Revista Brasileira de Ciências Ambientais
Brazilian Journal of Environmental Sciences

Safety of foods sold in street fairs: analysis of pesticide residues in lettuce (*Lactuca sativa* L.)

Segurança de alimentos comercializados em feiras livres: análise de resíduos de agrotóxicos em alface (*Lactuca sativa* L.)

Marcia Orth Ripke[1], Vanessa da Silva Corralo[1], Junir Antônio Lutinski[1]

ABSTRACT

Pesticides are chemical contaminants that can be found in food. Those with the greatest residual representation include insecticides, fungicides, and herbicides. The objective of this study was to analyze the presence of pesticide residues in lettuce (*Lactuca sativa* L.) sold at street fairs. This was a quantitative, cross-sectional study, carried out in street fairs in Chapecó, state of Santa Catarina, with producers of fresh vegetables, and consumers, and also analyzed pesticide residues in lettuce from conventional and organic cultivation. Data were collected using a semistructured questionnaire, administered to all producers, and a sample of consumers. Pesticide residues were analyzed in lettuce as it is the most purchased food by consumers. Pesticides surveyed included azoxystrobin, deltamethrin, imidacloprid, and glyphosate, as they are the most frequently applied on farms, and in cultivation of vegetables. Of the 67 vendors active in the seven street fairs, 30 were vegetable and fruit producers, and of these, 17 were conventional producers and 13 were organic farmers. The analysis of pesticide residues in lettuce from conventional production showed residues of azoxystrobin and imidacloprid, but below the maximum residue limits allowed by Anvisa. In samples of organic lettuce, residues of the analyzed pesticides were not detected. From the analysis of residues in lettuce, it is inferred that the food is safe in terms of the pesticides analyzed and that municipal public policies should prioritize systematic monitoring to ensure food safety and encourage the production of organic food.

Keywords: azoxystrobin; deltamethrin; imidacloprid; glyphosate; organic food.

RESUMO

Os agrotóxicos são contaminantes de natureza química que podem ser encontrados nos alimentos. Os de maior representatividade residual incluem os inseticidas, fungicidas e herbicidas. Objetivou-se analisar a presença de resíduos de agrotóxicos em alface (*Lactuca sativa* L.) comercializada em feiras livres. A pesquisa, com abordagem quantitativa e transversal, foi realizada em feiras livres de Chapecó/SC, com produtores feirantes de vegetais *in natura* e consumidores. Realizou-se, ainda, análise de resíduos de agrotóxicos em alface de cultivo convencional e orgânico. A coleta de dados constituiu-se na aplicação de um questionário semiestruturado a todos os produtores e a uma amostra de consumidores. As análises de resíduos de agrotóxicos foram realizadas em alface, por ser o alimento mais adquirido pelos consumidores. Os agrotóxicos pesquisados incluíram azoxistrobina, deltametrina, imidacloprido e glifosato, por serem os mais frequentemente utilizados nas propriedades e no cultivo de hortaliças. Dos 67 feirantes em atividade nas sete feiras livres, 30 eram produtores de hortaliças e frutas, e, deles, 17 eram produtores convencionais e 13 de orgânicos. As análises de resíduos de agrotóxicos em alface de produção convencional apresentaram resíduos de azoxistrobina e imidacloprido, porém abaixo dos limites máximos de resíduos permitidos pela Agência Nacional de Vigilância Sanitária (Anvisa). Nas amostras de alface orgânica não foram detectados resíduos dos agrotóxicos pesquisados. Das análises de resíduos em alface, infere-se que o alimento é seguro quanto aos agrotóxicos pesquisados e que políticas públicas municipais devem priorizar o monitoramento sistemático, visando garantir a segurança dos alimentos e estimular a produção de alimentos orgânicos.

Palavras-chave: alimento orgânico; azoxistrobina; deltametrina; imidacloprido; glifosato.

[1]Universitária Comunitária da Região de Chapecó – Chapecó (SC), Brazil.
Correspondence address: Junir Antônio Lutinski – Servidão Anjo da Guarda, 295-D – Efapi – CEP: 89809-900 – Chapecó (SC), Brazil.
E-mail: junir@unochapeco.edu.br
Conflicts of interest: the authors declare no conflicts of interest.
Funding: Universitária Comunitária da Região de Chapecó.
Received on: 05/05/2022. Accepted on: 08/12/2022.
https://doi.org/10.5327/Z2176-94781376

Introduction

Agricultural production in Brazil is increasingly dependent on the use of pesticides and synthetic chemical fertilizers (Ibama, 2021). This practice has led to water, soil, and food pollution with ecological and health consequences, in addition to the impoverishment of biodiversity (Vieira et al., 2024). The impacts of pesticide use on the environment and the consequences for public health need to be better understood in the context of different territories and population groups, especially due to the risk of possible food contamination (Carneiro et al., 2015; Friedrich et al., 2018).

The use of pesticides in food production is a widely used practice (Bombardi, 2017), authorized (Brasil, 1989), and growing in Brazil and worldwide (Ibama, 2021; World Health Organization, 2022). The toxicity of these active ingredients has been evidenced in vertebrates for over half a century (Carson, 1962), demonstrating that the action is not always restricted to the target organism (Midio and Martins, 2000). Living beings share biochemical and physiological similarities and, therefore, many cellular components or metabolic pathways in nontarget organisms, including humans, can be affected by these substances (Oga et al., 2014).

Pesticides are biocidal substances as both humans and other vertebrates can also be exposed to these compounds and suffer poisoning (Carson, 1962; Sabarwal et al., 2018; Lorenzatto et al., 2020). Consequences to humans described in the literature related to pesticides include allergies, neoplasms, intestinal microbiota disorders, endocrine system disruption, infertility, congenital malformations, autism, Parkinson's disease, and Alzheimer's disease (Samsel and Seneff, 2013; 2015).

Among the classes of pesticides, fungicides, insecticides, and herbicides are generally the most used in the food production chain (Ibama, 2021). Azoxystrobin is a fungicide dangerous to the environment, class III, and category V according to toxicity classification, considered unlikely to cause acute harm to humans (Anvisa, 2020). The deltamethrin insecticide belongs to class I environmental hazard, highly dangerous, and category IV according to toxicity classification, considered low toxic (Anvisa, 2020). The imidacloprid insecticide is an environmentally hazardous pesticide, class III, and category V according to toxicity classification (Anvisa, 2020). The glyphosate herbicide belongs to class III environmental hazard, dangerous to the environment, and category V according to toxicity classification, considered unlikely to cause acute harm to humans (Anvisa, 2020).

These pesticides were chosen to be analyzed in this study as they were the most frequently used on the property and in the production of vegetables, self-declared by the farmers of the street fairs in Chapecó in response to the questionnaire applied in the research. Residues of these active ingredients and others have already been identified and quantified at different levels in food samples by Anvisa, through the Pesticide Residue Analysis Program (PARA) (Anvisa, 2019). Pesticides are toxic substances that persist in food and the environment after application and tend to accumulate in organisms (Lorenzatto et al., 2020; Deus et al., 2022; Vieira et al., 2024). In this sense, residue monitoring is necessary for food, soil, water, and nontarget organisms, including humans.

The growing concern about the presence of pesticides and the possibility of contamination of food has aroused a worldwide interest in the production and consumption of organic food (Ifoam, 2022). Organic food production does not use synthetic fertilizers and pesticides, but organic compounds that optimize natural and socioeconomic resources (Ifoam, 2022). Agroecology is the system that balances all the components of life and, in this way, protects the health of humans and the environment (Primavesi, 2017). It is a system capable of producing enough food to supply the entire world population, with the potential to supply an even larger population, without necessarily increasing the cultivated agricultural land (Badgley et al., 2007). The Food and Agriculture Organization of the United Nations (FAO) reinforces the potential and need for ecological agriculture to replace conventional agriculture (FAO, 2007).

In this context, street fairs are urban spaces that sell fresh vegetables from conventional or organic production, from family farming (Fayad et al., 2019). Family farming accounts for more than 70% of the food produced by Brazilians (IBGE, 2017). In this scenario, the importance and the need to better understand the safety of food sold in street fairs regarding the presence of pesticide residues are highlighted. The objective of the present study was to analyze the presence of pesticide residues in lettuce (*Lactuca sativa* L.) sold in street fairs in Chapecó, state of Santa Catarina.

Materials and Methods

This is a quantitative, cross-sectional study involving the safety of foods sold in street fairs through the analysis of pesticide residues in lettuce (*Lactuca sativa* L.).

Ethical aspects

This study complied with the determinations of Resolutions 466/CNS/2012 (Brasil, 2012a) of the National Health Council of Brazil, which establishes guidelines to preserve the dignity, rights, safety, and well-being of research participants. This study was approved by the Human Research Ethics Committee of the Chapecó Region Community University (Unochapecó), with opinion 4803153.

Sampling

The research locus consisted of the seven street fairs in the municipality of Chapecó, state of Santa Catarina, in operation in the second half of 2021. The study was carried out with fresh vegetable producer vendors and the consumers of street fairs. Furthermore, the analysis of pesticide residues was carried out in lettuce (*Lactuca sativa* L.) variety crespa, Bruna.

All producer vendors over 18 years of age (n = 30) who produced and sold fresh vegetables and/or fruits in street fairs at least once a week were included in the research. In relation to consumers, a sample of 374 participants over 18 years of age who attended street fairs at least twice a month was defined. To define the sample of consumers, a probabilistic test was used using the EpInfo software (v. 7.2.2.6), with a margin of error of 5% and a confidence level of 95% based on the municipal information that 10,000 consumers attend monthly in those spaces.

Analyses of pesticide residues were carried out on fresh lettuce (*Lactuca sativa* L.) variety crespa, Bruna. A total of six samples were taken, three from conventional producers and three from organic production, representing the seven street fairs, as detailed in Table 1.

Data collection

The production system of food sold in street fairs was evaluated by a semistructured questionnaire built in the Google Forms tool. The questionnaire was administered by the researcher to all producer vendors who sold fresh vegetables (vegetables and/or fruits) in the seven street fairs in the municipality of Chapecó that were active in August 2021. Producers selling vegetables and fruits were approached in their own spaces of street fairs.

The fresh vegetable most purchased by consumers was defined by a semistructured questionnaire built using the Google Forms tool. The researcher herself administered the questionnaire to a sample of 374 consumers. Consumers were approached randomly and directly in the spaces of the street fairs (patio/parking) in August 2021.

Analysis of pesticide residues in lettuce (*Lactuca sativa* L.) var. crespa, Bruna

The collection of the fresh lettuce (*Lactuca sativa* L.) var. crespa, Bruna, was carried out in November 2021. The choice of lettuce took place after collecting data from the questionnaire administered to consumers in which they referred to leafy vegetables as the most purchased food in street fairs. The variety crespa Bruna lettuce was the one that producers were producing and selling on the date of collection. Each sample was composed of a minimum fresh weight of 1 kg of plant matrix, following the sampling procedures established by Anvisa (Anvisa, 2012).

Table 1 – Composition of lettuce samples for analysis of pesticide residues, street fairs in Chapecó, state of Santa Catarina, November 2021.

Samples/ production	Fair	Amount of lettuce collected
Sample 1, conventional	Presidente Médici Parque das Palmeiras	One producer – 350 g Two producers – 350 g each
Sample 2, conventional	Efapi Bela Vista	One producer – 500 g One producer – 500 g
Sample 3, conventional	São Cristóvão Calçadão Clevelândia	One producer – 200 g One producer – 200 g Three producers – 200 g each
Sample 1, organic	São Cristóvão	One producer – 1,000 g
Sample 2, organic	Calçadão	One producer – 1,000 g
Sample 3, organic	Clevelândia	Five producers – 200 g each

After collection, each lettuce sample was properly packed in a polyethylene bag and identified with the name of the street fair with the sample number and packed in a styrofoam box with gel ice suitable for transport. Samples were sent by air transport to the analysis laboratory accredited by Cgcre in accordance with ABNT NBR ISO/IEC 17025, under number CRL 0286, within an effective time of 24 h. The active ingredients most used on the property for vegetable production were analyzed in lettuce, according to the reports of the producers, to mention azoxystrobin, deltamethrin, imidacloprid, and glyphosate.

Upon arrival at the laboratory, lettuce samples were subjected to the multi-residue method in vegetables by GC-MS (gas chromatography coupled to mass spectrometry), GC-MS/MS (gas chromatography coupled to the detector by mass mass spectrometry), and LC-MS/MS (liquid chromatography coupled to mass mass spectrometry) (Anastassiades et al., 2003), with simultaneous analysis of the pesticides azoxystrobin and deltamethrin by the reference method (POPMET020-R11), and for imidacloprid (POPMET021-R11). Glyphosate was analyzed following the reference method (POPMET053-R04), used for the determination of glycine substitution in matrices of plant origin by GC-MSD (gas chromatography mass spectrometry detection) and GC-FPD (gas cromatography flame photometric detection). The results of the analyses were presented through a declaration of conformity report issued by the accredited laboratory and confronted with the maximum residue limits (MRLs) allowed for the lettuce crop by Brazilian legislation (Anvisa, 2022).

Data tabulation and analysis

Data collected from the questionnaire administered to the producers and consumers were tabulated in a database automatically generated by the Excel for Windows software. The results were presented as figures and tables. Descriptive frequency statistics were used to explore the data.

Results and Discussion

Of the 67 vendors identified in the seven street fairs in Chapecó, state of Santa Catarina, 30 were vegetable and fruit producers, and of these, 17 self-declared to produce using the conventional system and 13 using the organic model. The most frequently used pesticides on the property reported by producers included deltamethrin, azoxystrobin, imidacloprid, and glyphosate at the same frequency of use as lambda-cyhalothrin. In vegetable production, the most frequent pesticides were azoxystrobin, deltamethrin, imidacloprid, and lambda-cyhalothrin (Table 2). Deltamethrin, azoxystrobin, and imidacloprid are the most used pesticides both on the property of producer vendors and in the production of vegetables. Glyphosate is the fourth most-used pesticide on the property, so it was also included in the analyses.

The agronomic classes of herbicides, insecticides, and fungicides are ubiquitous in the food production chain in the conventional model (Ibama, 2021). They are mainly used in agriculture to combat potential pests, plant diseases, and weeds, and to a lesser extent in livestock production and silviculture (Oga et al., 2014).

Fresh vegetable lettuce was the food most frequently reported in purchases by consumers of street fairs (58%), followed by cruciferous such as arugula, cabbage, leaf cabbage, watercress, and broccoli (13.9%), and bananas (10.7%). Altogether, 10 groups of fresh foods were identified for sale in street fairs (Figure 1).

Table 2 – Profile of conventional production of fresh vegetables (vegetables and fruits) sold in street fairs in Chapecó, state of Santa Catarina, 2021.

Pesticides	Counting	Percentage
Pesticides used on the property		
Deltamethrin	7	41.2
Azoxystrobin	6	35.3
Imidacloprid	4	23.5
Glyphosate	4	23.5
Lambda-cyhalothrin	4	23.5
Abamectin	3	17.3
Indoxacarb	2	11.8
Thiacloprid	1	5.9
Spinetoram	1	5.9
Mancozeb	1	5.9
Teflubenzuron	1	5.9
Methomyl	1	5.9
Sulfluramid	1	5.9
Tebuconazole	1	5.9
Kasugamycin	1	5.9
Chlorfenapyr	1	5.9
Flumetraline	1	5.9
Procymidone	1	5.9
Pyriproxyfen	1	5.9
Pesticides used in vegetable production		
Azoxystrobin	7	58.3
Deltamethrin	6	50
Imidacloprid	5	41.7
Lambda-cyhalothrin	3	25
Indoxacarb	2	16.7
Thiacloprid	2	16.7
Mancozeb	2	16.7
Spinetoram	1	8.3
Teflubenzuron	1	8.3
Kasugamycin	1	8.3
Methomyl	1	8.3
Chlorfenapyr	1	8.3
Procymidone	1	8.3
Pyriproxyfen	1	8.3
Abamectin	1	8.3

This preference corroborates data from the Brazilian Agricultural Research Corporation (Embrapa), in which lettuce is the main leafy vegetable grown in all Brazilian states and the most consumed in Brazil (Embrapa, 2009). The same research institution points to the crespa variety as the most cultivated in both area and production volume (Embrapa, 2020).

This finding was also verified in street fairs in Chapecó in 2018, where lettuce was produced by 88.9% vendor producers (Bohner et al., 2018). Fante et al. (2020) found that 75.0% consumers preferred to purchase vegetables and 47% fruits in street fairs in Chapecó. Thus, consumers of street fairs have a high preference for fresh vegetable foods, which have quality and sustainable cultivation by family farming (Brasil, 2014; Fayad et al., 2019). In this scenario, the consumer is the one who defines the essential foods for them and their family, justifying their outing to the fairs.

In the three samples of lettuce from conventional producers in the street fairs, pesticide residues were detected. Imidacloprid in sample 1, azoxystrobin and imidacloprid in sample 2, and imidacloprid in sample 3, however, within the MRL established by Anvisa. Thus, they were considered satisfactory as they did not exceed the MRL determined by Brazilian legislation (Anvisa, 2022) (Table 3).

The officially accepted MRLs in food are expressed in milligrams of residue per kilogram of food (mg/kg). Brazilian legislation determines the MRL of 0.5 mg imidacloprid/kg lettuce and 1 mg azoxystrobin/kg lettuce (Anvisa, 2022). The Codex Alimentarius, the scientific body for creating international references for residues in food, determines the MRL of 2 mg imidacloprid/kg lettuce and 3 mg azoxystrobin/kg lettuce (World Health Organization, 2022). The European Union sets MRLs of the order of 2 mg imidacloprid/kg lettuce and 15 mg azoxystrobin/kg lettuce (European Commission, 2022b). Given these parameters, the Brazilian legislation is the most restrictive, imposing stricter limits for the fungicide azoxystrobin and the insecticide imidacloprid in lettuce.

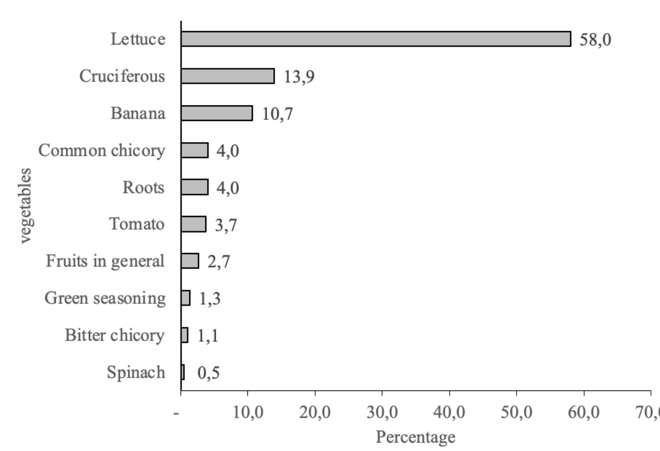

Figure 1 – Vegetables most purchased by consumers in street fairs in the municipality of Chapecó, state of Santa Catarina, 2021. n = sample (374).

Bombardi (2017) reported that the Brazilian legislation allows MRL for malathion, an acaricide used on lettuce, eight times higher than what the European Union legislation tolerates. Still, in this same context, the Brazilian legislation allows malathion residues in broccoli 250 times above the MRL allowed by the European Union. In this case, the Brazilian legislation is more flexible regarding the MRL for malathion in the vegetables in question. In view of the above, it is relevant to consider that the consumer, biochemically, is the same regardless of the laws that govern the MRL of different countries. In this case, Brazilians are more vulnerable, as the legislation allows higher levels of the active ingredient in the aforementioned foods, and there may be health risks associated with chronic occupational and dietary exposure (Carneiro et al., 2015).

In this context, the MRL refers to the maximum amount of pesticide residue in milligrams officially accepted per kilogram of food, with reference to good agricultural practices applied in the field. Thus, the MRL is an agronomic reference, derived from field studies simulating the correct use of pesticides by the farmer. In light of this knowledge, the MRL is an agronomic parameter with an impact on food safety and consumer health, as it theoretically establishes how much pesticide can be in the food without causing harm to human health (Anvisa, 2019).

Regarding the acceptable daily intake (ADI) expressed in milligrams of substance per kilogram of body weight (mg/kg b.w.), it represents the estimated amount of active ingredients present in foods that can be ingested daily throughout life without posing an appreciable risk to consumer health. The ADI for imidacloprid is 0.05 mg/kg b.w. and for azoxystrobin is 0.02 mg/kg b.w. The acute reference dose (ARD) is the estimated amount of a substance present in food that can be ingested over a 24-h period without posing an appreciable risk to the health of the consumer in mg/kg/b.w. The ARD for imidacloprid is 0.4 mg/kg b.w., and for azoxystrobin, it is not stated in the monograph of the active ingredient (Anvisa, 2022).

Toxicological safety parameters, such as ADI and ARD, are complex from a practical point of view (Anvisa, 2019), because the use of pesticides is a common practice in the food production chain and some regions use them more than others (Bombardi, 2017). In addition to the fact that the daily diet of individuals is diversified with a varied amount of food as required by each life cycle, it is possible that the ADI and ARD may be being exceeded and human health may be inevitably exposed to the action of varying levels of pesticides with health outcomes that need to be better studied (Carneiro et al., 2015).

Table 3 – Analytical results for samples of lettuce (*Lactuca sativa* L.) var. crespa, Bruna from conventional production sold in street fairs in Chapecó, state of Santa Catarina, 2021. Analyses carried out in November 2021.

Active ingredient (mg/kg)	Result	LD	LQ	MRL	Conclusion
Conventional production sample 1					
Azoxystrobin	ND	0.0033	0.01	1	
Deltamethrin	ND	0.0033	0.01	NA	
Imidacloprid	< LQ	0.0033	0.01	0.5	
Glyphosate	ND	0.0167	0.05	NA	
Analytical result with detection					
Imidacloprid	< LQ	0.0033	0.01	0.5	Satisfactory
Conventional production sample 2					
Azoxystrobin	< LQ	0.0033	0.01	1	
Deltamethrin	ND	0.0033	0.01	NA	
Imidacloprid	0.013	0.0033	0.01	0.5	
Glyphosate	ND	0.0167	0.05	NA	
Analytical result with detection					
Azoxystrobin	< LQ	0.0033	0.01	1	Satisfactory
Imidacloprid	0.013	0.0033	0.01	0.5	Satisfactory
Conventional production sample 3					
Azoxystrobin	ND	0.0033	0.01	1	
Deltamethrin	ND	0.0033	0.01	NA	
Imidacloprid	< LQ	0.0033	0.01	0.5	
Glyphosate	ND	0.0167	0.05	NA	
Analytical result with detection					
Imidacloprid	< LQ	0.0033	0.01	0.5	Satisfactory

LQ: limit of quantification; LD: limit of detection; ND: non-detected; MRL: maximum residue limit (Anvisa, 2022); NA: unauthorized.

In view of the above, the relationship between the large amounts of pesticides used in the food production chain with diseases and conditions associated with the modern world that include manifestations such as gastrointestinal microbiota disorders, obesity, diabetes, depression, autism, infertility, congenital malformations, cancer, Parkinson's, and Alzheimer's disease (Samsel and Seneff, 2013; 2015) is an inevitable reflection. There is also the biochemical individuality in which the toxic dose can be lower than the ADI and ARD for susceptible individuals, and the outcome of diseases can be anticipated (Oga et al., 2014).

The food monitoring by Anvisa through the PARA in 26 Brazilian states in the 2017/2018 cycle analyzed 286 lettuce samples. The active ingredients of pesticides verified within the MRL with the highest number of detections in the lettuce analyses included the insecticide imidacloprid in 89 samples, followed by the fungicides difenoconazole in 40 samples, dithiocarbamates in 40 samples, and, to a lesser extent, azoxystrobin in 17 samples (Anvisa, 2019).

Piaia et al. (2017) also detected imidacloprid residues in lettuce within the MRL of Brazilian legislation. The results of the samples from street fairs in Chapecó are similar to the results published in PARA, especially regarding the active ingredients, imidacloprid, and azoxystrobin, and corroborate the results of Piaia et al. (2017) regarding the detection of imidacloprid within the MRL. These findings point to the frequent use of insecticides and fungicides in the cultivation of the most consumed leafy vegetables in all Brazilian states (Anvisa, 2019; Embrapa, 2020). In this way, the permanent monitoring of pesticide residues in food needs to be supported by effective public policies.

Imidacloprid is a systemic neonicotinoid insecticide and is the second most sold insecticide in Brazil (Ibama, 2021). Due to the high toxicity of imidacloprid in native or exotic bees, the Brazilian Institute for the Environment and Renewable Natural Resources (IBAMA) in 2012 indicated the suspension of dispersion by aircraft, but this decision was soon suspended for economic reasons (Friedrich et al., 2021). The European pesticide regulatory body adopted severe restrictions in 2013 for the active ingredient imidacloprid and in May 2018 announced a ban on use in open areas due to harm to bees (European Commission, 2022a). Spraying the active ingredient on lettuce is permitted as long as harvesting takes place before flowering. Given the above, IBAMA admits the need for reassessment and mitigation measures of this pesticide for the protection of pollinators (Ibama, 2019a).

Azoxystrobin is a systemic fungicide belonging to the strobilurin group, with a high potential for water contamination with risks to biodiversity (Deus et al., 2022). Bioaccumulation may occur in fish, algae, microcrustaceans, earthworms, and microorganisms in soil and water (Ibama, 2019b) and may cause risks to other aquatic organisms (European Commission, 2022a). The risk to the life of nontarget organisms in aquatic ecosystems and soil is imminent, as seen in the scientific literature with the use of azoxystrobin.

Although the results under discussion were found in lettuce, other fresh vegetables monitored by the PARA for the 2017/2018 cycle also showed pesticide residues with insecticidal and fungicidal functions, as was the case of chayote in which the active ingredients most frequently detected included acephate, dimethoate, flutriafol, and tebuconazole; in peppers, imidacloprid, dithiocarbamates, and carbendazim; and in tomato, imidacloprid, fenpropathrin, and carbendazim (Anvisa, 2019). In view of the above, pesticide residues are widely found in fresh vegetables that are part of the daily diet and, in case they exceed the MRL, they can pose risks of acute and chronic poisoning to consumers, according to legislation and scientific studies (Carneiro et al., 2015; Anvisa 2019).

Another aspect that must be considered is the synergistic action between the different molecules of the various pesticides used in the food production chain. In light of this knowledge, MRLs are evaluated individually for each pesticide, and monitoring for the wide range currently in use in Brazil seems unfeasible (Anvisa, 2019). In view of the above, in-depth studies are necessary, as outcomes not yet fully understood in the health-disease binomial may be overshadowed in the universe of pesticides.

The active ingredient deltamethrin was analyzed in all lettuce samples in this study and was not detected in any of the samples. It is a pyrethroid insecticide not authorized by Brazilian legislation for use on lettuce but authorized for use on other vegetables, including pumpkins, broccoli, eggplant, garlic, onions, cauliflower, and chayote, and also authorized for use in fruit trees such as plum, persimmon, citrus, fig, guava, apple, papaya, and mango (Anvisa, 2022). In contrast, the European Union sets MRL for deltamethrin in lettuce in the order of 0.5 mg deltamethrin/kg (European Commission, 2022b). The Codex Alimentarius does not establish MRL for deltamethrin for use on lettuce (World Health Organization, 2022).

According to the report of the producers of street fairs, deltamethrin is one of the most-used pesticides in the production of vegetables and fruit. It is an easily hydrolyzable compound, with low residual power when associated with good agricultural practices (Midio and Martins, 2000). A study conducted in Campinas, state of São Paulo, showed similar results in which the presence of deltamethrin residues in lettuce was not detected (Oviedo et al., 2003). In view of the above, it is stated that there was no cross-contamination or purposeful contamination of deltamethrin used in other vegetables and fruits in the samples of the present study.

The PARA 2017/2018 cycle presented results of unauthorized pesticide residues on vegetables. Among the substances most detected in lettuce in this situation were acephate, chlorfenapyr, and carbendazim. In samples of chayote, residues of acephate, dimethoate, and carbendazim were found; in peppers, acephate; and in tomatoes, acephate, chlorpyrifos, and fipronil were detected (Anvisa, 2019). Piaia et al. (2017) detected the fungicides carbendazim, pyraclostrobin, and tebuconazole, and the insecticide chlorpyrifos, not authorized by Anvisa for use in lettuce. Regarding unauthorized pesticides for crops, there is no MRL established by legislation; therefore, there is no guarantee of safety, making the risks to consumer health imminent. Deltamethrin was not detected in the study samples in street fairs in Chapecó. Thus, there was no irregularity in the cited studies.

Another active ingredient researched and not authorized by Anvisa in lettuce was glyphosate. It is the most-used herbicide worldwide and the most commercialized in Brazil (Samsel and Seneff, 2015; Ibama, 2021). It is widely used in major food crops, especially genetically modified ones such as corn, soybeans, cotton, canola, alfalfa, and beets, to control weeds without killing the cultivated plant (Samsel and Seneff, 2015). In Brazil, the post-emergence use in some vegetables is allowed, such as peas, sweet potatoes, beets, chickpeas, yams, cassava, and radishes, and in fruits, such as plums, bananas, guava, figs, apples, papayas, and mangoes (Anvisa, 2022). Glyphosate was not detected in lettuce samples analyzed in street fairs in Chapecó.

Due to the massive and frequent use of glyphosate in the food production chain, its deleterious effects on the environment are evident in both aquatic and terrestrial ecosystems (Schneider et al., 2009; Droste et al., 2010; Samsel and Seneff, 2013; Annett et al., 2014; Vieira et al., 2024). The biodegradation half-life of glyphosate in the soil is highly variable, from a few days to several months. In water, the half-life is estimated to be between 1.5 and 130 days (Cetesb, 2018). Sanchís et al. (2012) detected glyphosate in groundwater in Catalonia, Spain. Olivo et al. (2015) detected glyphosate in well water in the rural area of Chapecó. In this context, the appearance of these molecules in groundwater samples raises questions such as contamination of food production through irrigation.

The presence of pesticide residues in fresh vegetables such as lettuce, highly consumed by the human species, worries not only the scientific community, but also the informed population. Above all, a diet based on fresh plants is considered to be health-promoting (Brasil, 2014). In contrast, this same diet may be associated with the incidence of diseases in the modern world, due to the presence of pesticide residues (IARC, 2017). According to Anvisa, consumers can adopt some measures to mitigate exposure to pesticides in food, such as opting for labeled foods, consuming organic foods, and purchasing seasonal foods that tend to receive a lower load of pesticides. On the contrary, procedures for washing food in running water and removing peels and external leaves contribute to the reduction of pesticide residues present on the outside, however, they are unable to eliminate systemic residues inside the food (Anvisa, 2019).

In view of the above, laws with greater restrictions on the release and authorization of pesticides in Brazil are aspired. In contrast, there is a strong movement led by the pesticide industry in line with agribusiness to change Federal Law 7802/89 (Brasil, 1989) that regulates pesticides, making the way of evaluating and re-evaluating pesticide records in Brazil more flexible (Anvisa, 2018). The Bill 6299/2002 (Brasil, 2002), also known as the "Poison Package," indicates, among other points, that pesticides can be allowed by the Ministry of Agriculture, Livestock and Supply (MAPA) even without conclusive analysis by other regulatory bodies, such as the IBAMA and ANVISA (Fiocruz, 2018) The simplification of the pesticide registration process without the effective participation of the health and environmental sectors leads to harmful effects to humans, animals, and the environment due to the lack of rigor involved in the process (Ibama, 2018).

The Bill 6299/2002 does not serve the Brazilian population, which should be the focus of the legislation, does not contribute to the production of safer food, does not propose new technologies for the farmer, and does not even strengthen the regulatory system for pesticides (Anvisa, 2018). It is necessary for farmers, as the main users of pesticides, to recognize these products as dangerous toxics, to be more careful in their use, and not to use them as mere agricultural inputs (Ibama, 2018). However, there is a need to strengthen instances such as the National Policy for Pesticide Reduction (PNARA), which is being processed as the Bill 6670/2016 (Brasil, 2016), and the National Policy on Agroecology and Organic Production (Brasil, 2012b). These policies are guidelines for mitigating the use of pesticides and opposing the food production system strongly established in the 1960s in the national territory.

Of the four active ingredients analyzed, there was no detection of residues in any of the lettuce samples from organic production. Thus, the samples were within the expected range for organics in relation to the pesticides analyzed in this study (Table 4).

Table 4 – Analytical results for samples of lettuce (*Lactuca sativa* L.) var. crespa, Bruna, from organic production sold in street fairs in Chapecó, state of Santa Catarina, in 2021. Analyses carried out in November 2021.

Active ingredient (mg/kg)	Result	LD	LQ	MRL
Organic production sample 1				
Azoxystrobin	ND	0.0033	0.01	0
Deltamethrin	ND	0.0033	0.01	0
Imidacloprid	ND	0.0033	0.01	0
Glyphosate	ND	0.0167	0.05	0
Organic production sample 2				
Azoxystrobin	ND	0.0033	0.01	0
Deltamethrin	ND	0.0033	0.01	0
Imidacloprid	ND	0.0033	0.01	0
Glyphosate	ND	0.0167	0.05	0
Organic production sample 3				
Azoxystrobin	ND	0.0033	0.01	0
Deltamethrin	ND	0.0033	0.01	0
Imidacloprid	ND	0.0033	0.01	0
Glyphosate	ND	0.0167	0.05	0

LQ: limit of quantification; LD: limit of detection; ND: non-detected; MRL: maximum residue limit (Anvisa, 2022); NA: unauthorized.

A study conducted in the municipality of João Pessoa, state of Paraíba, analyzed pesticide residues of the organophosphates, carbamates, and pyrethroids classes in organic lettuce sold at agroecological fairs and did not detect residues (Sarmento, 2016). Another study carried out in Francisco Beltrão, state of Paraná, showed a similar result — no residues of the pesticides azoxystrobin, iprodione, beta-cyfluthrin, and difenoconazole in organically produced lettuce (Biondo and Sousa, 2012).

In this context, it is not allowed to use pesticides or synthetic chemical fertilizers in the production chain of organic crops (Primavesi, 2016). Food produced with organic or agroecological management provides greater quality and safety for the consumer and the environment (Ifoam, 2022). It is considered that residues of synthetic chemical molecules used in conventional production persist in food (Anvisa, 2019). Organic cultivation is based on alternative management techniques to the use of pesticides, and it uses natural insecticides and fungicides such as Bordeaux mixture, extracts from numerous plants, crop rotation, and soil micronutrient balance, giving the plant resistance to pest attacks (Primavesi, 2016).

The rise of the organic food market follows a global trend associated with a higher level of consumer safety and lower environmental impact (Ipea, 2020; Ifoam, 2022). Access to substantiated information on food safety and the risks of dietary intake of pesticides in food should be part of consumer protection policies (Anvisa, 2019).

Conclusion

The fresh vegetable most consumed in street fairs in Chapecó, from conventional farming, despite having presented residues of the pesticides analyzed in the study, is safe for consumption by the population in light of the legislation. Lettuce from organic production is organic in terms of the tested pesticides since they were not detected in the vegetable, but other pesticides must still be tested to confirm that it is indeed organic.

This study points to the importance of systematic monitoring of food sold in these spaces through municipal public policies and the involvement of interdisciplinary studies. These measures favor the mitigation of the use of pesticides and their risks to human health and the environment.

Street fairs stand out as spaces to boost the commercialization of healthy organic foods to consumers with environmentally sustainable production.

Contribution of authors:

RIPKE, M. O.: Conceptualization; Data Curation; Formal Analysis; Funding; Acquisition; Investigation; Methodology; Project Administration; Resources; Software; Supervision; Validation; Visualization; Writing — Original Draft; Writing — Review & Editing. CORRALO, V. S.: Conceptualization; Data Curation; Formal Analysis; Funding; Acquisition; Investigation; Methodology; Project Administration; Resources; Software; Supervision; Validation; Visualization; Writing — Original Draft; Writing — Review & Editing. LUTINSKI, J. A.: Conceptualization; Data Curation; Formal Analysis; Funding; Acquisition; Investigation; Methodology; Project Administration; Resources; Software; Supervision; Validation; Visualization; Writing — Original Draft; Writing — Review & Editing.

References

Agência Nacional de Vigilância Sanitária (Anvisa), 2012. Ministério da Saúde. RDC nº 4, de 18 de janeiro de 2012. Diário Oficial da União, Brasília.

Agência Nacional de Vigilância Sanitária (Anvisa), 2018. Ministério da Saúde. Nota técnica PL nº 6.299/02: Anvisa continuará a denunciar riscos. Agência manifesta-se contrariamente ao Projeto de Lei aprovado na Comissão Especial da Câmara dos Deputados e que propõe que tais produtos não passem por avaliação sobre os riscos à saúde. Ministério da Saúde, Brasília.

Agência Nacional de Vigilância Sanitária (Anvisa), 2019. Programa de Análise de Resíduos de Agrotóxicos em Alimentos – PARA. Relatório das amostras analisadas no período de 2017-2018, Primeiro ciclo do plano plurianual 2017-2020. Gerência Geral de Toxicologia, Brasília.

Agência Nacional de Vigilância Sanitária (Anvisa), 2020. Ministério da Saúde. Monografias autorizadas (Accessed July 22, 2022) at.: https://www.gov.br/anvisa/pt-br/setorregulado/regularizacao/agrotoxicos/monografias/monografias-autorizadas-por-letra.

Agência Nacional de Vigilância Sanitária (Anvisa), 2022. Ministério da Saúde. Monografias de agrotóxicos: em vigência. (Accessed July 20, 2022) at.: https://www.gov.br/anvisa/pt-br/acessoainformacao/dadosabertos/informacoes-analiticas/monografias-de-agrotoxicos.

Anastassiades, M.; Lehotay, S.J.; Stajnbaher, D.; Schenck, F.J., 2003. Fast and easy multiresidue method employing acetonitrile extraction/partitioning and “dispersive solid-phase extraction” for the determination of pesticide residues in produce. Journal of AOAC International (Online), v. 86, (2), 412-431.

Annet, R.; Habibi, H.R.; Hontela, A., 2014. Impact of glyphosate and glyphosate-based herbicides on the freshwater environment. Journal of Applied Toxicology (Online), v. 34, (5), 458-479. https://doi.org/10.1002/jat.2997.

Associação Brasileira de Normas Técnicas (ABNT), 2017. NBR ISO/IEC 17025:2017 Terceira edição – 19.12.2017. Requisitos gerais para a competência de laboratórios de ensaio e calibração. Exactus metrologia e qualidade (Acessed Sept 13, 2022) at.: https://www.exactusmetrologia.com.br/sites/default/files/3-nbr_iso_iec_17025-2017_versao_exclusiva_treinamento.pdf.

Badgley, C.; Moghtader, J.; Quintero, E.; Zakem, E.; Chappell, M.J.; Aviles-Vasquez, K., 2007. Organic agriculture and the global food supply. Renewable Agriculture and Food Systems (Online), v. 22, (2), 86-108. https://doi.org/10.1017/S1742170507001640.

Biondo, M., Sousa, S.C., 2012. Determinação de agrotóxicos em alface orgânica e convencional produzidas no município de Francisco Beltrão-PR. Trabalho de conclusão de curso em Tecnologia em Alimentos, Universidade Tecnológica Federal do Paraná, Curitiba. Retrieved from: http://repositorio.utfpr.edu.br/jspui/bitstream/1/11642/2/FB_COALM_2012_1_02.pdf.

Bohner, T.O.L.; Pasqualotto, N.; Wizniewsky, J.G., 2018. Perfil dos agricultores convencionais e "agroecológicos" integrantes da feira de comercialização direta do município de Chapecó, SC. Caderno de Agroecologia, v. 13, (1), 1-6 (Accessed Apr 9, 2022) at.: http://cadernos.aba-agroecologia.org.br/index.php/cadernos/article/download/1119/963/.

Bombardi, L.M., 2017. Geografia do uso de agrotóxicos no Brasil e conexões com a União Europeia. São Paulo: FELCH-USP, 296 pp.

Brasil, 1989. Lei Federal Agrotóxicos. Lei nº 7.802, de 11 de julho de 1989. Diário Oficial da União, Sessão 1, v. 4, 1547.

Brasil, 2002. Projeto de Lei nº 6.299, de 2002. Altera os arts 3º e 9º da Lei nº 7.802, de 11 de julho de 1989, que dispõe sobre a pesquisa, a experimentação, a produção, a embalagem e rotulagem, o transporte, o armazenamento, a comercialização, a propaganda comercial, a utilização, a importação, a exportação, o destino final dos resíduos e embalagens, o registro, a classificação, o controle, a inspeção e a fiscalização de agrotóxicos, seus componentes e afins, e dá outras providências.

Brasil, 2012a. Ministério da Saúde. Conselho Nacional da Saúde. Resolução nº 466, de 12 de dezembro de 2012. Brasília, Diário Oficial da União.

Brasil, 2012b. Política Nacional de Agroecologia e Produção Orgânica (PNAPO). Decreto nº 7.794, de 20 de agosto de 2012. Institui a Política Nacional de Agroecologia e Produção Orgânica (Accessed Apr 18, 2022) at.: http://www.planalto.gov.br/ccivil_03/_ato2011-2014/2012/decreto/d7794.htm.

Brasil, 2014. Guia alimentar para a população brasileira. 2ª ed. Brasília: Ministério da Saúde, Secretaria de Atenção à Saúde, Departamento de Atenção Básica.

Brasil, 2016. Política Nacional de Redução de Agrotóxicos (Pnara). Projeto de Lei nº 6.670-A de 2016 (Accessed Apr 12, 2022) at.: https://www.camara.leg.br/proposicoesWeb/prop_mostrarintegra;jsessionid=C95C6EDCEAC5FC20303C3DA062E38CA7.proposicoesWebExterno1?codteor=1697945&filename=Avulso+-PL+6670/2016.

Carneiro, F.; Augusto, L.G.S.; Rigotto, R.M.; Friedrich, K.; Búrigo, A.C., 2015. Dossiê ABRASCO: Um alerta sobre os impactos dos agrotóxicos na saúde. Rio de Janeiro: Expressão Popular, 623 pp.

Carson, R., 1962. Silent Spring. New York: Penguin Books.

Companhia Ambiental do Estado de São Paulo (Cetesb), 2018. Ficha de Informação Toxicológica. Divisão de Toxicologia Humana e Saúde Ambiental (glifosato). Atualizado em maio de 2021 (Accessed July 20, 2022) at.: https://cetesb.sp.gov.br/laboratorios/wp-content/uploads/sites/24/2022/02/Glifosato.pdf.

Deus, C.T.; Brandt, E.M.F.; Pereira, R.O., 2022. Priority pesticides not covered by GM Ordinance of the Ministry of Health No. 888, of 2021, on water potability standard in Brazil. Brazilian Journal of Environmental Sciences (Online), v. 57, (2), 290-301. https://doi.org/10.5327/Z2176-94781077.

Droste, A.; Cassanego, M.B.B.; Windisch, P.G., 2010. Germination and sporophytic development of Regnellidium diphyllum Lindm. (Marsileaceae) in the presence of a glyphosate-based herbicide. Brazilian Journal of Biosciences, v. 8, (2), 174-178 (Accessed Jul 10, 2022) at.: https://www.seer.ufrgs.br/index.php/rbrasbioci/article/view/114925.

Empresa Brasileira de Pesquisa Agropecuária (Embrapa), 2009. Ministério da Agricultura, Pecuária e Abastecimento. Embrapa Hortaliças. Comunicado Técnico. Tipos de alfaces cultivados no Brasil (Accessed July 13, 2022) at.: https://www.infoteca.cnptia.embrapa.br/infoteca/bitstream/doc/783588/1/cot75.pdf.

Empresa Brasileira de Pesquisa Agropecuária (Embrapa), 2020. Ministério da Agricultura, Pecuária e Abastecimento. Embrapa Hortaliças. Guia para identificação de pragas da alface. Documentos, 182 (Accessed July 13, 2022) at.: https://www.embrapa.br/busca-de-publicacoes/-/publicacao/1127374/guia-para-identificacao-de-pragas-da-alface.

European Commission, 2022a. Neonicotinoids (Accessed May 20, 2022) at.: https://ec.europa.eu/food/plant/pesticides/approval_active_substances/approval_renewal/neonicotinoids_en.

European Commission, 2022b. Pesticide residues (s) and maximum residues levels (mg/kg) (Accessed July 20, 2022) at.: https://ec.europa.eu/food/plant/pesticides/eu-pesticides-database/mrls/?event=details&pest_res_ids=22&product_ids=&v=1&e=search.pr.

Fante, C.; Gallina, L.S.; Confortin, F.G.; Lutinski, J.A., 2020. Perfil e preferências dos consumidores de produtos em feiras livres na cidade de Chapecó (SC). Revista Saúde (Online), v. 46, (1), 1-15. https://doi.org/10.5902/2236583441701.

Fayad, J.A.; Arl, V.; Comin, J.J.; Mafra, A.L.; Marchesi, D.R., 2019. Sistema de plantio direto de hortaliças: método de transição para um novo modelo de produção. São Paulo: Expressão Popular, 432 pp.

Food and Agriculture Organization (FAO), 2007. International Conference on Organic Agriculture and Food Security. Rome (Accessed Apr. 29, 2022) at.: https://www.stopogm.net/old/sites/stopogm.net/files/FAOOrgIntConf.pdf.

Friedrich, K.; Silveira, G.R.; Amazonas, J.C.; Gurgel, A.M.; Almeida, V.E.S.; Serpa, M., 2021. Situação regulatória internacional de agrotóxicos com uso autorizado no Brasil: potencial de danos sobre a saúde e impactos ambientais. Caderno de Saúde Pública (Online), v. 37, (4), 1-18. https://doi.org/10.1590/0102-311X00061820.

Friedrich, K.; Soares, V.E.; Augusto, L.G.S.; Gurgel, A.M.; Souza, M.M.O.; Alexandre, V.P.; Carneiro, F.F., 2018. Agrotóxicos: mais venenos em tempos de retrocesso de direitos. Revista OKARA: Geografia em Debate (Online), v. 12, (2), 326-347. https://doi.org/10.22478/ufpb.1982-3878.2018v12n2.41320.

Fundação Oswaldo Cruz (Fiocruz), 2018. Ministério da Saúde. Nota técnica 14. Assunto: análise do Projeto de Lei nº 6.299/2002 (Accessed Apr 29, 2022) at.: http://contraosagrotoxicos.org/wp-content/uploads/2018/05/Fiocruz-NT-agrot-PL.pdf.

Instituto Brasileiro de Geografia e Estatística (IBGE), 2017. Censo Agro 2017. Resultados definitivos (Accessed May 29, 2022) at.: https://censoagro2017.ibge.gov.br/.

Instituto Brasileiro do Meio Ambiente e dos Recursos Renováveis (Ibama), 2018. Ministério do Meio Ambiente. Processo nº 02000.000406/2016-93 interessado: divisão de assuntos parlamentares. Nota Técnica nº 2/2018. Brasília (Accessed Apr 12, 2022) at.: http://www.ibama.gov.br/phocadownload/noticias/noticias2018/SEI_02000.000406_2016_93.pdf.

Instituto Brasileiro do Meio Ambiente e dos Recursos Renováveis (Ibama), 2019a. Ministério do Meio Ambiente. Diretoria de Qualidade Ambiental – DIQUA. Coordenação-Geral de Avaliação e Controle de Substâncias Químicas – CGASQ. Coordenação de Controle Ambiental de Substâncias e Produtos Perigosos – CCONP. Avaliação de risco ambiental do ingrediente ativo imidacloprido para insetos polinizadores parecer técnico IBAMA 6220406 (Accessed Apr 16, 2022) at.: http://ibama.gov.br/phocadownload/qualidadeambiental/notas-tecnicas/2019-10-25-Ibama-Parecer-Imidacloprido-CP_17-OUT-19.pdf.

Instituto Brasileiro do Meio Ambiente e dos Recursos Renováveis (Ibama), 2019b. Ministério do Meio Ambiente. Perfil ambiental da azoxistrobina (Accessed Apr 20, 2022) at.: http://www.ibama.gov.br/phocadownload/agrotoxicos/perfis-ambientais/2019/2019-08-16-Ibama-Perfil-Ambiental-Azoxistrobina.pdf.

Instituto Brasileiro do Meio Ambiente e dos Recursos Renováveis (Ibama), 2021. Ministério do Meio Ambiente. Os 10 ingredientes ativos mais vendidos-2020. Consolidação de dados fornecidos pelas empresas registrantes de produtos técnicos, agrotóxicos e afins, conforme art. 41 do Decreto nº 4.074/2002.

Instituto de Pesquisa Econômica Aplicada (Ipea), 2020. Demanda crescente estimula a produção orgânica no Brasil e no mundo (Accessed Apr 18, 2022) at.: http://repositorio.ipea.gov.br/bitstream/11058/9678/1/TD_2538.pdf.

International Agency for Reseach on Cancer (IARC), 2017. Iarc monographs on the evaluation of carcinogenic risks to humans. Some organophosphate insecticides and herbicides. IARC, v. 112.

International Federation of Organic Agriculture Movements (Ifoam), 2022. The World of Organic Agriculture. Statistics e Emerging Trends. Swiss Confederation. Organics International, and African partners.

Lorenzatto, L.; Silva, M.I.; Roman Junior, W.; Rodrigues Junior, S.; Sá, C.; Corralo, V., 2020. Rural workers exposure to organophosphates and carbamates. Brazilian Journal of Environmental Sciences, v. 55, (1), 19-31. https://doi.org/10.5327/Z2176-947820200528.

Midio, A.F., Martins, D.I., 2000. Toxicologia de Alimentos. São Paulo: Varela, 295 pp.

Oga, S.; Camargo, M.M.A.; Batistuzzo, J.A.O., 2014. Fundamentos de toxicologia. 4ª ed. São Paulo: Atheneu, 682 pp.

Olivo, V.E.; Tansini, A.; Carasek, F.; CordenuzzI, C.D.; Fernandes, S.; Fiori, M.A.; Dal Magro, J., 2015. Método rápido para determinação de glifosato em água subterrânea usando cromatografia líquida de alta eficiência e extração em fase sólida após derivatização. Revista Ambiente e Água (Online). v. 10, (2), 286-297. https://doi.org/10.4136/ambi-agua.1548.

Oviedo, M.T.P.; Toledo, M.C.F.; Vicente, E., 2003. Resíduos de agrotóxicos piretroides em hortaliças. Revista Ecotoxicologia e Meio Ambiente (Online), v. 13, 9-18. https://doi.org/10.5380/pes.v13i0.3160.

Piaia, T.L.; Schmitz, L.S.; Leaẽs, F.L.; Migliorini, M.V., 2017. Determinação de resíduos de agrotóxicos presentes em alfaces cultivados no município de São Luiz Gonzaga. VI Salão Integrado Ensino, Pesquisa e Extensão, II Jornada de Pós-Graduação, I Seminário Estadual sobre Territorialidade, Ciências da Vida. UERGS (Accessed Apr 10, 2022) at.: http://conferencia.uergs.edu.br/index.php/SIEPEX/visiepex/paper/viewPaper/1550.

Primavesi, A., 2016. Manejo ecológico de pragas de doenças. 2ª ed. São Paulo: Expressão Popular, 139 pp.

Primavesi, A., 2017. História de vida e agroecologia. 2ª ed. São Paulo: Expressão Popular, 479 pp.

Sabarwal, A.; Kumar, K.; Singh, R.P., 2018. Hazardous effects of chemical pesticides on human health-Cancer and other associated disorders. Environmental Toxicology and Pharmacology, v. 63, 103-114. https://doi.org/10.1016/j.etap.2018.08.018.

Samsel, A.; Seneff, S., 2013. Glyphosate's suppression of Cytochrome P450 enzymes and amino acid biosynthesis by the gut microbiome: pathways to modern diseases. Entropy (Online), v. 15, (4), 1416-1463. https://doi.org/10.3390/e15041416.

Samsel, A.; Seneff, S., 2015. Glyphosate, pathways to modern diseases III: Manganese, neurological diseases, and associated pathologies. Surgical Neurology International (Online), v. 6, 45. https://doi.org/10.4103%2F2152-7806.15387/.

Sanchís, J.; Kantiani, L.; Lorca, M.; Rubio, F.; Ginebreda, A.; Fraile, J.; Garrido, T.; Farré, M., 2012. Determination of glyphosate in groundwater samples using an ultrasensitive immunoassay and confirmation by on-line solid-phase extraction followed by liquid chromatography coupled to tandem mass spectrometry. Analytical and Bioanalytical Chemistry (Online), v. 402, (7), 2335-2345. https://doi.org/10.1007/s00216-011-5541-y.

Sarmento, H.M., 2016. Determinação de agrotóxicos em alface (Lactuca sativa L.) orgânicas comercializadas em feiras agroecológicas de João Pessoa-PB. Monografia, Graduação Farmácia, Universidade Federal da Paraíba, Campina Grande.

Schneider, M.I.; Sanchez, N.; Pineda, S.; Chi, H.; Ronco, A., 2009. Impact of glyphosate on the development, fertility and demography of Chrysoperla externa (Neuroptera: Chrysopidae): Ecological approach. Chemosphere (Online), v. 76, (10), 1451-1455. https://doi.org/10.1016/j.chemosphere.2009.05.029.

Vieira, C.; Marcon, C.; Droste, A., 2024. Phytotoxic and cytogenotoxic assessment of glyphosate on Lactuca sativa L. Brazilian Journal of Biology, v. 84, e257039. https://doi.org/10.1590/1519-6984.257039.

World Health Organization, 2022. Food and Agriculture Organization of the United Nations. Codex Alimentarius. International Food Standards. Pesticide index (Accessed July 20, 2022) at.: https://www.fao.org/fao-who-codexalimentarius/codex-texts/dbs/pestres/pesticides/en/.