents (54%) wash vegetables for less than one minute (just running water) and various vegetables are consumed raw. Moreover, over half of the used AS are systemic which can penetrate into the plant tissues and for this reason, processing methods (washing, peeling, cooking, etc.) are less effective in pesticide residual reductions.

Therefore, these results stress the need for a national dietary exposure survey in order to assess chronic, acute, and cumulative risks more realistically. Tunisian authorities should set and enforce MRLs for pesticide residues present in food commodities. In addition, an efficient program for monitoring the pesticide use conducted continuously is essential as a strategy for the management of food safety in Tunisia. Furthermore, there is an urgent need for field education for the application of good agricultural practices and awareness-raising amongst consumers on the importance of some household processing activities to remove and reduce the pesticide residue levels in vegetables. This may contribute greatly to ensuring food safety and reducing potential health problems for the consumers.

References

Ahouangninou C, Boko S, Logbo J, Komlan F, Martin T, Fayomi B. 2019. Analyse des déterminants des pratiques phytosanitaires des producteurs maraîchers au sud du Bénin. Afrique SCIENCE, 15(5):252–265.

Anifandis G, Amiridis G, Dafopoulos K, Daponte A, Dovolou E, Gavriil E, Gorgogietas V, Kachpani E, Mamuris Z, Messini C, et al. 2017. The In Vitro Impact of the Herbicide Roundup on Human Sperm Motility and Sperm Mitochondria. Toxics, 6(1):2.

Bahrouni H. 2010. Caractérisation de l'efficacité technique des systèmes de pulvérisation et des pertes de pesticides appliqués aux cultures basses dans les régions méditerranéennes : cas de la Tunisie. Thèse de Doctorat. Montpellier SupAgro et INAT de l'université de Carthage, Tunisie. P122

Bonnechère A, Hanot V, Bragard C, Bedoret T, van Loco J. 2012b. Effect of household and industrial processing on the levels of pesticide residues and degradation products in melons. Food Additives and Contaminants: Part A, 29(7):1058–1066.

Bonnechere A, Hanot V, Jolie R, Hendrickx M, Bragard C, Bedoret T, Loco JV. 2012a. Processing Factors of Several Pesticides and Degradation Products in Carrots by Household and Industrial Processing. Journal of Food Research, 1(3):68.

Bonnechère A, Hanot V, Jolie R, Hendrickx M, Bragard C, Bedoret T, Van Loco J. 2012c. Effect of household and industrial processing on levels of five pesticide residues and two degradation products in spinach. Food Control, 25(1):397–406.

Brouwer M, Huss A, van der Mark M, Nijssen PCG, Mulleners WM, Sas AMG, van Laar T, de Snoo GR, Kromhout H, Vermeulen RCH. 2017. Environmental exposure to pesticides and the risk of Parkinson's disease in the Netherlands. Environment International, 107:100–110.

Chavarri MJ, Herrera A, Arino A. 2005. The decrease in pesticides in fruit and vegetables during commercial processing. International Journal of Food Science and Technology, 40(2):205–211.

Chebbi H, Pellissier J, Khechimi W, Rolland J. 2019. Rapport de synthèse sur l'agriculture en Tunisie. CIHEAM-IAMM. Available from: https://hal.archives-ouvertes.fr/hal-02137636. [Accessed 2021 Jun 20].

Chourasiya S, Khillare PS, Jyethi DS. 2015. Health risk assessment of organochlorine pesticide exposure through dietary intake of vegetables grown in the periurban sites of Delhi, India. Environmental Science and Pollution Research, 22(8):5793–5806.

Chung SW. 2018. How effective are common household preparations on removing pesticide residues from fruit and vegetables? A review. Journal of the Science of Food and Agriculture, 98(8):2857–2870.

Claeys WL, Schmit J-F, Bragard C, Maghuin-Rogister G, Pussemier L, Schiffers B. 2011. Exposure of several Belgian consumer groups to pesticide residues through fresh fruit and vegetable consumption. Food Control, 22(3-4):508–516.

Darko G, Akoto O. 2008. Dietary intake of organophosphorus pesticide residues through vegetables from Kumasi, Ghana. Food and Chemical Toxicology, 46(12):3703–3706.

Elgueta S, Moyano S, Sepúlveda P, Quiroz C, Correa A. 2017. Pesticide residues in leafy vegetables and human health risk assessment in North Central agricultural areas of Chile. Food Additives and Contaminants: Part B: Surveillance Communications,10(2):105–112.

EU Pesticides database. 2021. European Union Pesticides database. Available from: https://ec.europa.eu/food/plant/pesticides/eu-pesticides[Accessed 2021 Dec 13].

European Food Safety Authority (EFSA). 2021. Overview of the MRL review progress under Article 12 of Regulation (EC) No 396/2005. Available from : https://www.efsa.europa.eu/sites/default/files/pesticides-MRL-review-progress-report.pdf

Farha W, Abd El-Aty AM, Rahman MdM, Jeong JH, Shin H-C, Wang J, Shin SS, Shim J-H. 2017. Analytical approach, dissipation pattern and risk assessment of pesticide residue in green leafy vegetables: A comprehensive review. Biomedical Chromatography, 32(1):e4134.

Fenoll J, Hellín P, Martínez CM, Flores P. 2007. Pesticide Residue Analysis of Vegetables by Gas Chromatography with Electron-Capture Detection. Journal of AOAC INTERNATIONAL, 90(1):263–270.

GIL (Groupement Interprofessionnel des Légumes). 2015. Filières légumes. Ministère de l'Agriculture, des Ressources Hydrauliques et de la Pêche. Tunisie.

Hendriadi A, Sulistiyorini S, Devilana MR. 2021. Pesticides Residues in Fresh Food of Plant Origin: Case Study in Indonesia. AGRIVITA Journal of Agricultural Science, 43(2).

Institut National de la Statistique(INS). 2014. Recensement Général de la Population et de l'Habitat. Recensement Général de la Population et de l'Habitat. Available from: http://ins.tn/sites/default/files/publication/pdf/RGPH%202014-V1_0.pdf. [Accessed 2021 Nov 22]

Institut National de la Statistique(INS). 2018. Enquête Nationale sur le Budget, la Consommation et le Niveau de vie des ménages 2015 : Volume B. Available from : http://ins.tn/sites/default/files/publication/pdf/consommation-2015%20V2.pdf. [Accessed 2021 Nov 22].

Jacobsen RE, Fantke P, Trapp S. 2015. Analysing half-lives for pesticide dissipation in plants. SAR and QSAR in Environmental Research, 26(4):325–342.

Kaushik G, Satya S, Naik SN. 2009. Food processing a tool to pesticide residue dissipation – A review. Food Research International, 42 (1):26–40.

Keikotlhaile B, Spanoghe P. 2011. Pesticide residues in fruits and vegetables. Pesticides—formulations, effects, fat, e:243–252.

Khaldi R, Dhehibi B, Rached Z, Dharaief M. 2009. La consommation de la pomme de terre et des légumes frais en Tunisie : un diagnostic contrasté et des effets prix et dépenses alimentaires différenciés par milieu d'habitat. New Medit., 8:14–22.

Kim B, Baek M-S, Lee Y, Paik JK, Chang M-I, Rhee G-S, Ko S. 2016. Estimation of Apple Intake for the Exposure Assessment of Residual Chemicals Using Korea National Health and Nutrition Examination Survey Database. Clinical Nutrition Research, 5(2):96.

Krol WJ, Arsenault TL, Pylypiw, HM, Incorvia Mattina MJ. 2000. Reduction of Pesticide Residues on Produce by Rinsing. Journal of Agricultural and Food Chemistry, 48(10):4666–4670.

Kumari D, John S. 2019. Health risk assessment of pesticide residues in fruits and vegetables from farms and markets of Western Indian Himalayan region. Chemosphere, 224:162–167.

Lee MG, Jung D. 2009. Processing factors and removal ratios of select pesticides in hot pepper leaves by a successive process of washing, blanching, and drying. Food Science and Biotechnology, 18(5):1078–82.

Leili M, Pirmoghani A, Samadi MT, Shokoohi R, Roshanaei G, Poormohammadi A. 2016. Determination of pesticides residues in cucumbers grown in greenhouse and the effect of some procedures on their residues. Iranian journal of public health, 45(11):1481.

Lewis K, Tzilivakis J. 2017. Development of a Data Set of Pesticide Dissipation Rates in/on Various Plant Matrices for the Pesticide Properties Database (PPDB). Data, 2(3):28.

Li Y, Zhang C, Yin Y, Cui F, Cai J, Chen Z, Jin Y, Robson M, Li M, Ren Y, et al. 2014. Neurological Effects of Pesticide Use among Farmers in China. International Journal of Environmental Research and Public Health, 11(4):3995–4006.

Łozowicka B, Kaczyński P, Mojsak P, Rusiłowska J, Beknazarova Z, Ilyasova G, Absatarova D. 2020. Systemic and non-systemic pesticides in apples from Kazakhstan and their impact on human health. Journal of Food Composition and Analysis, 90:103494.

Lu M-X, Jiang WW, Wang J-L, Jian Q, Shen Y, Liu X-J, Yu X-Y. 2014. Persistence and Dissipation of Chlorpyrifos in Brassica Chinensis, Lettuce, Celery, Asparagus Lettuce, Eggplant, and Pepper in a Greenhouse. Zhang Y, editor. PLoS ONE, 9(6):e100556.

Malhat F, Loutfy NM, Ahmed MT. 2016. Dissipation pattern and risk assessment of the synthetic pyrethroid Lambda-cyhalothrin applied on tomatoes under dryland conditions, a case study. International Journal of Food Contamination, 3(1):1–7.

Mamane A, Baldi I, Tessier J-F, Raherison C, Bouvier G. 2015. Occupational exposure to pesticides and respiratory health. European Respiratory Review, 24(136):306–319.

Mehmood Y, Arshad M, Kaechele H, Mahmood N, Kong R. 2020. Pesticide residues, health risks, and vegetable farmers' risk perceptions in Punjab, Pakistan. Human and Ecological Risk Assessment: An International Journal, 27(3):846–864.

Mostafalou S, Abdollahi M. 2013. Pesticides and human chronic diseases: Evidences, mechanisms, and perspectives. Toxicology and Applied Pharmacology, 268(2):157–177.

Nougadère A, Sirot V, Kadar A, Fastier A, Truchot E, Vergnet C, Hommet F, Baylé J, Gros P, Leblanc J-C. 2012. Total diet study on pesticide residues in France: Levels in food as consumed and chronic dietary risk to consumers. Environment International, 45:135–150.

Ong KC, Cash JN, Zabik MJ, Siddiq M, Jones AL. 1996. Chlorine and ozone washes for pesticide removal from apples and processed apple sauce. Food Chemistry, 55(2):153–160.

Park DW, Kim KG, Choi EA, Kang GR, Kim TS, Yang YS, Moon SJ, Ha DR, Kim ES, Cho BS. 2016. Pesticide residues in leafy vegetables, stalk and stem vegetables from South Korea: a long-term study on safety and health risk assessment. Food Additives and Contaminants: Part A, 33(1):105–118.

PPDB - Pesticides Properties DataBase. 2021. Available from: http://sitem.herts.ac.uk/aeru/ppdb/. [Accessed 2021 Nov 22].

Pugliese P, Moltó JC, Damiani P, Marín R, Cossignani L, Mañes J. 2004. Gas chromatographic evaluation of pesticide residue contents in nectarines after non-toxic washing treatments. Journal of Chromatography A, 1050(2):185–191.

Ramadan MFA, Abdel-Hamid MMA, Altorgoman MMF, AlGaramah HA, Alawi MA, Shati AA, Shweeta HA, Awwad NS. 2020. Evaluation of Pesticide Residues in Vegetables from the Asir Region, Saudi Arabia. Molecules, 25(1):205.

Ramezani MK, Shahriari D. 2014. Dissipation behaviour, processing factors and risk assessment for metalaxyl in greenhouse-grown cucumber. Pest Management Science, 71(4):579–583.

Rasmusssen RR, Poulsen ME, Hansen HCB. 2003. Distribution of multiple pesticide residues in apple segments after home processing. Food Additives and Contaminants, 20(11):1044–1063.

Rawn DFK, Quade SC, Sun W-F, Fouguet A, Bélanger A, Smith M. 2008. Captan residue reduction in apples as a result of rinsing and peeling. Food Chemistry, 109(4):790–796.

Ríos-González A, Jansen K, Javier Sánchez-Pérez H. 2013. Pesticide risk perceptions and the differences between farmers and extensionists: Towards a knowledge-in-context model. Environmental Research, 124:43–53.

Sabarwal A, Kumar K, Singh RP. 2018. Hazardous effects of chemical pesticides on human health-Cancer and other associated disorders. Environmental toxicology and pharmacology, 63:103–114.

Satpathy G, Tyagi YK, Gupta RK. 2012. Removal of Organophosphorus (OP) Pesticide Residues from Vegetables Using Washing Solutions and Boiling. Journal of Agricultural Science, 4(2):69–78.

Sinha SN, Rao MVV, Vasudev K. 2012. Distribution of pesticides in different commonly used vegetables from Hyderabad, India. Food Research International, 45(1):161–169.

Son D, Somda I, Legreve A, Schiffers B. 2017. Pratiques phytosanitaires des producteurs de tomates du Burkina Faso et risques pour la santé et l'environnement. Cahiers Agricultures, 26(2):25005.

Soudani N, Belhamra M, Toumi K. 2020. Pesticide use and risk perceptions for human health and the environment: a case study of Algerian farmers. PONTE International Scientific Researches Journal, 76(5).

Thongprakaisang S, Thiantanawat A, Rangkadilok N, Suriyo T, Satayavivad J. 2013. Glyphosate induces human breast cancer cells growth via estrogen receptors. Food and Chemical Toxicology, 59:129–136.

Tomer V. 2013. Vegetable Processing At Household Level: Effective Tool Against Pesticide Residue Exposure. IOSR Journal of Environmental Science, Toxicology And Food Technology, 6(2):43–53.

Toumi K, Joly L, Tarchoun N, Souabni L, Bouaziz M, Vleminckx C, Schiffers B. 2018. Risk assessment of Tunisian consumers and farm workers exposed to residues after pesticide application in chili peppers and tomatoes. Tunisian Journal of Plant Protection, 13(1):127–143.

Toumi K, Joly L, Vleminckx C, Schiffers B. 2019a. Exposure of workers to pesticide residues during re-entry activities: A review. Human and Ecological Risk Assessment: An International Journal, 25(8):2193–2215.

Upadhayay J, Rana M, Juyal V, Bisht S, Joshi R. 2020. Impact of Pesticide Exposure and Associated Health Effects. Pesticides in Crop Production : Physiological and Biochemical Action : 69–88.

Naré WA R, Savadogo P, Gnankambary Z, Nacro H, Sedogo M. 2015. Analyzing Risks Related to the Use of Pesticides in Vegetable Gardens in Burkina Faso. Agriculture, Forestry and Fisheries, 4(4):165–172.

Yang T, Doherty J, Zhao B, Kinchla AJ, Clark JM, He L. 2017. Effectiveness of Commercial and Homemade Washing Agents in Removing Pesticide Residues on and in Apples. Journal of Agricultural and Food Chemistry, 65(44):9744–9752.

Zohair A. 2001. Behaviour of some organophosphorus and organochlorine pesticides in potatoes during soaking in different solutions. Food and Chemical Toxicology, 39(7):751–755.