A Review on Mycotoxins in Spices from the Brazilian Market in the Light of the Last Ten Years

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Abstract. The consumption of spices in Brazil is common and even a cultural habit. Due to the subtropical climate of the country and the lack of adequate sanitary measures in the production chain, the risk of spice contamination by toxigenic microfungi is increased. The presence of mycotoxins in food is of concern because even in small amounts, they can trigger acute and chronic diseases. This review summarizes data from 20 references, including papers and academic thesis, concerning the presence of mycotoxins and microfungi in spices commonly consumed in Brazil in the last 10 years. A total of 16 spices, 6 mycotoxins, and 28 classifications of mycotoxin producers are reported, and most of the microfungi found belong to the *Aspergillus* genus. The *Penicillium* genus also appears in a great number of references. The most found mycotoxins are Aflatoxins (AFs) and Ochratoxin A (OTA). The difference in the number of references which presented contamination above and below the limits established by the Brazilian legislation was small, indicating that the contamination of spices could represent a food safety issue in Brazil.

Keywords. Aflatoxins, ochratoxins, microfungi, Brazil, spices, contamination

1. Introduction

Spices have been used for many years by various peoples, mainly for culinary and medicinal purposes. In Brazil, their consumption is common throughout the territory (1). Because some spices naturally have antioxidant and antimicrobial properties, they are also used for better food preservation (2). However, unfavorable processing and storage conditions have made such products become major sources of microbial and fungal contamination, which can bring serious risks to human health (3). They have the ability to produce chemical compounds called mycotoxins, which are molecules from their secondary metabolism that, even in small quantities (1), can lead to acute and chronic problems, such as liver cancer, reduction of immunity, alterations in the protein metabolism, gangrene, convulsions, and respiratory problems, among others (4). The objective of this review was to identify the occurrence of mycotoxins and their producers in the Brazilian scientific literature in the last 10 years, that is, since 2013. All the relevant literature was considered, and it is mostly composed of scientific articles and academic thesis, which amounted to a total of 30 references used for both theoretical background and for obtaining the information sought. Only 20 of the 30 references contained satisfactory information that could be inserted in two different comparative tables. The selection criteria included the presence of the words “mycotoxins” or “microfungi” in “Brazilian market” or “Brazil” in “spices” besides the reliability of the methodology used. The search was conducted first in English and further in Portuguese through the Google Scholar search tool. Google Scholar was the chosen tool because it is free, it has good coverage of non-English sources, and it is a database with a wide scope.

2. Spices in Brazil

2.1 Spices as a Part of the Brazilian Diet

The use of spices in Brazilian cuisine is very common and distinct in the regions of the country. They are part of the Brazilian culture, being used in typical dishes, such as in the “moquecas” of the Bahian and Capixaba cuisines or in “tererê” and “chimarrão”, drinks characteristic of the southern region of the country (5). They are also used in the preparation of wines, farinaceous products and sauces or jams (1).

As an example, chilli peppers can be mentioned (*Capsicum spp.*), consumed fresh, as appetizers, processed or even as part of other seasonings. It is estimated an average pepper consumption of 0.5g per person daily. The pink pepper or Brazilian peppertree (*Schinus terebinthifolius*) is also widely used, especially in gourmet cuisine, because it gives a distinctive flavor to desserts and drinks (6).

2.2 Brazilian Spice Production

Brazil stands out mainly because of black pepper production (*Piper nigrum L.*), being its fourth largest producer worldwide (7). About 40,000 tons/year are produced, and most of this production is destined for export. Moreover, according to the Instituto de Economia Agricola, in 2019, tea, mate and spices exports from January to September accounted for 0.31% of Brazil's sectoral foreign sales (1).

The production of pepper (*Capsicum spp.*) is also an important economic activity, strengthening the ties between family agriculture and agro-industry. Used by the indigenous people of the country for a long time as food and medicine, its annual production is about 280 tons in an area equivalent to 13 thousand hectares. Pepper is, therefore, one of the most cultivated vegetables in the country, and the domesticated species produced are *Capsicum annuum, Capsicum chinese, Capsicum baccatum* and *Capsicum frutescens* (6). Another group of spices that is also widely used in Brazil is pink pepper (*Schinus terebinthifolius*), produced mainly on the Brazilian coast (6).

2.3 Brazilian Regulation of Mycotoxin in Spices

According to Brazilian legislation, spices are products composed of parts of one or more plant species, and the mixture of these with other ingredients forms seasonings (1). In Brazil, the current legislation establishes a maximum of 20µg/kg for aflatoxins, being 5 µg/kg for AFB1 (11), and 30µg/kg for Ochratoxin A (OTA) in spices (12). This resolution only mentions *Capsicum spp.* (dry, whole or crushed fruit and spice mixtures), *Piper spp.* (fruit, black and white pepper), *Myristica fragrans* (nutmeg), and *Zingiber officinale* (ginger) (13, 2). There is no information on fumonisins in spices, probably because their occurrence in spices is rare compared to aflatoxins and OTA. Also, there are no maximum limits for herbs intended for beverage preparation (e.g., infusions) (11).

3. Mycotoxins and Their Producers Included in This Review

Mycotoxicosis caused by ingestion of mycotoxin-contaminated foods is a huge health problem in most countries, mainly in developing countries like Brazil. Acute and chronic contamination have been well documented as the effect of such contaminations (4)

3.1 Aflatoxins (AFs)

Produced by *Aspergillus spp.*, the AFs are the world's most significant (4) and studied mycotoxins (8). They are widely exposed to humans at high levels (4), which is a concern because of their toxicity. It is estimated that about 4.5 billion people are exposed to aflatoxins. They mostly occur in tropical countries because of the ideal climate conditions and the poor postharvest and storage medium. The aflatoxins B1, B2, G1 and G2 are considered the most abundant, toxic and carcinogenic mycotoxins (4). For example, AFB1 is synergistic with hepatitis B virus (HBV) infection and has been related to liver cancer and immune suppression (4).

3.2 Ochratoxin A (OTA)

Characterized as possibly carcinogenic to humans (category 2B), the OTA is a mycotoxin produced mostly by species of *Aspergillus*, but also *Penicillium*. It has nephrotoxic, genotoxic, teratogenic and carcinogenic properties (9). In laboratory studies, it has been shown that it is related to the emergence of malignant tumors in the urinary system, chronic kidney disease, and kidney damage (10).

3.3 Fumonisins

Produced by species of *Aspergillus* and *Fusarium* (4), the contamination of spices by fumonisins is not very frequent so Brazilian legislation does not establish levels of fumonisin contamination in spices. They are mostly related to the contamination of corn and its derivatives, and the most dangerous is FB1. The investigators suggest that its toxic action result from the inhibition of sphingolipid biosynthesis, which may cause severe cellular damage. As these mycotoxins are hydrosoluble, they can remain undetectable most of the time, being more dangerous to human health (4).

4. Mycotoxins and Microfungi in Spices from the Perspective of Research in the Last Ten Years (Since 2013)

The tables showed in the appendixes of this paper are presented for a clarified vision of the information found in the selected literature. The first table relates the reported mycotoxin-producing species and spices and the second one shows the mycotoxins found in each spice. The "Reference" column present in both tables shows the articles where the information was found.

4.1 Mycotoxin Levels in Spices in Relation to Brazilian Legislation

The contamination of spices by mycotoxins is variable in the general literature (14) However, in most part of the selected articles which brought this information in this review, the level of contamination by mycotoxins was under the Brazilian legal legislation tolerances (9, 5, 6, 2, 15, 7, 16, 17). However, the difference between the number of articles under and above the Brazilian regulation was small, indicating that the contamination of spices by mycotoxins could represent a food safety issue in Brazil (11, 18, 13, 19, 20, 12).

Specifically, spices whose limit was exceeded for aflatoxins were colorau, paprika, turmeric, star anise, mentha, nutmeg, black and white pepper and rosemary (18, 13, 21, 11). Rosemary is not covered by Brazilian regulation for mycotoxins, which should be reviewed within the legislation (2). For ochratoxins, the limit was exceeded in paprika, anise, star anise, mentha and nutmeg (13, 21, 11). The other mycotoxins found are not covered by Brazilian legislation, probably because they are considered emerging mycotoxins (11).

5. Discussion

The chosen literature revealed that the contamination of the spices is maximized due to poor sanitary conditions within the process of its production, including all the steps: harvesting, storage, processing and commercialization (1).

In tropical countries, such as Brazil, the occurrence of high temperatures, humidity and rainfall rates are conditions which naturally provide a suitable environment for microbial growth, especially fungi growth. Then, it is known that the substrate's water content is a key point during spice production since it is a parameter to determine whether the final product will or will not have mycotoxin contamination. That is why the dehydration step is critical and it should be carried out even more carefully in such countries. (14).

It was expected that these factors were more considered by the spice market in Brazil, however as showed by Brito (6), many products are not stored appropriately regarding the temperature conditions, increasing the risk of contamination by fungi and mycotoxins. (6). As an example, it is known that spices marketed in bulk, that is, outside of the grocery stores, have higher levels of mycotoxin contamination. Bulk markets are very common and even cultural places for buying and selling in Brazil. The contamination is probably higher in these markets because the supplier control is not well regulated, as well as the temperature and humidity in the points of sale (7). Negligence in decontamination practices, inadequate consumer habits and the lack of efficient methodologies for contaminant removal can also be sufficient reasons for that (10).

In such matter, the mainly potentially toxigenic fungi which contaminate spices in the Brazilian market are from the genders *Aspergillus* and *Penicillium*. The ingestion of food contaminated by mycotoxins, even in low quantities, can cause chronic and acute effects on human organs and other animal species. (1). Among the existing ways of food contamination, the microbiological one is of major concern, because it is the most frequent (22). Some parts of the selected literature mentioned an interesting fact which is the correlation between the antimicrobial properties of the spices and lower levels of contamination (2, 14). Even so, this relation is not significant to prevent contamination in most spices (19).

6. Conclusions and Perspectives

The stricter control of the raw material used by the industry (7), the evaluation of the current forms of transport and storage, as well as of the agricultural measures used in the management of spices commercialized in Brazil should be carried out so that the fungal contamination of these foods can be reduced (1).

The adoption of good agricultural practices in planting, harvesting and drying and the maintenance of low water activity values during the process of storage, transport and trade of spices must be monitored (7), as this is the main way to ensure the safety of the final product (10). The complete elimination of chemical contaminants along the spices production chain is very difficult, therefore, strict control of all its stages becomes essential (10).

It is also important that farmers and other people involved in the spices production chain may have sufficient knowledge of the sanitary risk involved in handling these products and the measures that are necessary to avoid such contaminations (10). On the other hand, consumers should take certain precautions when purchasing spices, always checking the hygienic-sanitary conditions, especially in bulk products (23). In addition, proper cooking of food preparations containing spices can also be a good practice for increased safety in the consumption of such foods. In family cooking, where the consumption of spices is usually allied to a food cooking process, a reduced risk of contamination has been reported (24).

A few decontaminating methods were cited within the literature reviewed as possible prospects for use in the spice industry. They are ionizing radiation and ozonization. Ionizing radiation is a technique regulated and approved for use in spices in Brazil by ANVISA (Brazilian Health Regulatory Agency) since 2001. The ozonization is a technique considered safe by the FDA, however, in Brazil, it is only regulated for use in water (7). Ozone gas has oxidative potential, so it destroys the microorganism cell wall and consequently reduces the production of undesirable metabolites without causing environmental damage, besides being economically feasible (25).

Such methods should at least be considered, because, as already described above, contaminations above safety limits constitute a serious public health problem, along with a reduction in the economic value of the product and loss of exports (22), directly interfering with people's quality of life and in the economy (10).

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The references with "*" are not present in the text. They are only present in the Appendixes.

Appendix 1

Table 1 - Mycotoxin producing species reported in spices marketed in Brazil since 2013

Mycotoxin producers	Spice: *latin* name	Spice: common name	Reference
Alternaria spp.	*Piper nigrum L.; Curcuma longa L.; Cinnamomum cassia L.; Cuminum cyminum L.; Pimpinella anisum L.*	Black pepper; Turmeric; Chinese Cinamon; Cumin; Anise	Oliveira et al., 2017; Costa, 2021; Neto, Silva and Machado, 2013
Aspergillus carbonarius	*Piper nigrum L.*	Black and White pepper	Da Silva et al., 2021; Garcia, et al., 2018; Garcia, Mallmann and Copetti., 2018; Persson, 2017
Aspergillus chevalieri	*Capsicum annuum L.*	Paprika	Yasumura, 2019
Aspergillus flavus	*Rosmarinus officinalis L.; Cinnamomum cassia Ness ex Blume; Cinnamomun zeylanicum Breyn; Pimpinella anisum L.; Origanum vulgare L.; Piper nigrum L.; Capsicum baccatum L.; Bixa orellana L.; Pimpinella anisum L.; Ilex paraguariensis St. Hil.*	Rosemary; Chinese Cinnamon; Ceilon Cinnamon; Anise; Oregano; Black and White pepper; Locoto; Achiote; Anise; Yerba mate	da Silva, Carneiro and Moreira, 2022; Silva et al., 2019; Garcia, et al., 2018; Garcia, Mallmann and Copetti., 2018; Persson, 2017; Neto, Silva and Machado, 2013
Aspergillus luchuensis	*Allium sativum L.*	Garlic	Vanzela et al., 2020
Aspergillus niger	*Rosmarinus officinalis L.; Allium sativum L.; Cinnamomum cassia Ness ex Blume; Pimpinella anisum L.; Origanum vulgare L.; Piper nigrum L.; Capsicum frutescens; Capsicum baccatum L.; Bixa orellana L.; Pimpinella anisum L.; Ilex paraguariensis St. Hil.*	Rosemary; Garlic; Chinese Cinnamon; Anise; Oregano; Black pepper; Tabasco pepper; Locoto; Achiote; Anise; Yerba mate	da Silva, Carneiro and Moreira, 2022; Da Silva et al., 2021; Vanzela et al., 2020; Silva et al., 2019
Aspergillus niger complex	*Origanum vulgare L.; Piper nigrum L.; Capsicum baccatum L.; Pimpinella anisum L.; Cinnamomum cassia Ness.; Rosmarinus officinalis L.*	Oregano; Black and White pepper; Locoto; Anise; Chinese Cinamon; Rosemary	Garcia, et al., 2018; Garcia, Mallmann and Copetti., 2018; Persson, 2017
Aspergillus nomius	*Piper nigrum L.*	Black and White pepper	Garcia, et al., 2018; Garcia,
Aspergillus novoparasiticus	*Ilex paraguariensis St. Hil.*	Yerba mate	Silva et al., 2019
Aspergillus ochraceus	*Cinnamomum cassia Ness ex Blume; Origanum vulgare L.; Piper nigrum L.; Pimpinella anisum L.*	Chinese Cinamon; Oregano, Black and White pepper; Anise	Da Silva et al., 2021; Garcia, et al., 2018; Garcia, Mallmann and Copetti., 2018; Neto, Silva and Machado, 2013
Aspergillus oryzae	Mixture of cornmeal or cassava flour with powdered annatto, *Bixa orellana*	Colorau (colorant mixture with annatto)	Neto, Silva and Machado, 2013
Aspergillus pallidofulvus	*Ilex paraguariensis St. Hil.*	Yerba mate	Silva et al., 2019

Aspergillus parasiticus	*Rosmarinus officinalis L.; Cinnamomum cassia Ness ex Blume; Origanum vulgare L.; Piper nigrum L.;* mixture of cornmeal or cassava flour with powdered annatto, *Bixa orellana*	Rosemary; Chinese Cinnamon; Oregano; Black and White pepper; Colorau (colorant mixture with annatto)	Garcia, et al., 2018; Garcia, Mallmann and Copetti., 2018; Persson, 2017; Neto, Silva and Machado, 2013
Aspergillus pseudotamarii	*Piper nigrum L.*	Black pepper	Persson, 2017
Aspergillus section Circumdati	*Capsicum frutescens; Ilex paraguariensis St. Hil.; Piper nigrum L.*	Capsicum; Yerba mate; Black pepper	Silva et al., 2019; Persson, 2017
Aspergillus section Cremei	*Ilex paraguariensis St. Hil.*	Yerba mate	Silva et al., 2019
Aspergillus section Flavi	*Piper nigrum L.; Schinus terebinthifolius; Capsicum frutescens; Capsicum baccatum L.; Capsicum annuum L.; Ilex paraguariensis St. Hil.*	Black pepper; Brazilian peppertree; Tabasco pepper; Locoto; Paprika; Yerba mate	Yasumura, 2019; Silva et al., 2019; Persson, 2017
Aspergillus section Nigri	*Schinus terebinthifolius; Capsicum frutescens; Capsicum baccatum L.; Capsicum annuum L.; Ilex paraguariensis St. Hil.; Piper nigrum L.*	Brazilian peppertree; Tabasco pepper; Locoto; Paprika; Yerba mate; Black pepper	Yasumura, 2019; Silva et al., 2019; Persson, 2017
Aspergillus spp.	*Cinnamomum zeylanicum Breyn; Cinnamomum cassia Ness ex Blume; Origanum vulgare L.; Piper nigrum L.; Capsicum annuum L.; Laurus nobilis; Ocimum basilicum L.; Pimpinella anisum L.;* Colorau (mixture of cornmeal or cassava flour with powdered annatto, *Bixa orellana); Syzygium aromaticum L.; Rosmarinus officinalis L.; Capsicum baccatum; Curcuma longa L.; Cuminum cyminum L.; Capsicum frutescens; Schinus terebinthifolius; Allium schoenoprasum; Coriandrum sativum; Allium sativum L.*	Ceilon Cinamon; Chinese Cinamon; Oregano, Black pepper; Paprika; Bay laurel; Basil; Anise; Colorau (colorant mixture with annatto); Clove; Rosemary; Locoto; Turmeric; Cumin; Tabasco pepper; Brazilian peppertree; Chives; Coriander; Garlic	Neto, Silva and Machado, 2013; Teixeira-Loyola et al., 2014; Garcia, 2015; Oliveira et al. (2016); Oliveira et al., 2017; Brito (2018); Nunes et al. (2020); Costa, 2021; Vanzela et al., 2020; Garcia, et al., 2018
Aspergillus tamarii	*Piper nigrum L.*	Black pepper	Persson, 2017
Aspergillus welwitschiae	*Allium sativum L.; Piper nigrum L.; Ilex paraguariensis St. Hil.*	Garlic; Black pepper; Yerba mate	Da Silva et al., 2021; Vanzela et al., 2020; Silva et al., 2019
Aspergillus westerdijkiae	*Piper nigrum L.*	Black pepper	Da Silva et al., 2021

Clasdosporium spp.	*Cinnamomum zeylanicum Breyn; Cinnamomum cassia Ness ex Blume; Syzygium aromaticum L.; Laurus nobilis; Ocimum basilicum L.; Origanum vulgare L.; Allium schoenoprasum; Coriandrum sativum; Rosmarinus officinalis L.; Pimpinella anisum L.; Piper nigrum L.; Capsicum baccatum L.*	Ceilon Cinamon; Chinese Cinamon; Clove; Bay laurel; Basil; Oregano; Chives; Coriander; Rosemary; Anise; White and Black pepper; Locoto	Teixeira-Loyola et al., 2014; Nunes et al. (2020); Costa, 2021; Garcia, et al., 2018; Neto, Silva and Machado, 2013
Eurotium spp.	*Rosmarinus officinalis L.; Cinnamomum cassia Ness ex Blume; Pimpinella anisum; Capsicum baccatum; Origanum vulgare L.; Syzygium aromaticum; Piper nigrum; Capsicum frutescens; Schinus terebinthifolius*	Rosemary; Chinese Cinamon; Anise; Locoto; Oregano; Clove; Black and White pepper; Tabasco pepper; Brazilian peppertree	Garcia, 2015; Brito (2018); Costa, 2021; Persson, 2017
Fusarium spp.	*Piper nigrum L.; Capsicum frutescens; Capsicum baccatum; Schinus terebinthifolius; Allium sativum L.; Pimpinella anisum*	Black pepper; Tabasco pepper; Locoto; Brazilian peppertree; Garlic; Anise	Brito (2018); Costa, 2021; Vanzela et al., 2020; Neto, Silva and Machado, 2013
Paecylomices spp.	*Piper nigrum L.; Cinnamomum zeylanicum Breyn; Origanum vulgare L.; Pimpinella anisum;* Colorau *(* mixture of cornmeal or cassava flour with powdered annatto, *Bixa orellana)*	Black pepper; Ceilon Cinamon; Oregano; Anise; Colorau (colorant mixture with annatto)	Neto, Silva and Machado, 2013; Costa, 2021
Penicillium spp.	*Cinnamomum zeylanicum Breyn; Cinnamomum cassia Ness ex Blume; Syzygium aromaticum L.; Origanum vulgare L.; Piper nigrum L.; Laurus nobilis; Ocimum basilicum L.; Pimpinella anisum L.;* "Colorau" (mixture of cornmeal or cassava flour with powdered annatto, *Bixa orellana); Rosmarinus officinalis L.; Curcuma longa L.; Cuminum cyminum L.; Allium schoenoprasum; Coriandrum sativum; Allium sativum L.; Capsicum baccatum L.*	Ceilon Cinamon; Chinese Cinamom; Clove; Oregano; Black pepper; Bay laurel; Basil; Anise; Colorau (colorant mixture with annatto); Rosemary; Turmeric; Cumin; Chives; Coriander; Garlic; Locoto	Neto, Silva and Machado, 2013; Teixeira-Loyola et al., 2014; Oliveira et al. (2016); Oliveira et al., 2017; Nunes et al. (2020); Costa, 2021; Vanzela et al., 2020; Garcia, et al., 2018
Rhizopus spp.	*Syzygium aromaticum L.; Laurus nobilis; Ocimum basilicum L.; Pipper nigrum L.; Cinnamomun zeylanicum Breyn; Origanum vulgare L.*	Clove; Bay laurel; Basil; Black pepper; Ceilon Cinamon; Oregano	Persson, 2017; Neto, Silva and Machado, 2013

Appendix 2

Table 2 - Mycotoxins reported in spices marketed in Brazil since 2013

Spice: latin name	Spice: common name	Identified mycotoxins	Amount of AFs	Amount of OTA	Amount of other mycotoxins	Reference
Mixture of cornmeal or cassava flour with powdered annatto, *Bixa orellana*	Colorau	AFs; OTA	<2-32μg/kg	<2-8μg/kg	–	Iha, Rodrigues & Trucksess, 2021; Iha, Rodrigues & Briganti, 2021
Capsicum annuum L.	Paprika	AFs; OTA	0-40 μg/kg	0.56-223 μg/kg	–	Iha, Rodrigues & Trucksess, 2021; Iha, Rodrigues & Briganti, 2021; Yasumura, 2019
Capsicum baccatum L.	Locoto	AFs; OTA	1,81μg/kg	2,25μg/kg	–	Brito, 2018; Garcia, et al., 2018; Garcia, 2015
Capsicum frutescens	Tabasco pepper	AFs; OTA	0,54 μg/kg	3,42μg/kg	–	Brito, 2018
Cinnamomum cassia Ness ex Blume	Chinese Cinamon	AFs; OTA; Beauvericin (BEA)	not indicated	not indicated	62.92μg/kg	Caldeirão et al., 2021; Garcia, et al., 2018; Garcia, 2015
Curcuma longa L.	Turmeric	AFs; OTA	<2-32μg/kg	<2-8μg/kg	–	Iha, Rodrigues & Trucksess, 2021; Iha, Rodrigues & Briganti, 2021
Foeniculum vulgare	Fennel	AFs	3.12μg/kg	–		Garcia, Mallmann & Copetti, 2018
Ilex paraguariensis St. Hil.	Yerba mate	AFs; OTA; FB2	not indicated	not indicated	–	Silva et al., 2019
Illicium verum	Star anise	AFs, OTA, Sterigmatocystin (STE); Beauvericin	854.87 μg/kg	187.34μg/kg	51.56–181.35μg/kg	Caldeirão et al., 2021
Mentha spicata L.	Mentha	HT-2 ; Beauvericin	164.22μg/kg	51.03μg/kg	<LOQ-554.93μg/kg	Caldeirão et al., 2021
Myristica fragrans	Nutmeg	AFs; OTA	2.71-48.67μg/kg	0.92-65.49μg/kg	–	Iha, Rodrigues & Trucksess, 2021; Iha, Rodrigues & Briganti, 2021
Origanum vulgare L.	Oregano	AFs; OTA	not indicated	not indicated	–	Garcia, et al., 2018; Garcia, 2015
Pimpinella anisum L.	Anise	AFs; OTA; HT-2	4.4μg/kg	404.09μg/kg	44.26-228.23μg/kg	Garcia, et al., 2018; Garcia, Mallmann and Copetti., 2018; Garcia, 2015; Caldeirão et al., 2021
Piper nigrum L.	Black and White pepper	AFs; OTA	0.05-32μg/kg	0.15-13μg/kg	–	Iha, Rodrigues & Trucksess, 2021; Iha, Rodrigues & Briganti, 2021; de Sá, 2017; da Silva et al., 2021; Garcia, et al., 2018; Persson, 2017; Garcia, 2015
Rosmarinus officinalis L.	Rosemary	AFs; OTA; Sterigmatocystin	2.7μg/kg -126.18μg/kg	not indicated	45.54-75.23μg/kg	Caldeirão et al., 2021; Garcia, Mallmann & Copetti., 2018; Garcia, 2015
Schinus terebinthifolius	Brazilian peppertree	AFs; OTA	0,13μg/kg	0,08μg/kg	–	Brito, 2018; Garcia, et al., 2018
Zingiber officinale Roscoe	Ginger	AFs; OTA	0.10-9.55 μg/kg	0.10-7.10 μg/kg	–	Iha, Rodrigues & Briganti, 2021