SCIENCE AND FOOD TECHNOLOGY
DOI: 10.12957/demetra.2026.89357

DEMETRA
Alimentação, Nutrição & Saúde

e-ISSN:2238-913X

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This article originated from the master's thesis entitled "Pesticide residues in fresh plant-based products sold in supermarkets in Santa Catarina: a study on the food traceability and monitoring program - RAMA (2018-2023)", authored by Gledciani Alves Teodoro and supervised by Jéssica Fernanda Hoffmann, presented to Professional Master's Degree in Nutrition e Alimentos, University of Valle do Rio dos Sinos – UNISINOS. Year: 2024.

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Assistant Editor
Fabiana Bom Kraemer

Results of the analysis of pesticide residue reports in fresh food of plant origin: a study of the Rama Programme 2018-2023

Resultados da análise de relatórios de resíduos de agrotóxicos em alimentos de origem vegetal in natura: um estudo do Programa Rama 2018-2023

Abstract

Introduction: Monitoring pesticide residues in food is essential to ensure compliance with maximum residue limits in products available to consumers. In Brazil, surveillance reports on pesticide residues are integral to food quality and safety control systems. The state of Santa Catarina is a key region within this monitoring framework. *Objective*: To evaluate pesticide residue reports from the Food Traceability and Monitoring Programme in supermarkets in the state of Santa Catarina from 2018 to 2023. *Methods*: This exploratory retrospective study analysed documentary data from pesticide residue reports in fresh plant-based foods. *Results*: A total of 3,538 sampling reports were analysed, encompassing 53 food items and 700 product varieties, from January 2018 to December 2023. The number of monitored active ingredients increased from 242 in 2018 to 419 in 2023. Non-compliance was observed annually, including the presence of unauthorised and prohibited substances. The highest frequencies of non-compliance were identified in oranges, strawberries, lettuce, bell peppers, and carrots. *Conclusion*: These findings highlight the ongoing need for systematic monitoring and traceability of pesticide residues in fresh plant-based foods to strengthen food safety assurance.

Keywords: Pesticides. Food Consumption. Food Contamination. Monitoring. Food Safety.

Resumo

Introdução: Os resíduos de agrotóxicos em alimentos devem ser monitorados para que estas substâncias não estejam acima dos limites máximos permitidos nos produtos adquiridos em supermercados e consumidos pela população. No Brasil, relatórios de rastreabilidade desses resíduos fazem parte do controle de qualidade e segurança alimentar. O estado de Santa Catarina possui participação relevante neste segmento. *Objetivo*: Avaliar os relatórios de resíduos de agrotóxicos do programa de Rastreabilidade e Monitoramento de Alimentos (RAMA) dos anos de 2018-2023 em supermercados no estado de Santa Catarina. *Método*: Estudo de pesquisa documental exploratória, através da análise retrospectiva dos relatórios de resíduos de agrotóxicos em alimentos de origem vegetal *in natura*. ***Resultados:*** 3.538 laudos de coletas no período de janeiro de 2018 a dezembro de 2023 analisados, sendo 53 produtos e 700 variedades de produtos. Os ingredientes ativos monitorados no período começaram com 242 (2018) e finalizaram com 419 (2023). Em todos os anos foram encontradas inconformidades, desde substâncias não autorizadas até proibidas. Laranja, morango, alface, pimentão e cenoura apresentam maior frequência de não conformidades. ***Conclusão***: Os resultados reforçam a necessidade de monitoramento e rastreabilidade de resíduos de agrotóxicos em alimentos de origem vegetal *in natura*, para ofertar alimentos seguros aos consumidores.

Palavras-chave: Agrotóxicos. Consumo Alimentar. Contaminação de Alimentos. Monitoramento. Segurança Alimentar.

INTRODUCTION

Concerns have been raised regarding the use of pesticides in food production, and the implementation of monitoring programs has been shown to be beneficial for both farmers and consumers. These programs help ensure control over production and safety in consumption.[1] In the context of fruits and vegetables, it is well established that they play a significant role in human nutrition, contributing to the agri-food system through their nutritional properties. There is ongoing concern regarding pesticide use in food production, reinforcing the importance of programs that oversee this practice and support both production control and food safety.[2]

Proper control of chemical substances requires clear labeling and transparent communication regarding their use, ensuring compliance with current legislation on Maximum Residue Limits (MRLs). MRLs represent the maximum level of pesticide residues legally permitted in food without posing a risk to consumer health.[3]

The monitoring of pesticide residues in fresh plant products intended for human consumption is regulated by Joint Normative Instruction No. 02/2018, which establishes procedures for the implementation of traceability throughout the production chain for monitoring and control purposes nationwide.[4] This traceability system aims to ensure safe production for consumption and transparency in the relationship between producers and retailers.[5]

One such initiative is the Food Traceability and Monitoring Program (RAMA). This program, developed by the Brazilian Supermarket Association (ABRAS), aims to enhance the safety of fruits and vegetables by adhering to Good Agricultural Practices (GAP), aligning with global trends in the retail sector and addressing consumer concerns. Six supermarkets have been selected to participate in a program that provides them with a set of information. This set of information enables the conscious development of their suppliers for the promotion and marketing of quality food. The RAMA program is consistent with both public and private strategies for the sustainable development of the supply chain.[6]

In this context, and given the importance of pesticide residue monitoring for public health, the present study aimed to evaluate the retrospective results of pesticide residue analyses in fresh plant-based foods collected through this program in the state of Santa Catarina between 2018 and 2023.

METHODS

This documentary analysis examined the findings from laboratory reports on the presence of pesticide residues in fresh plant-based foods. The reports are available in the Paripassu *software*, which handles traceability and monitoring exclusively for supermarkets participating in the RAMA program. The present study procured data from 25 supermarket chains, encompassing 343 stores that participated in the RAMA program.

A total of 3,538 sample reports were analyzed from January 2018 to December 2023. The collected data corresponded to 53 products (species or item, e.g., apple) and 700 product varieties (cultivar or type, e.g., Fuji apple).[7] The number of active ingredients monitored increased from 242 in 2018 to 419 by the end of 2023. At this stage,the reports were analyzed to obtain information regarding residues in fresh plant-based products, specifically fruits, vegetables, and leafy greens (FVG).

The data were organized into tabular form in Microsoft Excel spreadsheets, with the separation of the data based on food variety and the nature of non-compliance. The food categories included fruits with edible peel, fruits with inedible peel, leafy vegetables, non-leafy vegetables, and roots and tubers. The non-compliance were classified as follows: The first issue is considered to be of no concern. The second issue pertains to an unauthorized substance (NA). The third issue is associated with a substance that exceeds the maximum residue limit (MRL). The fourth issue is a combination of the previous two issues, namely the application of an unauthorized active ingredient and the improper handling of authorized pesticides. The fifth issue is classified as prohibited. This categorization provides a clear approach for a comprehensive assessment of pesticide residues in food.[8,9]

The concepts are defined as follows:to each type of substance is imperative. Prohibited substances are those which are strictly prohibited in Brazil and are often obtained through illicit means. The classification of legal substances is as follows: MRL, utilized as an agronomic parameter, is derived from studies simulating the appropriate use of the chemical. NA signifies a sample containing an unauthorized active ingredient, while NA&MRL denotes the application of an unauthorized active ingredient and improper use of authorized pesticides within the same sample. According to the available documentation, priority was given to the FLVs that are part of Anvisa's Program for the Analysis of Pesticide Residues in Food (PARA). The RAMA Program uses these FLVs as a technical reference for food monitoring. The products are listed in the strictly descriptive table

Table1. Products prioritized in data collection according to PARA in the 2018-2023 cycle. Florianópolis-SC, 2024.

Sample	Category
Fruits with edible peel	Apple Strawberry Pear Grape Guava
Fruits with inedible peel	Pineapple Banana Orange Lemon Papaya Mango Passionfruit
Leafy vegetables	Lettuce Kale
Non-leafy vegetables	Zucchini Broccoli Onion Chayote Corn Cucumber Bell pepper Okra Cabbage Tomato
Roots andtubers	Potato Sweet potato Beetroot Carrot Cassava

Source: PariPassu® Report(2023).

RESULTS

Information regarding pesticide residues was collected from 53 fresh plant-based products during the period covered by this study (2018–2023) at supermarkets in Santa Catarina. In the course of the analyses, 419 active pesticide ingredients were investigated, and residues of 92 distinct active ingredients were identified in the total number of samples (3,538 samples), resulting in an annual average of 31% of samples deemed unsatisfactory—that is, these food samples did not meet the minimum quality and safety standards defined by the RAMA program. Non-compliance is defined as the presence of pesticide residues that are unauthorized, prohibited, or exceed the levels permitted by law. The percentage of unsatisfactory samples is shown in Table 2.

Table 2. Historical data on the results of analyses showing irregularities in supermarkets in Santa Catarina during the 2018-2023 cycle. Florianópolis-SC, 2024.

Ano	Number of samples evaluated	%Unsatisfactory samples				%Satisfactory samples
		Prohibited	NA&LMR	LMR	NA	
2018	105	0	8%	8%	25%	59%
2019	126	0	4%	5%	21%	70%
2020	150	2%	5%	9%	15%	69%
2021	162	0	3%	6%	23%	68%
2022	160	0	4%	8%	15%	73%
2023	145	0	1%	3%	21%	75%

Prohibited - use of a prohibited substance, NA and LMR - Application of an unauthorized active ingredient and handling errors with authorized pesticides, LMR - use of a substance exceeding the maximum permitted residue limit, NA - use of a substance not authorized for the crop.
Source: Research data (2023).

The number of samples evaluated has increased since 2018, with a slight decline in 2023. An analysis of the reports indicated that, in 2018, 25% of the 105 samples contained unauthorized residues, with 8% exceeding the Maximum Residue Limit (MRL) and 8% classified as Unauthorized and MRL (NA&MRL). In 2019, 70% of the 126 samples exhibited no non-compliance, while 21% contained unauthorized residues. In 2020, 150 samples were analyzed, with 2% exhibiting prohibited residues, 15% showing unauthorized (NA) residues, 9% exhibiting maximum residue levels (MRL), and 5% exhibiting both NA and MRL. In 2021, 68% of the 162 samples exhibited no non-compliance, while 23% contained unauthorized residues. A decline was documented in 2022, with 15% NA and increases in MRL (8%) and NA&MRL (4%). In 2023, of the 145 samples examined, 75% exhibited no occurrences, 21% showed NA, 3% showed MRL, and 1% showed NA&MRL. In 2023, the total number of samples analyzed decreased; however, 75% of them were classified as satisfactory. These results indicated a variation in non-compliance, reinforcing the importance of monitoring pesticide use to ensure food safety.

During the period of the ongoing pandemic of the COVID-19 pandemic in 2020 and 2021, the PARA program suspended its collection of samples, in accordance with the safety guidelines that had been implemented at the national level.[10] However, the RAMA program continued to collect and analyze samples, as it recognized that food products that were in compliance with established standards were of equal importance.

Distribution of Non-Compliant Samples – 2018-2023 Cycle

Pursuant to the food categories delineated above, a total of 848 samples were subjected to analysis. As illustrated in Table 3, the results for each food category are presented with regard to the presence of pesticide residues in supermarkets in Santa Catarina.

Of the 848 samples that were subjected to analysis, 175 (21%) were classified as fruits with edible peel, of which 32% exhibited non-compliance. Specifically, 31 samples contained unauthorized residues, 15 samples exceeded MRLs, and 11 samples contained both unauthorized residues and MRLs.

In the category of fruits with inedible peel, of the 257 samples (30%), 15% revealed non-compliance. It is noteworthy that the majority of these samples (21) contained residues that were not authorized for the crop in question. Furthermore, two samples were found to contain prohibited residues, and 16 samples exceeded the maximum residue limits (MRLs) established for the particular crop.

The leafy vegetable group, which constituted a 6% of samplesof the 52 samples that were subjected to analysis, revealed that 54% of them exhibited non-compliance. The majority of these non-compliance were attributed to the presence of substances not authorized for the crops (11 samples), while nine samples exceeded the MRLs and eight contained both unauthorized residues and MRLs.

With regard to non-leafy vegetables, which constituted 263 samples (31%) and accounted for 42% of non-compliance, it was observed that this group contained the most samples in the study and the highest number of unauthorized substances (84 samples). Within this category, 13 samples demonstrated concentrations that exceeded the established MRLs, while 15 samples exhibited the presence of both unauthorized residues and MRLs.

In the roots and tubers category, which constituted 12% of the 101 samples that were analyzed, 21% were classified as non-compliant. Of these, 19 samples contained unauthorized residues, and one sample contained a prohibited residue and an MRL above the permitted level.

Table 3. Distribution of the number of samples in the 2018-2023 cycle according to product category and type of irregularity identified. Florianópolis-SC, 2024.

Category	Number of Samples Evaluated	NA	LMR	NA&LMR	Proibido	%Nonconformity
Fruits with edible peel	175	31	15	11	0	32%
Fruits with inedible peel	257	21	16	0	2	15%
Leafy vegetables	52	11	9	8	0	54%
Non-leafy vegetables	263	84	13	15	0	42%
Roots and tubers	101	19	1	0	1	21%
Total	848	166	54	34	3	30%

Prohibited - use of a prohibited substance, NA and LMR - Application of an unauthorized active ingredient and handling errors with authorized pesticides, LMR - use of a substance exceeding the maximum permitted residue limit, NA - use of a substance not authorized for the crop.
Source: Research data (2023).

Results by Food Item Monitored

Table 4 presents a comprehensive overview of the number of samples analyzed for each food type within its designated category. It also enumerates the number of non-compliance and non-compliances identified. As illustrated in Figure 1, the active ingredients detected in the analyzed food samples exhibited non-compliance within each category.

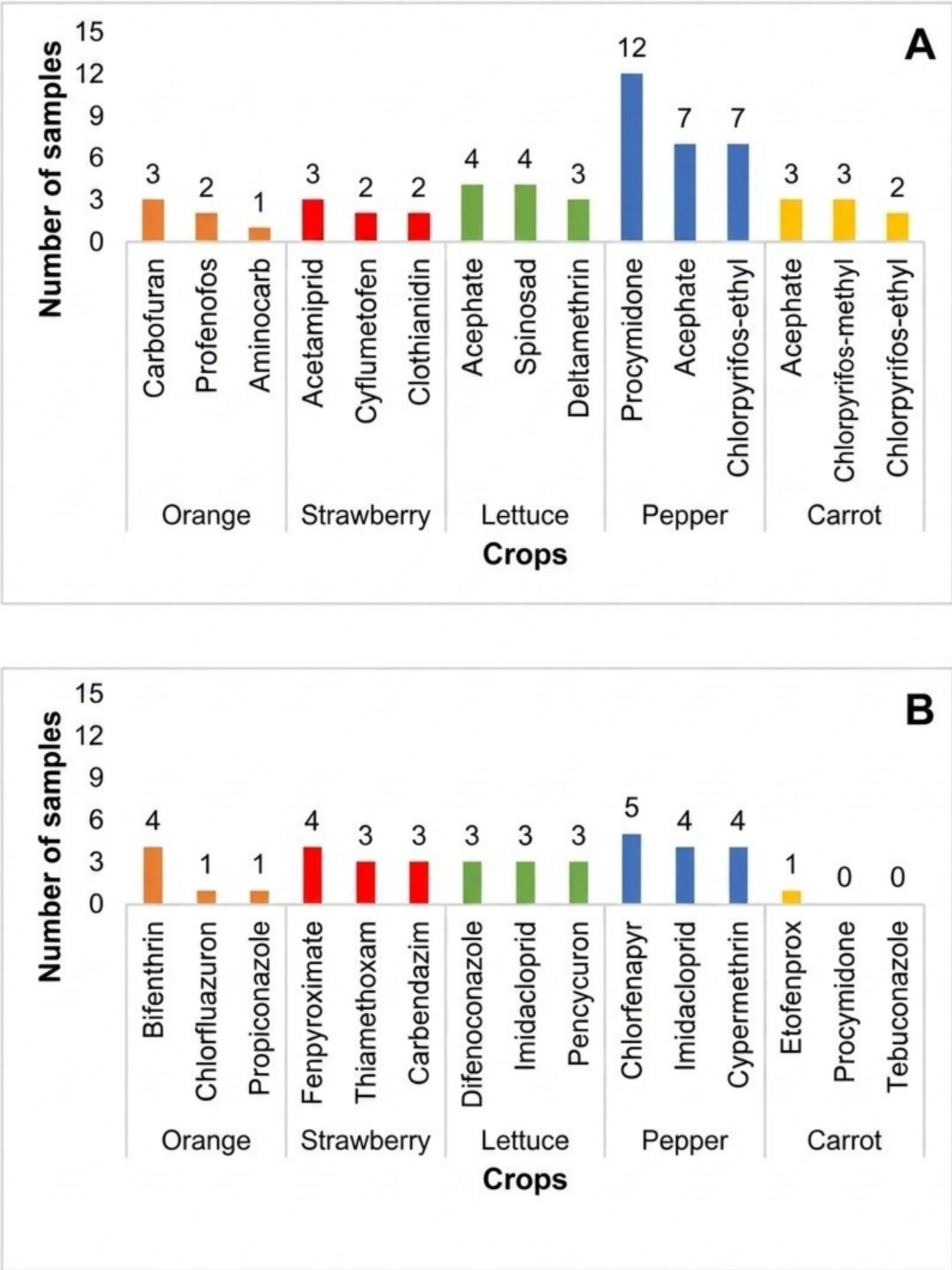
With respect to the components identified by food category, in fruits with inedible peel - specifically oranges, with 68 samples - bifenthrin was the pesticide detected in 66.67% of samples with an MRL; profenofos was detected in 40% of the samples with NA; and carbofuran in 60% of the analyzed samples, also with NA. The pesticide that was prohibited for these samples was orthophenylphenol.

Table 4. Distribution of samples by food and classification by type of irregularity identified, 2018 to 2023. Florianópolis-SC, 2024.

Category	Products	Samples	NA	LMR	NA & LMR	Prohibited	Total number of non-conforming products
Fruits with inediblepeel	Orange	68	5	6	0	2	13
	Pineapple	26	1	5	0	0	6
	Papaya	51	5	1	0	0	6
	PassionFruit	18	4	1	0	0	5
	Banana	37	3	2	0	0	5
	Lemon	33	1	1	0	0	2
	Mango	22	0	0	0	0	0
	Organic Banana	2	2	0	0	0	2
Fruits with ediblepeel	Strawberry	41	8	6	6	0	20
	Grape	59	7	8	4	0	19
	Pear	14	8	0	0	0	8
	Apple	48	5	1	1	0	7
	Guava	13	3	0	0	0	3
Leafy vegetables	Lettuce	36	10	6	4	0	20
	Kale	16	1	3	4	0	8
Non-leafy vegetables	Bell Pepper	62	29	1	9	0	39
	Tomato	77	14	8	2	0	24
	Cucumber	32	12	2	3	0	17
	Zucchini	29	8	1	0	0	9
	Chayote	8	8	0	0	0	8
	Okra	4	4	0	0	0	4
	Organic Tomato	4	3	0	0	0	3
	Onion	25	2	0	1	0	3
	Cabbage	7	1	1	0	0	2
	Broccoli	12	2	0	0	0	2
	Organic Bell Pepper	1	1	0	0	0	1
	Pumpkin	1	0	0	0	0	0
	Corn	1	0	0	0	0	0
Roots andtubers	Carrot	34	11	1	0	0	12
	Organic Carrot	3	3	0	0	0	3
	Beetroot	21	2	0	0	0	2
	Potato	40	2	0	0	0	2
	Cassava	1	0	0	0	1	1
	Sweet Potato	2	1	0	0	0	1

Prohibited - Use of prohibited substance, NA and LMR - Application of unauthorized active ingredient and handling error of authorized pesticides, LMR - Use of substance exceeding the maximum permitted residue limit, NA - Use of substance not authorized for the crop. Source: Research data (2023).

Figure 1. Incidence of Active Ingredients NA (A) or LMR (B) by crop in samples from the RAMA Program 2018 to 2023.



The data presented in Figure 1 summarize the quantitative distribution of pesticide residues. The samples were separated based on the use of NA (A) and MRL (B) substances. The quantitative data regarding the total volume of samples analyzed by crop are presented below.

Among fruits with edible peel, strawberries are notable, with 41 samples, in which 25% of the samples showed levels above the maximum limit for the active ingredients thiamethoxam, carbendazim, and abamectin. Furthermore, the fempiroximate concentration was found to exceed the MRL in 33.33% of the samples. The NA ingredients identified in strawberry crops were: cyflumetofen, clothianidin, spiromesifen, and imidacloprid in 14.29% of the samples, and acetamiprid in 21.43%.

Among leafy vegetables, lettuce exhibited 36 samples, of which 30% were found to contain three types of active ingredients with levels above the MRL: difeniconazole, imidacloprid, and pencicurom. With regard to active ingredients that have not received approval, acephate was detected in 28.57% of the samples, indicating a notable presence of the compound. A similar trend was observed with the active ingredient spinosad, which was detected in 28.57% of the samples, suggesting a comparable rate of non-compliance concerning this compound.

In the non-leafy vegetable group, a total of 62 samples were examined, revealing that the active ingredients imidacloprid and cypermethrin were detected at levels above the MRL in 40% of the samples. The active ingredient chlorfenapyr was detected in 50% of the samples with unsatisfactory MRLs, indicating a more substantial presence of this compound, which exceeds established standards. Conversely, acephate and chlorpyrifos-ethyl were detected in 18.42% of the samples classified as NA.

The active ingredient proximidone was identified in 31.58% of samples, indicating the presence of unauthorized substances.

In the final analysis, a total of 34 samples were included in the roots and tubers category, which included carrots. Of the samples examined, 11 were found to contain NA substances, while one sample was found to exceed the MRL. A thorough analysis of the carrot samples revealed the presence of the active ingredient etofenprox in all of them, indicating a pervasive presence of this compound. Furthermore, acephate and chlorpyrifos-methyl were detected in 27.27% of the samples, indicating the presence of the active ingredient NA.

DISCUSSION

In the category of fruits with inedible peels, oranges exhibited the highest number of non-compliant samples, with a total of 13, followed by papayas and bananas, both with 6 non-compliant samples. Among fruits with edible peels, strawberries exhibited the highest frequency of non-compliant findings, with 20 samples deemed non-compliant, primarily due to the presence of unauthorized residues and residues exceeding maximum residue limits (MRLs). Among leafy vegetables, lettuce and kale showed higher frequencies, with 20 and 8 non-compliant samples, respectively, mainly due to the presence of unauthorized residues. Among non-leafy vegetables, bell peppers exhibited the highest prevalence of non-compliant samples, with 39 samples, followed by tomatoes, with 24. In the root and tuber group, carrots exhibited the highest number of non-compliant samples, with 12 samples. Cassava and sweet potatoes each had one non-compliant sample due to residues detected above the maximum permitted limits.

According to a PARA report covering the 2017–2022 period, residues exceeding the permitted MRLs, NA levels, and even prohibited substances have been detected in orange samples on an ongoing basis. Although residues are primarily concentrated in the peel, potential health risks remain.[10] The Family Budget Survey (POF) demonstrated an increase in the consumption of fruits such as apples, bananas, and oranges, from 3.2% in 2008 to 3.5% in 2018. This increase in consumption may indicative increased consumer exposure to pesticide residues.[11]

According to analyses conducted by the PARA Program during the first seven years, strawberries, lettuce, and tomatoes had the highest levels of unsatisfactory samples among fruits with edible peels. It is noteworthy that certain compounds, including carbendazim, chlorpyrifos, methamidophos, and acephate, have been banned by the European Union. In Brazil, methamidophos is the only chemical that has been prohibited, raising concerns about population exposure regarding the population's exposure to these potentially harmful chemicals.[12] It is noteworthy that, according to data collected by PARA, one-third of the food consumed in Brazil is contaminated with pesticides. In the ranking of the ten most contaminated foods, strawberries rank second, with 64.4% of samples yielding unsatisfactory results.[13]

A study conducted in the state of Minas Gerais in 2012 on the presence of residues in fruits and vegetables found percentages exceeding 20% of unsatisfactory samples in some crops that contained NA residues. Among the substances analyzed was lettuce, in which acephate was identified as an unauthorized active ingredient.[14]

According to the PARA report, during the 2017–2022 multi-year plan, 142 samples of bell peppers were analyzed, in which dithiocarbamates and imidacloprid were found. In the present study, acephate, procymidone, and profenofos were identified as pesticides not authorized for utilization in the cultivation of the crop in question.[11]

A 2023 investigation revealed that bell peppers (68%), strawberries (61%), and grapes (43%) were among the products with the highest number of unsatisfactory samples in the state of Paraná.[15] A 2022 study revealed that bell pepper, carrot, and strawberry crops had the highest rates of non-compliance due to the presence of pesticide residues in Brazil, with 90%, 67%, and 59% of samples, respectively. These findings highlight the need for rigorous oversight of these products.[13] Thirteen active ingredients were detected with the greatest frequency: carbendazim, chlorpyrifos, and acephate. These findings corroborate data from previous reports released by Anvisa.

For root and tuber crops, a study published in 2021 reported that, between 2013 and 2017, chlorpyrifos was detected in 6.8% of samples analyzed in the PARA study in tomato, zucchini, carrot, lettuce, kale, and strawberry crops. As previously reported, a study was conducted on the presence of pesticide residues in various fruits and vegetables, including chlorpyrifos. Of the 16 carrot samples that were analyzed, one sample had a concentration of 0.01 mg/kg, not authorized for that crop.[11,16]

The RAMA Program is a strategy designed to support supermarkets in maintaining compliance with current health regulations. This is achieved by promoting transparency and traceability of products throughout the entire production chain. This initiative fulfills the requirements set forth by regulatory agencies and contributes to the enhancement of consumer confidence in establishments. It demonstrates a commitment to the quality and safety of the food sold, which is essential for maintaining trust in the food industry.

The operational workflow of the RAMA program commences with the direct collection of samples from store shelves (in instances of pre-packaged products) or from boxes delivered by the supplier (in instances of bulk deliveries), which are subsequently subjected to laboratory analysis to diagnose non-compliance and trace the origin. In contrast to punitive mechanisms that entail immediate suspension, the program prioritizes corrective intelligence. Each non-compliant report is integrated into the SARA system, requiring suppliers to submit an action plan within 30 days. This action plan, formulated under technical responsibility, outlines the mitigation of causes and preventive measures. This system is designed to ensure the right to response and to ensure the real-time traceability.

CONCLUSION

The findings of this analysis of pesticide residue monitoring reports highlight the presence of pesticide residues in fresh plant-based foods, which are widely consumed by the population. Consequently, consumers may be exposed to products that pose potential health risks.

These data highlight the need for continuous monitoring through programs capable of tracking, reporting, and supporting corrective actions to ensure food safety and compliance. In this context, the RAMA program functions as a strategic tool by supporting corrective actions and continuous improvement.

SARA records can support producer training and, through traceability data, help identify compliant suppliers and promote continuous improvements throughout the production chain.

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Contributors

Teodoro GA contributed to the conception and design, obtained authorization for data access, performed data analysis and interpretation, reviewed and approved the final version; Hoffmann JF contributed to data analysis and interpretation, reviewed and approved the final version; Rodrigues CTA contributed to the design, formatting, data collection, analysis, and interpretation, reviewed and approved the final version.

Conflict of Interest: The authors declare that there is no conflict of interest.

Received: January 27, 2025
Accepted: March 15, 2026