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Residual incidence of pesticides in vegetable products sold in southern Brazil

Resíduos de pesticidas em vegetais vendidos na região Sul do Brasil

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ABSTRACT

Pesticide use is a widespread practice in agricultural production for pest control. The use of these products must adopt Good Agricultural Practices; therefore, the food is expected to be according to the current parameters. For this, the National Program for the Control of Residues and Contaminants of the Ministry of Agriculture and Livestock created a diagnosis of the products' quality. In this way, the program carried out pesticide analyses to evaluate the conformity of products of plant origin. From the analyzed products, fruits with broad commercialization and production in a state with more analyses were segregated. Based on these data, the banana, potato, apple, tomato, and grape results in the Rio Grande do Sul state (Southern Brazil) were analyzed and interpreted. This survey was conducted from 2016 to 2020, and data were compiled to assess the conformity of fresh vegetables. Samples with residual levels of pesticides above the maximum reference limit for the crop or with residual not allowed for the crop no-tolerance were considered non-conformance. The overall compliance rate for the highlighted vegetables was greater than 95%. The data were similar to countries with rigorous monitoring and application standards for this chemical hazard. Most of the non-conformities occurred due to the presence of residues above the maximum reference limit for the crop, especially due to the presence of insecticides from the chemical groups organophosphates and pyrethroids. These results show that food produced and consumed in Brazil has quality characteristics similar to those in developed countries. Illustrating that the food consumed by the population is safe. To obtain better results, technical assistance to farmers is essential, aiming to reduce the incidence of residues above the Maximum Limit for the crop.

KEYWORDS: fruits; vegetables; agriculture; health; chemical analysis; pesticides; quality Brazil.

RESUMO

A utilização de agrotóxicos é uma prática altamente frequente na produção agrícola, por contribuir no controle de pragas. O uso desses produtos deve respeitar as Boas Práticas Agrícolas (BPA), e, como consequência espera-se que os alimentos se enquadrem nos parâmetros vigentes. Para que essa garantia seja validada, há o Programa Nacional de Controle de Resíduos e Contaminantes (PNCRC) Vegetal do Ministério da Agricultura e Pecuária (MAPA), visando a elaboração de um diagnóstico da qualidade dos produtos. Com base nesses estudos, fez-se uma análise e interpretação dos resultados obtidos com os alimentos: banana, batata, maçã, tomate e uva comercializados no Rio Grande do Sul. Foram compiladas informações de documentos emitidos para o programa, no período entre 2016 a 2020, a fim de avaliar a conformidade dos alimentos in natura. Foram consideradas não conformes as amostras que apresentavam teores residuais de agrotóxicos acima do limite máximo de referência (LMR) para a cultura ou aquelas com residual não permitido para a cultura (NPC). O índice de conformidade geral para os hortícolas destacados foi superior a 95%. Os dados foram semelhantes aos de países citados como rigorosos no monitoramento e fiscalização desse perigo químico. A maior parte das não conformidades (NC) ocorreu pela presença de resíduos acima do LMR para a cultura, em especial pela presença de inseticidas dos grupos químicos organofosforados e piretróides. Estes resultados demonstram que os alimentos produzidos e consumidos no Brasil possuem características de qualidade semelhantes à de países desenvolvidos. Ilustrando o que o alimento ingerido pela população é seguro. Para se obterem melhores resultados é essencial assistência técnica para os agricultores, visando diminuir a incidência de resíduos acima do Limite Máximo para o produto.

PALAVRAS-CHAVE: frutas; vegetais; agricultura; saúde; analyses químicas; agrotóxicos; qualidade Brasil.

INTRODUCTION

The world demand for food has increased, and increasing crop productivity without expanding agricultural areas is challenging; pesticide application is a tool that contributes to increasing this productivity (CALDAS & JARDIM 2011). In order to achieve efficient, large-scale production of food protected from pests, pesticides have proven to be an effective alternative in maintaining crop production and productivity (PASSOS & REIS 2013). These agricultural agents chemically and biologically control most organisms negatively affecting crops, increasing agricultural production and enhancing food supply worldwide (GRANELLA et al. 2013).

However, the consumers' tendency to seek better-quality food is notorious. This demand is closely linked to the issue of pesticide residues in food since the objective is to avoid ingesting contaminated food as it can be potentially harmful to human health (MEIRA 2015). The obligatory agronomic prescription, the implementation of Good Agricultural Practices (GAP), and traceability, in addition to additional programs and systems such as integrated production and hazard analysis and critical control points, among others, have been the driving tools for more rational use of these products (MATTOS et al. 2009). Nevertheless, there have been non-compliance reports (SDA/MPA 2019 e 2021).

Thus, government actions to implement public policies and programs to control pesticide residues in food are essential (MANTELLI 2020). Countries worldwide have implemented programs to monitor and control this issue to mitigate potential damage to public health. Examples of such programs are the Program for the Analysis of Pesticide Residues in Food (PARA), which was created by the National Health Surveillance Agency (ANVISA), and the National Program for Control of Residues and Contaminants (PNCRC), created by the Ministry of Agriculture, Livestock, and Food Supply (MAPA) (BRASIL 2022). Monitoring programs are based on technical standards and pesticide registration processes.

One of the main norms guiding measuring phytosanitary residues in food establishes the maximum residue limits (MRL) each crop can contain. The MRLs are defined through acceptable daily intake (ADI) indices; these values suggest the concentrations in each food that can be consumed without damaging the consumer's health (FERREIRA et al. 2018). The proper use of phytosanitary products promotes a series of benefits to agriculture when the authorized active ingredient is applied to the crop in a controlled manner, at the recommended doses and forms, and respecting the withdrawal periods (i.e., the safety interval between the last application and the harvest) (GRANELLA et al. 2013). Food contamination by pesticides indicates that their use may not follow GAP recommendations, which farmers should strictly adhere to (EMBRAPA 2013).

Non-conformance with GAPs can lead to sanctions for producers who do not follow them. Thus, monitoring programs are mechanisms that help comply with GAP, impacting the final quality of the food and encouraging the proper use of pesticides, reflecting on the public health of the population and the competitiveness of Brazilian agribusiness (PASSOS & REIS 2013). In this context, this study aimed to collect, interpret and diagnose the results analytical results for checking pesticide residues in foods: banana, potato, apple, tomato, and grape collected through the PNCRC-vegetables in Rio Grande do Sul State (RS). As a hypothesis, it is assumed that the main vegetables consumed in the State of Rio Grande do Sul have high levels of pesticide residues, differing from the quality of foods consumed in developed countries. It is believed that the highest rate of non-conformities is related to the use of products not permitted for the crop.

MATERIAL AND METHODS

Descriptive research was conducted by compiling information and processing data from Official Test Results issued in five years (2016–2020) for five vegetal foods largely consumed in RS: banana, potato, apple, tomato, and grape; 263 samples were analyzed to assess potential non-conformities due to pesticide residues in the products.

The choice of products was based on data released by the PNCRC, the collections carried out, and information from the states, with the products with the highest production being chosen. The data showed that the vegetables sampled for the PNCRC vary according to the year. Considering that there is no annual sampling of all vegetables, it was impossible to carry out an annual comparison of the pesticide residues detected. Thus, for some vegetables, the comparison was made according to the year of collection, with intervals.

The results from the sampling units identified above refer to products collected by civil servants assigned to inspection services for products of plant origin (or similar) from MAPA or associated institutions, such as the Department of Agriculture of RS in various commercialization points: packaging facilities, industrial facilities, supermarkets, distribution centers, and wholesalers. The sampling followed the procedures described in the PNCRC Manual - Vegetal. This standard instrument guides the actions to be taken and developed to avoid cross-contamination and ensure that the laboratory analyses represent the product's real situation (MAPA 2013a).

The samples were collected and sent to official MAPA laboratories, Federal Agricultural Defense Laboratories, or accredited laboratories in sealed boxes. In the laboratories, specific reception, storage, and analysis procedures were followed, with a guarantee of the quality of the results, following international guidelines (MAPA 2013a). Residual determination of pesticides was carried out using the method of Multiresidues of Pesticides in Food by QuEChERS and HPLC-EMEM, in which liquid chromatography equipment coupled to mass spectrometers were used. These techniques allow one to separate, identify, and quantify analytes separating the compounds in liquid medium and subsequently by mass detection (PANIAGUA & SANTOS 2021).

The residual quantities measured in the laboratory analyses were compared with the monographic indices of the active ingredients identified. The pesticide residues that presented levels above the MRL for the crop were considered non-conformance. In addition, residues of active ingredients of pesticides that were not registered for the crop in which they were detected were also considered non-conformance, the so-called products not allowed for the crop or no-tolerance. Non-conformance, or violation, was considered the laboratory uncertainty values identified in the analytical reports for classification (MAPA 2013b).

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RESULTS AND DISCUSSION

Although the sample size is small (n = 263) (Figure 1), there has been an expansion of the Department of Products of Vegetal Origin actions together with the PNCRC of MAPA in recent years. This is proven by using more robust plans and the change in how the program is approached, which went from a simple monitoring program to an inspection program, directly impacting the improvement of processes, focusing on risk analysis and on products with greater potential for problems.

Maintaining systems for monitoring solid pesticide residues is extremely important when we think about public health issues, as several studies demonstrate the harmful effects of ingesting these substances, such as acute and chronic effects (LOPES & ALBUQUERQUE 2018).

When compared to the 2001–2010 period, which was analyzed by CALDAS & JARDIM (2011), there was a significant increase in samples collected for the program since, in that period, 1,484 samples were analyzed, covering the entire scope of crops in the PNCRC throughout Brazil. The number of collections of the five products selected in RS (263) is similar to those analyzed by the US Food and Drug Administration (FDA) from 2016 to 2018 for plant products, such as potatoes, apples, tomatoes, and grapes.

Although the current amount was higher than the period previously cited, when comparing data from RS with data from programs in developed countries such as Germany, there appears to be a notable difference in the number of products evaluated. For instance, Germany analyzed 58,836 samples from 2016 to 2019, an average of over 14,000 aliquots of fruits, vegetables, and other agricultural products analyzed annually, measuring residues of about 294 pesticides (BVL, 2016, 2017, 2018, 2019). This demonstrates that Brazil must further improve the PNCRC to prevent potentially problematic foods from reaching consumers. Likewise, this measure guarantees the competitiveness of Brazilian agribusiness, as foreseen in MAPA's mission. Hence, with countries that import our agricultural products, preventing pesticide residues from being found in the destination country is indispensable, as this could impact Brazil's exports due to any embargoes suffered.

The analysis of the laboratory results revealed that 251 samples were compliant, corresponding to 95% of the products. The conformity index of RS products is similar to 2014–2018 data in Belgium, which found conformity indexes near 95% (94.7–95.6%) in fruit, vegetable, and other cereal samples (BELGIUM 2018). It is also close to the values reported by the FDA between 2016 and 2018 for fruits and vegetables, with an average of 95% compliance.

The general compliance index presents good numbers, demonstrating the quality and potential of Brazilian agricultural products. Furthermore, 56 samples (21.30%) did not contain pesticide residue; only 12 samples (4.56%) showed non-compliance, constituting 14 identified problems. The number of nonconformities is higher than that of samples with problems because the same sample can present more than one violation.

The number of samples without pesticide residue in RS is slightly lower than the data found in Belgium from 2014 to 2018 for fruits, vegetables, and other cereals, which detected, on average, 29.5% of samples without residues (BELGIUM 2018). In addition, the numbers are very close to those found in the averages of analyses performed on potatoes, apples, tomatoes, and grapes from 2016 to 2018 by the FDA. The values of pesticide-free samples were also close to 22% in the US.

Such information denotes that the quality of the products analyzed in RS has very similar characteristics to those of developed countries and demonstrates the strengths and opportunities for the Brazilian agricultural sector, especially in meeting the global food demand. Within the non-conformities detected, the highest proportion of non-conformities was due to the detection of residues above the MRL and the presence of prohibited agricultural pesticides. Of the 14 non-conformities, 10 were caused by product residues above the maximum allowed.

Os dados encontrados nos produtos analisados no Rio Grande do Sul diferem daqueles registrados no estado de Minas Gerais, no período de 2013 a 2017, onde foi constatado que 62,3% dos produtos de origem vegetal estavam contaminados por resíduos de agrotóxicos, e no estado do Rio Grande do Sul, entre os produtos analisados, o número ficou bem abaixo (RIBEIRO et al. 2021).

By analyzing the historical data, we observed a shift in the profile of the non-conformities found compared to those in the 2001–2010 period (CALDAS & JARDIM 2011). This is because in those years, by evaluating data from the PARA and PNCRC, the authors verified that most of the non-conformities occurred due to an unauthorized active ingredient for the crops (banana, potato, apple, tomato, and grape), particularly methamidophos, chlorpyrifos, and dithiocarbamates, which are prohibited in Brazil since 2012. Two of these residues have continued to be detected.

The analyses performed on fruits destined for export corroborate the information on changes in the NC profile detected, as described by CISCATO et al. (2009), who evaluated 112 samples from 2006 to 2007 and found that 5.4% of products were non-compliant due to pesticide residues above the MRL for the crops (banana, potato, apple, tomato, and grape), and 17.8% of samples were non-compliant due to the presence of no-tolerance pesticides. Another important piece of data is that brought by LOPES & ALBUQUERQUE (2021), who stated that in the period from 2001 to 2015 the main cause of non-conformities in foods analyzed for ANVISA's PARA was caused by active ingredients not authorized for food processing. culture or for the country, thus reinforcing the change that has occurred.

Figure 1 shows the detections found in the product analyses within the group that presented pesticides in disagreement with what is allowed for the crop (i.e., the MRL). Residual indices ranged from 0.01 to 0.57 mg kg^{-1} when considering the uncertainty of the methods. As for the no-tolerance pesticides found, violations occurred due to very low concentrations, all below 0.01 mg kg^{-1}, also considering the uncertainty of the methods. Hence, it is likely that despite the non-conformities, the residuals found are in very low concentrations.

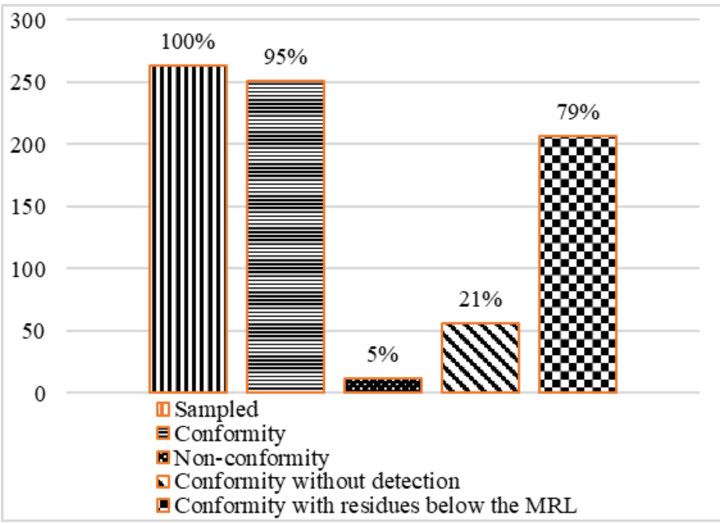

Figure 1. Types of non-conformities found from 2016 to 2020.

When the specific data of each product for RS were analyzed, we found no non-conformities in any apple sample for 2016 to 2019, and in 2020, the collection was not carried out. The low incidence of non-conformities in apples, such as RS, was also observed in Germany, which analyzed 606 and 684 samples in 2017 and 2018, respectively, and only 0.3% of the crops each year showed some residual at non-compliant levels (BVL 2016, 2017, 2018, 2019). Compared to the analyses carried out by the Australian Department of Agriculture and Water Resources, which also has a program that analyzes pesticide residues in apples, RS numbers showed a superior compliance performance (AWE 2016, 2017, 2018, 2019, 2020).

When compared with data from the state of Minas Gerais, for the period from 2013 to 2017, it is clear that the results for the state of RS were better, and in the workforce located in the southeast of the country, there was non-compliance close to 13%, while in the state of Rio Grande do Sul, there were no non-compliances in the period (RIBEIRO et al. 2021).

The data for the RS samples is highly relevant since, as described by CALDAS & JARDIM (2011), apples from 2001 to 2010 were the crops that had the most samples collected to investigate pesticide residues. The product had the highest percentages of non-conformities, most caused by the presence of unauthorized pesticides for the crop. This demonstrates that there has been an update in pesticide registration in Brazil and improvements in the implementation of good agricultural practices by farmers since, according to EMBRAPA (2013), the contamination of products of plant origin by pesticides may be associated with the lack of monitoring of good agricultural practices (GAP) by rural producers.

BARIZON et al. (2013) also reported that in a sample of 170 apples analyzed in 2009 in the PARA, 3.5% presented pesticides not allowed for the crop, and 1.8% presented residue levels above the MRL. In addition, of 218 samples collected for the PNCRC, 2.3% had no-tolerance pesticides, and 0.9% had residues above the MRL, highlighting that farmers have improved processes following GAP, and technical recommendations, using registered pesticides and respect the period of degradation of the pesticide.

Although we see an apparent improvement in issues related to pesticide residues in apples, we need to pay attention, in particular, to climate issues that can influence the emergence of diseases in the fruits, enhancing applications. This case was cited by LOPES & ALBUQUERQUE (2021), who found that in 2015, there was a finding of pesticide residues contrasting with those that occurred in previous years in the apple product, which may have occurred due to some climatic condition that favored the incidence of pests.

As for the evaluation of residues in the other crops (Figure 2), we observed no collection of bananas within the PNCRC Vegetal for RS in the first four years of the series. In 2020, laboratory analyses found a 14.28% incidence of non-compliance. Potatoes were not collected in 2016 and did not show non-compliance in the following three years, with a small incidence of pesticides above the MRLs in 2020.

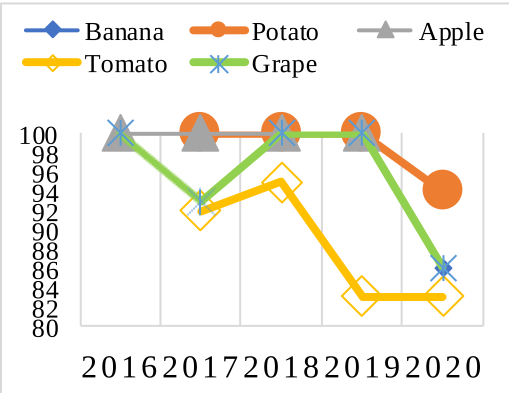

Figure 2. RS compliance rates from 2016 to 2020 and percentage of sample compliance.

Tomatoes had an incidence of residues above the MRL or no-tolerance in all years the product was collected in RS from 2017 to 2020. As for the fruit of the Vitaceae family, from which samples were collected, there was an oscillation of violations over the years, with 100% compliance in 2016, 2018, and 2019 and a slight incidence of non-compliance in 2017 and 2020.

Thus, the rates shown in Figure 3 were obtained when checking the compliance percentages over the years. The apple was the crop that presented the highest compliance standards, and the banana had the lowest compliance over the years; however, for the case of RS, the product was only collected in 2020 (7 samples), of which only 1 presented a violation. All crops showed compliance rates above 86%

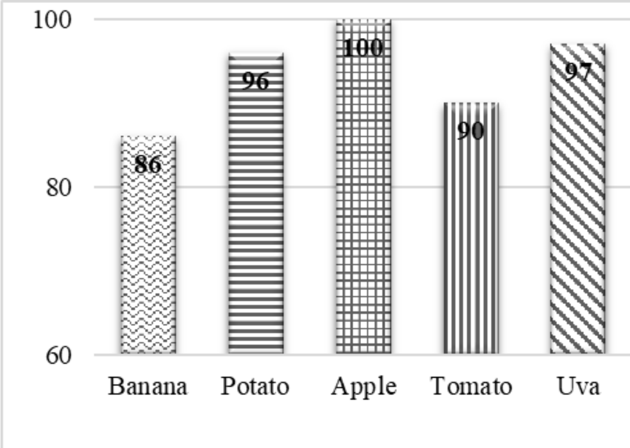

Figure 3. RS compliance rates from 2016 to 2020 and percentage of sample compliance.

The analysis of the results shows that the chemical groups of the pesticides most detected within the non-conformity samples correspond to organophosphates and pyrethroids (Figure 4). The two chemical groups have insecticidal action to control pests in crops. This is understandable from a technical point of view since various pests affect crops, and their control is essential because they can be potential vectors of diseases as they harm fruit tissues.

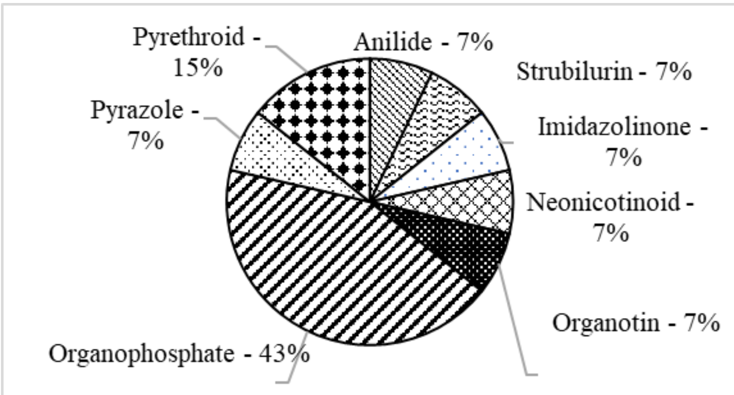

Figure 4. Percentage of nonconformities by chemical groups

Within the total quantity of samples analyzed without considering the segregation of non-conformities, carbendazim was the most common residue, as it was found in 108 samples, especially in the apple samples. Applying this pesticide for apple cultivation is made through the leaves, and the MRL is 5.0 mg kg^{-1}, representing a relatively high value. This led to a lower incidence of non-conformities because the concentrations were between 0.01 and 1.07 mg kg^{-1}, and considering the laboratory uncertainty, values were well below the MRL of the crop. These data corroborate CALDAS & JARDIM (2011), who also reported that the active pesticides most frequently detected in horticultural products were dithiocarbamates and carbendazim.

Within the list of collections carried out in the Brazilian program (i.e., PNCRC), apples and tomatoes were the products with the most samples analyzed in RS (84 and 67, respectively). Bananas had the lowest number of samples analyzed, as they were only included in the program in 2020. Forty-five samples of potatoes and 60 samples of grapes were also collected; these two products had compliance rates above 95%.

The analysis on bananas showed that only one non-compliance was found, caused by no-tolerance residues for pesticides classified agronomically as an insecticide. The active pesticide detected was lambda-cyhalothrin, which consists of a product registered for various fruit and vegetable crops except for the banana. Most of the time, the application is made through the leaves. In the case of the violation found, the concentration identified was 0.00709 mg kg^{-1}.

The current data showed a slight negative oscillation between the data of banana samples in 2009 for the PARA, in which 170 samples were evaluated, and 1.8% presented violations due to unauthorized pesticides, 1.8% due to MRL, and the 30 collections carried out for the PNCRC, where, in the same year, no sample presented NC (BARIZON et al. 2013). The highest percentage of non-conformities from 2016 to 2020 was closely linked to the sampling, and given the low number of collections, there were higher rates of non-compliance due to the non-compliance of only one sample.

The tests to evaluate the levels of pesticides in potatoes in RS for 2016–2020 did not show the presence of no-tolerance pesticides, and the presence of pesticide residues was verified in two samples. Non-compliance was due to the presence of pesticides classified as insecticides and acaricides. Imidacloprid is an insecticide used via the foliar route to control pests such as green leafhoppers and aphids (AGROFIT 2021). The safety period for the product is 21 days, and the MRL is 0.05 mg kg^{-1} of the pesticides (ANVISA 2021). In the case of these pesticides, the concentration found was 0.05017 mg kg^{-1} after discounting the uncertainty value, with the NC represented by a relatively low amount of residue. Methamidophos, however, corresponds to a pesticide of prohibited use in Brazil, although it also corresponds to a metabolite derived from other substances, such as acephate.

Because it is impossible to infer that the product is a pesticide banned in Brazil and not derived from metabolization processes, non-compliance is considered a product above the MRL, according to the monographic index of the pesticides likely to cause the metabolite. Thus, it is considered that the pesticides are classified as insecticide and acaricide used via the foliar route, with a safety interval of 21 days; the MRL of the pesticides for the potato crop is 0.01 mg kg^{-1} (ANVISA 2018). Phytosanitary controls pests of the Aphidoidea family on Solanaceae (AGROFIT 2021). In this case, the concentration was 0.01108 mg kg^{-1} when discounting the uncertainty.

The low rate of non-conformities, similar to what occurs in RS, was also observed in countries such as Germany, which collected, in 2018, a quantity of 404 samples, none of which presented NC (BVL, 2016, 2017, 2018, 2019); Belgium also reported only 2.7% of non-compliant potatoes in 2018 in 37 samples (BELGIUM 2018). The FDA found no sample with pesticides no-tolerance or above the MRL in 70 samples in 2016–2018.

By comparing with samples analyzed in Brazil, there was no significant change in the results in 2009 (roughly 96% of compliance). However, there was a change in the profile of the NC since, in the previous period, for the PARA, 1.2% had unauthorized pesticides out of a total of 165 samples, and in the PNCRC samples, 3.3% had no-tolerance pesticide residues out of 30 samples (BARIZON et al. 2013). In the current situation, the NC was caused by residues above the MRL for potatoes. Likewise, in an analysis carried out in the state of Minas Gerais, a low incidence of non-conformities was found, at around 3%, within a list of 30 samples, which was caused by a product not permitted for cultivation (RIBEIRO et al. 2021).

Among the products analyzed (Figure 5), the tomato showed the highest ratio of non-conformities out of 67 samples collected, and 7 showed some residue above the MRL or no-tolerance, most of which was due to residues above the MRL. The organophosphate insecticide and acaricide acephate (acephate + methamidophos) were the pesticides in most samples (57%). This pesticide is permitted for use in foliar applications in tomato crops, with a vast safety period of 35 days; the reference MRL for the product is 0.02 mg kg^{-1} (ANVISA 2018). Additionally, it is used in tomato crops to control Aphids, Thrips, *Diabrotica speciosa*, leaf miners, fruit borers, and red spider mites (AGROFIT 2021). The concentrations detected in tomatoes ranged from 0.0414 to 0.5676 mg kg^{-1}.

Within the group of no-tolerance pesticides, there was an incidence of two pesticides in tomato samples: the fungicide fentin (0.007 mg.kg^{-1}, excluding uncertainty), which is registered for some vegetables and grains and is used to control stains, anthracnose, and rust and has a protective effect; and the insecticide fipronil, also classified as ant killer and termite killer (0.00741 mg kg^{-1}), registered to control pests, such as thrips, caterpillars, and termites, in forest species, and large crops.

The highest incidence of non-conformities in Solanáceas was also recorded by RIBEIRO et al. (2021) in an evaluation carried out from 2013 to 2017 in the state of Minas Gerais and demonstrates that, historically, the product presents problems. It should be noted, however, that non-conformities in tomatoes in the state of Minas Gerais were almost 35%, a figure much higher than that found in RS.

The incidence of pesticide residues with no tolerance or above the MRL in the tomatoes from RS differs from those sold in Germany since pesticide residues are uncommon in tomatoes sold there. In 2018 and 2019, 360 and 589 samples were analyzed, respectively, and only 0.3% in each year presented NC (BVL 2016, 2017, 2018, 2019); this is similar to data from Belgium in 2018, in which 106 tomato samples were collected and none presented NC (BELGIUM 2018). As for the FDA, 105 samples were analyzed from 2016 to 2019 and only 0.95% had NC.

When comparing the data from 2016 to 2020 with the results of the PARA and PNCRC in 2009, it appears that in the previous year, 144 samples were collected for the PARA and 31.3% had unauthorized pesticides and 1.4% above the MRL, unlike what currently occurs. As for the 2009 PNCRC samples, 3.3% had no tolerance out of 30 samples (BARIZON et al. 2013).

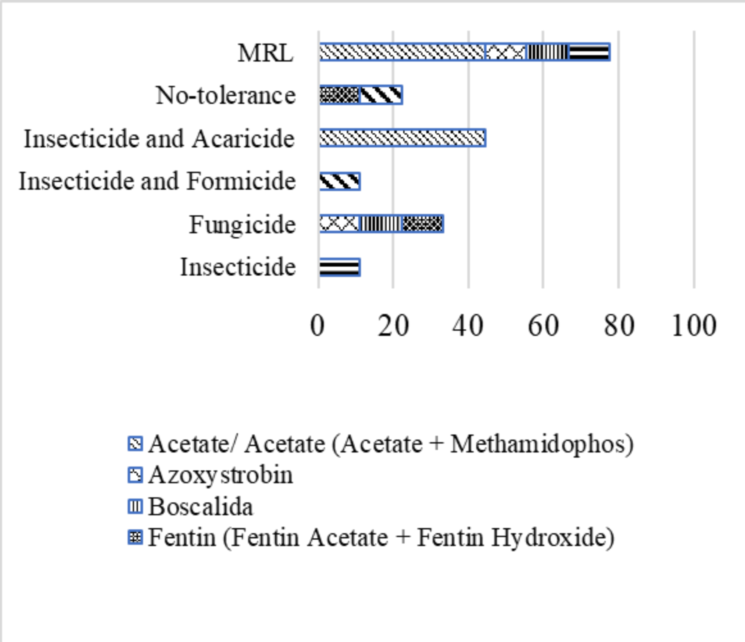

Figure 5. Percentage of non-compliances for tomatoes between 2016 and 2020 (MRL - maximum reference limit; NAC – not allowed for crops).

Finally, the grape presented only two non-compliant samples out of 60 analyzed samples, making up an index of 97% of compliant products. Of these, one residue belonged to the agronomic class of fungicides and one to the agronomic class of insecticides and acaricides. The fungicide found (Ciazofamida) showed pesticide residue levels above the MRL (i.e., 0.25 mg kg^{-1}), which is 0.2 mg kg^{-1} for grapes. The insecticide/acaricide dimethoate (dimethoate + omethoate) corresponded to the active pesticide not recommended for grapes of the Vitaceae family, which were found at a concentration of 0.00858 mg kg-^{1}. Dimethoate (dimethoate + omethoate) is registered for some vegetables, such as apples, citrus, and tomatoes, and for other crops, including cotton and wheat. Dimethoate also controls *Anastrepha fraterculus* and other pests, such as *Diabrotica speciosa*, Aphids, and Mites (AGROFIT 2021).

Germany and the USA also analyzed grape samples and found lower NC rates than RS. The former analyzed 546 samples in 2018 (0.4% NC), and in 2019, it analyzed 383 samples (0.3% NC) (BVL 2016, 2017, 2018, 2019), while the latter analyzed 103 samples from 2016 to 2019 and only one result, in 2018, presented a pesticide above the MRL (FDA 2016, 2017, 2018). Data related to grapes deserves special attention. If compared with the data analyzed by RIBEIRO et al. (2021), in Minas Gerais. At the time, the authors found that for a group of 18 samples analyzed, 66.7% were unsatisfactory. A number much higher than that found in the southern state of the country.

Although NC occurred from 2016 to 2020 in RS, it should be noted that the current compliance values are higher than those identified in the PARA and described by BARIZON et al. 2013. In 2009, 165 grape samples were analyzed, and of these, 35.2% had NC due to the presence of no-tolerance pesticide residues and 12.7% due to the presence of residue above the MRL; in addition, 8.5% of the samples had non-compliance due to both situations.

Although we have two programs related to monitoring pesticide residues in Brazil (PARA and PNCRC), it is clear that there is a lot to evolve, especially in increasing the number of products analyzed and greater harmonization. CENTURIÓN et al. (2023), even suggests harmonization at Mercosur level, so that procedures can be established within the bloc for greater residual control of pesticides, including favoring the export of our products and guaranteeing the quality of the food consumed by the population.

This becomes relevant, as it is necessary to avoid the ingestion of pesticide residues above acceptable daily limits, when all foods consumed by the population are added together. MARQUES & SILVA (2021), for example, found that according to studies carried out until 2016, a large part of the population was consuming more pesticides than technically acceptable, thus reinforcing the need to strengthen programs such as PNCRC-Vegetal.

CONCLUSION

On average, 95% of bananas, potatoes, apples, tomatoes, and grapes commercialized from 2016 to 2020 in Rio Grande do Sul State conformed to legal parameters. Among the 263 samples analyzed, 251 were within legal limits, including 56 with no pesticide residue. The banana was the crop with the highest rate of non-conformities (14%); however, it was only collected in 2020, with a low sample number (n = 7). There were no non-conformities in apples. Most of the non-conformities occurred due to the presence of pesticides above the maximum residue limit of the crop, especially due to the presence of residues of organophosphate insecticides and pyrethroids. The residue with the highest incidence was Carbendazim (108 samples). When compared to analytical results from international waste analyses of pesticides, it appears that Brazilian results, for the products listed, are similar to those from developed countries.

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