



Mycotoxins contaminating herbs and spices in Africa: A review

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Abstract

There is an increasing demand for herbs and spices within the African continent either for culinary or medicinal purposes. Though herbs and spices are regularly consumed in small quantities in the diets, they serve as good sources for antioxidant components. Their nutritive nature renders them susceptible to contamination with toxigenic fungi such as *Aspergillus*, *Penicillium* and *Fusarium* species. Exposure to mycotoxins leads to mycotoxicoses that are detrimental to human health. Aflatoxins and ochratoxins are the most prevalent mycotoxins found contaminating herbs and spices and they have been reported to be carcinogenic in nature. Contamination of herbs and spices with mycotoxins also contributes to rejection of produce from Africa by the global market leading to economic losses. Good agricultural practices such as plant disease management and proper post harvest handling of herbs and spices limits mycotoxin levels in herbs and spices but do not eliminate them completely. Currently, physical techniques offer the most efficient post harvest reduction of mycotoxins in herbs and spices but the largest potential for future developments lies with biotechnology. The present review focuses on occurrence of mycotoxins in culinary herbs and spices within African countries providing insights into mitigation strategies for reduced human exposure to mycotoxicoses.

Keywords: Herbs, Spices, Fungi, Mycotoxins

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1. Introduction

From a historical perspective, herbs and spices have played important roles in shaping many events in the world. Great voyagers such as legendary Christopher Columbus made tremendous explorations in search of herbs and spices used for different purposes (Kittredge, 2012). There exist some differences between culinary herbs and spices; however the two terms are used interchangeably. A spice is a vegetable that is aromatic in either whole, ground or broken forms and can be extracted from all parts of the plant except leaves. Culinary herbs are fresh or dried leaves from plants used for flavoring of food and medicinal purposes (Food and Drug Administration, 2007). Herbs and spices serve as antioxidants, preservatives and colorants in many cultures (Srinivasan, 2014). Within the African continent, the spice and herb markets are dominated by cumin, celery,

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coriander, cardamom, chili, pepper, ginger, basil, rosemary and thyme among others (Research and Markets, 2017). These products are available in both powdered and tincture forms and have been on high demand for their aromatic, medicinal, seasoning and flavoring attributes (Melanie and Michael, 2011; and Carlsen et al., 2010). For instance Kenyan farmers in Nakuru County earn up to approximately US \$ 2000 by exporting basil to the European market. With a demand of 6 tons per month, farmers are able to produce only 1.6 tons and thus the markets are experiencing a deficit in supply (Fresh Plaza, 2016). Despite their culinary and medicinal importance, herbs and spices are often contaminated by microorganisms either in the pre harvest, post harvest or storage stages (Vitullo et al., 2011).

Different researchers have studied and documented the natural occurrence of mycotoxins in culinary herbs and spices with little to no emphasis on the associated health and economic impacts as it is the case with maize (Altyrn and Twaruzek, 2020; and Romagnoli et al., 2007). Many herbs and spices are grown without the use of pesticides and this partly contributes to their vulnerability to mold contamination (Abbas et al., 2010). Previous studies estimate that 25% of world's crops including herbs and spices are affected by fungal growth or moulds with 60 -80% of these contamination being mycotoxin related (Schaarschmidt and Fauhl-Hassek, 2018). The main fungal contaminants of herbs and spices include *Aspergillus*, *Fusarium* and *Penicillium* species which are associated with production of mycotoxins such as; aflatoxins (*Aspergillus* spp.), fumonisins, trichothecenes, zearalenone (*Fusarium* spp.) and ochratoxins (*Aspergillus* and *Penicillium* spp.) (Anjorin et al., 2013).

Serious economic and health consequences have been reported from such contaminations which may result from extended drying times, elevated moistures, poor production techniques and storage facilities and failure to use antifungal pesticides at planting stage among other factors (Cho et al., 2008). One of the most predisposing factors of herbs and spices to toxigenic mycoflora is the processing procedure (Hackl et al., 2013). Open sun drying and milling associated with the traditional processing of harvested herbs and spices exposes them to microbial contamination. For most herbs and spices, the initial step of processing involves sorting of the samples followed by heating at temperatures between 80-90 °C for approximately 5 min before sun drying (Akpo-Djèntin et al., 2017). These temperatures cannot eliminate mycotoxins which are chemically stable to temperatures of up to 160 °C and above (Karlovsy et al., 2016). Despite presence of high levels of mycotoxins on some herbs and spices (Fundikira, 2018; Singh and Cotty, 2017; and Mwangi et al., 2014) it's important to note that some countries have registered low to undetectable mycotoxin levels in selected herbs and spices lower than the set limits by EU and WHO/FAO. Such findings were reported on chillies from Benin, Togo and Mali, Thyme in Nigeria, black pepper from Morocco, sweet pepper and cumin from Algeria and ginger from South Africa and Nigeria (Haruna et al., 2017; Azzoune, et al., 2016; Hell et al., 2009; and Zinedine et al., 2006). These reports are a promising statistics with a possibility of accessing clean and mycotoxin free herbs and spices for human consumption. Strict adherence to recommended agronomic practices that aim at preventing fungal contamination of herbs and spices at pre and post harvest stages and proper mycotoxin analysis of end products makes such trends a possibility. African governments have a role to play in ensuring the herbs and spices available in the market are free or low in mycotoxin levels by monitoring producers' adherence to the food processing policies and regulations.

2. Economic value of commercial herbs and spices in Africa

Approximately 50 types of spices and herbs are of economic importance with a global market value of S\$2.3 bn and an annual import growth rate of 8.5% (Fasoyiro, 2014). The main global market share for herbs and spices are Europe and the US. Europe imports most of the spices and herbs from developing countries and according to a survey report by Mordor intelligence a constant supply of African spices and seasoning within Europe market was observed between 2013 and 2017 with a cumulative percentage increase of 6.6% (Figure 1).

Most consumers in the US are exploiting the medicinal and culinary value of spices such as ginger, pepper, cumin, turmeric and cinnamon (Nguyen et al., 2018). The demand for these spices in the US which imports mostly from Africa has seen per capita spice consumption tripling from 1.2 to 3.7 pounds between 1996 and 2015. Between 2007 and 2016, US spent approximately \$1.5 mn annually to import spice commodities from Africa and other key export players. This represents an annual growth rate of 10%. In terms of quantity, the most imported spices include ginger, pepper, capsicum and paprika, cinnamon, cumin and turmeric (Figure 2).

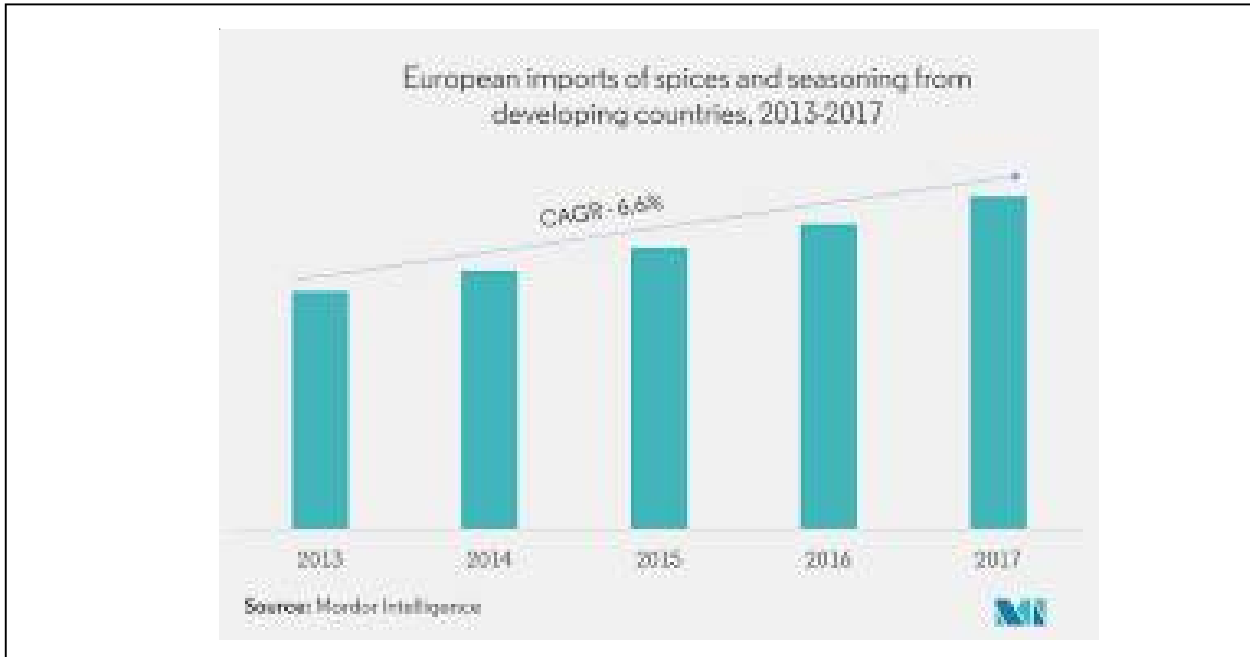


Figure 1: Imports of spices and seasonings from developing countries (2013-2017)

Source: Mordor Intelligence; retrieved from www.nordorintelligence.com

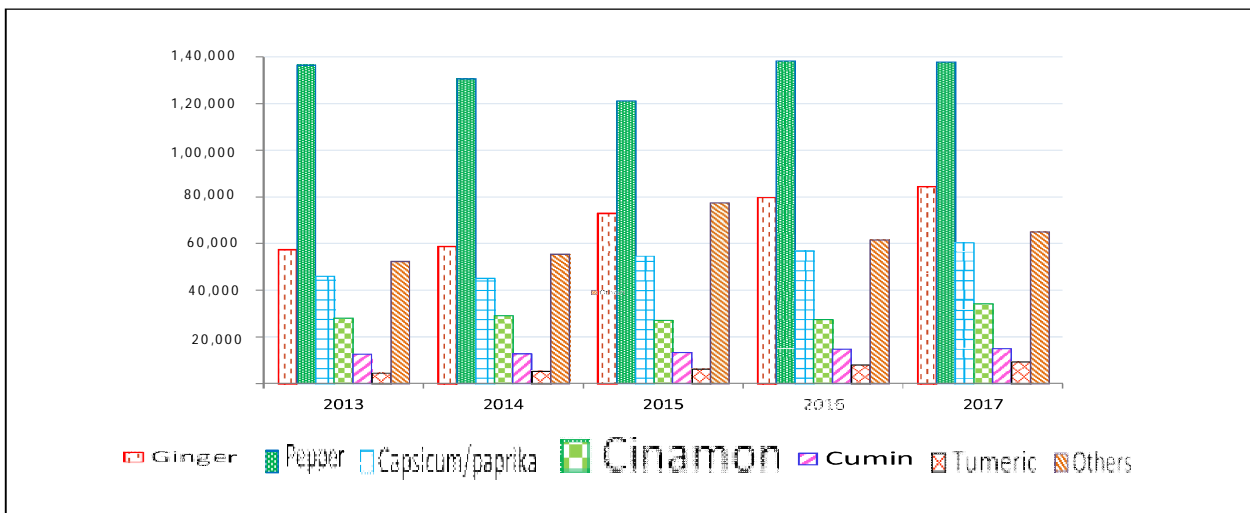


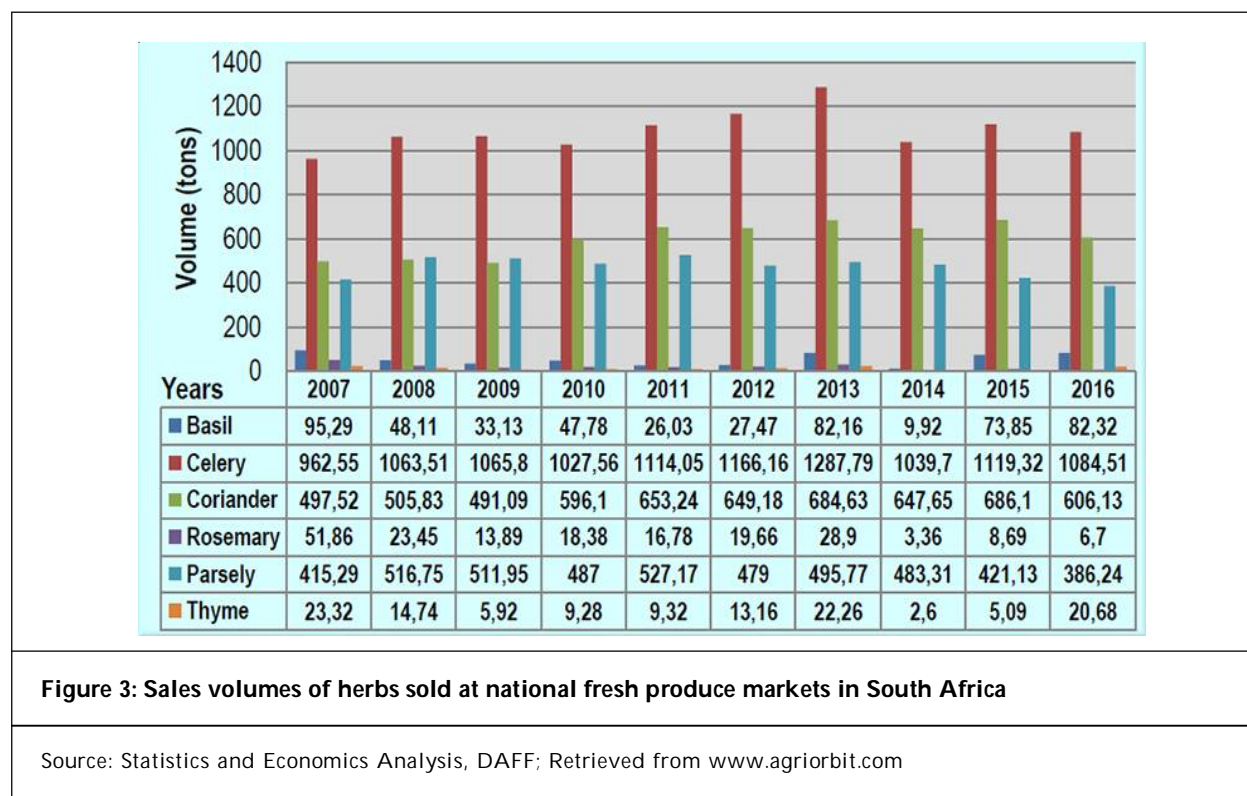
Figure 2: The US import quantity (MT) of the top spices during a five-year period 2013-2017

Source: The United State Department of Agriculture, Foreign Agricultural Service (USDA FAS)

Herbs and spices are not only produced for culinary purposes; they are also cultivated and used as medicinal sources (Carlsen, et al., 2011). More over some herbs are included in the manufacture of dyes, cosmetics and perfumes (Santos et al., 2009). With such diverse uses comes an increasing demand for herbs and spices within the African continent (CBI Market Intelligence, 2015). Global seasoning and spice market is expected to reach \$ 20.46 bn by 2025 which represents a compound annual growth rate of 3.9% for the forecast period while the global demand for herbs is expected to reach \$6.75 bn by 2025 (Grand view research, 2020). Main drivers behind the escalating market growth have been the change in the taste preference by consumers which includes authentic cuisines alongside rising disposable income and large supply (Mordor Intelligence, 2020).

Developing countries have an added advantage of dominating the export market since most of the spices and herbs are produced in the tropics. According to the 2015 European market survey report, Africa accounts

for 12% of global spice and herb production with Nigeria, Ethiopia, Madagascar and Tanzania being the main exporters to Europe and US markets (CBI, 2019). However, producers of herbs and spices in Africa mainly focus on domestic and regional markets and it's thus responsible for only 6% of the imported volume to Europe. For example most of the herbs produced in South Africa are sold locally with the 2017 annual report by National Agricultural Marketing Council indicating the sale of parsley and coriander in greatest quantities between 2007 and 2016 in South Africa (NAMC, 2017). The annual production of celery was 96,255 tons in the year 2007 and 108,451 tons by close of financial year 2016 (Figure 3), indicating an increase in its demand over the years. The main regional export markets for South African herbs and spices include Kenya, Uganda, North Africa and Sudan (Egharevba and Gamaniel 2017).



In the year 2014, developing countries made direct exports amounting to 302,000 tons an equivalent of € 1 bn monetary value. Virtually they were the source of all spices traded in the EU with the main products being pepper, ginger and capsicums. In 2018, more than 70% of total European imports of dried ginger were directly sourced from developing African countries (CBI, 2019). In 2013 and 2014, spice exports in Ethiopia amounted to 15,000 MT per annum which was monetized at \$26 mn. The most exported spice was ginger, followed by chillies, turmeric and black cumin (ENTAG, 2018). Spices such as sweet basil, ginger, African black pepper, guinea pepper and turmeric are commonly cultivated by Nigerian farmers with a vast majority of other spices found growing in the wild (Egharevba and Gamaniel, 2017). Ginger and black pepper dominates the international market with the rest being consumed locally. Approximately 23% of Nigeria's GDP comes from ginger exports. In the year 2016, Nigeria was ranked third highest exporter of ginger preceding china and India. In 2017, 349.9 k tons of ginger were sourced from Nigeria which was an equivalent of 11.5% global share in terms of production. Such trends have contributed to diversification of economic policies leading to a shift from dependence on oil exports to inclusion of agricultural products like herbs and spices (Yoon et al., 2020).

A wide range of spices are grown in Tanzania with the most important of them being clove, pepper, chillies, cinnamon, cardamom, ginger, coriander, vanilla, and garlic (BTC, 2012). The main export product for Pemba and Zanzibar regions in Tanzania is cloves which accounts for 90% of the total spice exports (REPOA, 2018). For four consecutive years in the past decade, Tanzania was ranked third globally in the spice export market (ITC, 2014). In Ethiopia, spice growers enjoy more benefits compared to other agricultural commodities despite its low contribution to the global spice market. For instance, in the year 2001, close to 1 million tons of spices were produced in Southern Ethiopia, Amahara and Oromia regions. In 2006/2007 financial year, total land coverage of red chillies was 80,000 ha with 1.1 million households engaging in red chili production which

earned them over 1.25 billion ETB (ITC, 2010). Colorful cuisines and deep spice trade heritage have for a long time been associated with North African countries such as Morocco, Libya, Egypt, Algeria and Tunisia. With its strategic location along trade routes between Western Europe and Middle East, North Africa is best known for the export of herbs and spices such as paprika, cinnamon, cumin, cayenne, cloves, nutmeg allspice, turmeric and cardamom (Wyk, 2013).

Spices and herbs have a wide possibility of being cultivated in different agro ecological zones in Africa (Matthews and Jack, 2011). Most of the cultivation is traditional with little to no improved seed or planting material. The business activity in production, processing and marketing is also limited. Practices and techniques involved in cultivation are based on knowledge that has been passed from generation to generation resulting to low production levels (Fasoyiro, 2014). Production constraints such as poor agronomic practices and insufficient post harvest treatment have contributed to contamination of spices and herbs with toxigenic fungi (Azzoune, et al., 2016). Such negligence has led to rejection of some export products from Africa by major markets like the EU. Recently chili peppers from Ethiopia worth 10 million USD were rejected by EU due to contamination with high levels of aflatoxins and ochratoxin (Yewondwossen, 2019). According to report compilation from EU (RASFF, 2013) mycotoxin contamination of food and feed exported to EU market ranked top of the list for the reasons behind rejection of exports from Africa (Kareem et al., 2015). The unit rejection of mycotoxin contaminated herbs and spices in the US over the period of 2002-2008 was much higher compared to any other commodity with Egypt and Ghana topping the list (UNIDO, 2011).

Considering the contribution of African herbs and spices to global economic growth, and the monetary loss that comes with rejection of contaminated products by mycotoxins its prudent for African governments to put in place harmonized measures and policies that aim at ensuring only quality products free of mycotoxigenic contaminants are available for local consumption and export.

3. Prevalent mycotoxigenic fungi contaminating herbs and spices and their impact on human health

Periodic consumption of contaminated food exposes human beings to mycotoxins leading to nutritional deficiencies and immunosuppressant and hence development of other opportunistic infections (Negedu et al., 2011). About 4.5 billion people, majorly from developing countries are at risk of chronic exposure to aflatoxins from contaminated food hence the need to monitor levels of aflatoxins and other mycotoxins in food crops so as to avoid toxicoses (Filazi and Sireli, 2013). From previous studies, it's evident that most herb/spice samples have fungal loads above 1×10^3 cfu/g (El-Dawy et al., 2019; Temu 2016; and Gnonlonfin et al., 2013) which is the permissible limit set by World Health Organization for all food products. The most prevalent mycotoxigenic fungi found contaminating herbs and spices include *Aspergillus*, *Penicillium* and *Fusarium* species (Hashem and Alamri, 2010). A summary of frequency of fungi isolation on herbs and spices in selected African countries is provided in Table 1. Most of these fungi produce mycotoxins which are known to cause different ailments in different parts of the human body which include the liver, digestive system, kidney, respiratory organs and skin (Roze et al., 2013; and Amaike and Keller, 2011).

Some health defects associated with mycotoxins include allergic reactions, metabolic, biochemical and reproductive deficiencies, fetal alterations, immune diseases, and death in cases of chronic exposure (Arce-López et al., 2020; Tesfamariam et al., 2019; and Norbäck et al., 2016). The adverse effects of mycotoxin contamination on human health are dependent on the type of toxin, conditions under which the consumer is exposed, their age and gender, health status and immune system, level of toxin accumulation in the body and its metabolism (Al-Jaal et al., 2019; and Fromme et al., 2016).

Many *Aspergillus* species such as *A. flavus* and *A. nomius* which have been frequently isolated from herbs and spices (Singh and Cotty, 2017; Azzoune, et al., 2016; and Hell et al., 2009) produce aflatoxins such as AFB1, AFB2, AFG1 and AFG2. These mycotoxins especially AFB1 are carcinogenic (group 1), immunosuppressive and mutagenic. If the exposure to these toxins is high enough they are likely to cause toxicity, carcinogenicity and mutagenicity in the order of AFB1 > AFG1 > AFB2 > AFG2. (Baranyi et al., 2013; and Okoth and Kola, 2012). Ochratoxins are also detrimental toxins produced by *A. ochraceus*, *A. carbonarius* and *A. niger* and have been termed cytotoxic especially to the lymphocytes by many researchers. Ochratoxin A is capable of suppressing functions of monocytes and granulocytes and also known to be nephrotoxic, carcinogenic and teratogenic to humans (Darwish et al., 2014). As a result it has been classified as a group 2B carcinogen by IARC with the kidney being its main target organ (Duarte et al., 2010b).

Table 1: Frequency of fungal isolation from culinary herbs and spices in Africa				
Country	Contaminated herbs and spices	Fungi isolate	Frequency of isolation/CFU	Reference
Nigeria	Thyme, Ethiopian pepper, African nutmeg, chilli powder, garlic, ginger, clove	<i>Aspergillus spp</i> <i>A. parasiticus</i> <i>Nigrospora sphaerica</i> <i>A. flavus</i> <i>A. niger</i> <i>Mucor hiemalis</i> <i>Penicillium citrinum</i>	43/56 isolates 37.5% 1.8% 26.8% 7.1% 1.8% 3.6%	Haruna et al., 2017
	Ashanti pepper, black pepper, calabash nutmeg	<i>Aspergillus spp</i> <i>Penicillium spp</i> <i>Fusarium spp</i> <i>Rhizopus spp</i>	92.82% 2.79 1.47 3.03	Ezekiel et al., 2013
Southern Benin	Ginger, garlic black pepper	<i>Aspergillus spp</i> <i>Penicillium spp</i> Other fungi	48.5% 6% 45.5%	Gnonlonfin et al., 2013
Togo		<i>Aspergillus spp</i>	100%	
Benin, Mali, Togo	Hot chillies	<i>A. Flavus</i> <i>A. Niger</i> <i>F. verticilliodes</i> <i>Rhizopus stolonifer</i>	71 28 42% 13%	Hell et al., 2009
Egypt	Cumin, ginger	<i>Aspergillus spp</i>	78.24%,	El-Dawy et al., 2019
Algeria	Aniseed, black pepper, caraway, cinnamon, coriander, cumin, ginger, red pepper, saffron, sweet cumin, and sweet pepper	<i>Aspergillus</i> <i>Penicillium</i> <i>Mucor</i> <i>Fusarium</i> and <i>Eurotium spp</i>	56.4% 25.1% 12.8% 5.7%	Azzoune et al., 2016
Ethiopia	Red chillies and cumin	<i>Aspergillus spp</i> <i>Mucor</i> <i>Penicillium, geotrichum spp</i> <i>Eurotium, rhizopus and fusarium spp</i>	16.6% 41.6% 12.5% 8.33%	Tulu et al., 2014
Tanzania	Cloves, ginger, cardamom, cinnamon,	<i>Aspergillus spp</i>	>50% isolates	Temu 2016
Ghana	Aniseed, rosemary	<i>Aspergillus spp</i>	1.50-1.88 log ₁₀ CFU/g	Ahene et al., 2011

Fusarium spp are also contaminants of herbs and spices and have been associated with toxin production (Bakker, et al., 2018; Pasquali, et al., 2016; and McCormick et al., 2011). For instance Trichothecenes such as deoxynivalenol and nivalenol are responsible for a number of human toxicoses which stems from inhibition of mitochondrial functions as well as DNA, RNA and protein synthesis. Such effects may lead to the arrest of cell cycle, cellular oxidative stress, and dysfunction of the cell membrane (Gerez et al., 2015; Arunachalam and Doohan, 2013; and Pestka, 2010).

Penicillium spp which have previously been isolated from culinary herbs and spices (Haruna et al., 2017; and Tulu et al., 2014) also produce toxins which have been reported to cause human ailments (Averkieva, 2009). For instance the disease 'beriberi' is a mycotoxicosis which results from *P. citreonigrum* infestation producing citreoviridin toxin. Citreoviridin is associated with respiratory complications, convulsions, vomiting, hypothermia, flaccid paralysis and cardiovascular disturbances (Zain, 2011). *P. citrinum* *P. expansum* and *P. verrucosum* produce citrinin a toxin believed to cause kidney damages to humans following prolonged exposure while Penitrem A, is a toxin produced by *P. crustosum* which causes vomiting and dizziness (Bragulat et al., 2008). In temperate regions ochratoxin A is produced by *P. verrucosum* *P. viridicatum* and *A. ochraceus*. This toxin is nephrotoxic in nature and it's responsible for degeneration of kidneys (Santos et al., 2009; and Herperkan, 2006).

Following the dangers associated with mycotoxins produced by different *Aspergillus*, *Fusarium* and *Penicillium* species it's prudent to note that several studies have indicated the dominance of these fungi on herbs and spices (Hammami et al., 2014, Kong et al., 2014, Yogendrarajah, 2015., Toma and Abdulla, 2013; Sumanth et al., 2010; and Bokhari, 2007). Therefore, continuous consumption of contaminated herbs and spices results into constant and recurrent health risk to consumers and death in cases of chronic exposure. For instance, an estimate of 123 people succumbed to aflatoxin contamination in eastern part of Kenya in the year 2004 (Nyaga, 2010) while in 2016 several deaths in Tanzania were attributed to aflatoxicosis (WHO, 2018). In a situation where frequency of *Aspergillus* spp isolation from pepper and nutmet in Nigeria was as high as 92% (Ezekiel et al., 2013) and 100% on ginger and garlic from Benin (Gnonlonfin et al., 2013) consumers are likely to experience chronic exposure to aflatoxins. Being secondary metabolites it is a daunting task to prevent mycotoxins from occurring in the production chain of herbs and spices as well as predicting their presence using the existing agronomic practices (Karlovsy et al., 2016). However their frequency can be reduced by strict adherence to pest and disease management practices at pre harvest stages and proper handling of post harvest produce (Hackl et al., 2013).

4. Levels of mycotoxins in commercial herbs and spices

Herbs and spices are among the main food groups vulnerable to mycotoxin contamination because they serve as raw materials for the growth of moulds (Nurtjahja, 2019). The high presence of xerophilic storage moulds on herbs and spices is due to their nutritive nature and conducive environmental conditions under which mycotoxin producing moulds thrive well (Romagnoli et al., 2007). The processing methods predispose herbs and spices to toxigenic mycoflora (Hackl et al., 2013). Open sun drying and milling of some herbs and spices exposes them to microbial contamination (Singh and Cotty, 2017). Mycotoxin production is stimulated by environmental factors and thus extend of contamination differs with geographical location and susceptibility of the herbs and spices to contaminating fungi (Ashiq, 2015; and Jeswal and Kumar, 2015). Aflatoxins and ochratoxins are the main mycotoxins found contaminating herbs and spices in the tropics (Omotayo et al., 2019; Azzoune, et al., 2016; and Zaied et al., 2010). They have been listed among the carcinogenic types of mycotoxins with Aflatoxin B1 being of global health interest due to its association with hepatocellular carcinoma that currently ranks third leading cause of cancer worldwide. Ochratoxin has been classified as a group 2B carcinogen (IARC, 2012). Temperatures of 25 °C and relative humidity of 95% (tropical climatic conditions) are the optimal conditions under which aflatoxin B1 and ochratoxin A are produced (Agriopoulou et al., 2020) hence the prevalence of these two toxins on African herbs and spices. To avoid microbial contamination, a period of 10 days is recommended for the storage of fresh herbs and spices using coolers with the moisture levels being kept below 11% as advised by European Spice Association (Tulu et al., 2014) however such conditions are not adhered to by many producers within the African continent.

Risks associated with mycotoxin contamination in food products are depended on exposure and hazards (Ali and Watt, 2019). Globally, the risks may be the same but exposure varies with differences in levels of

contamination and dietary preferences (Akpo-Djenontin et al., 2016). Daily intakes of spices have been estimated by the food balance sheets of the US Food and Agricultural Organization to be between 2 to 22 g/person/day worldwide (FAO, 2012) however this amount differs with an individual's preference for aroma, taste and color. The European Union, FAO and WHO have set tolerable limits of AFs and OTA on herbs and spices that are of global economic importance as indicated in Table 2. For EU, the permissible limit for AFB1 is 5 µg/kg and for total AFs is set at 10 µg/kg. The USA and most African countries such as Nigeria have set maximum limits of AFs in herbs and spices at 20 µg/kg (CAC, 2018). Most of the commercial herbs and spices have been reported to have high levels of AFs and OTA beyond the set limits (Fundikira, 2018; Mwangi et al., 2014; and Ezekiel et al., 2013).

Table 2: Recommended maximum limits by WHO/FAO in the most traded spices globally

Spice	AFs (µg/kg)	OTA (µg/kg)
Nutmeg	20-30	20-30
Dried Chilli	20-30	20-30
Ginger	15-20	20-30
Paprika	15-20	20-30
Pepper	15-20	10-15
Turmeric	10-15	10-15

Source: CAC, 2018

Despite the rising global demand for herbs and spices, Africa's global market share has declined. Like any other export product from Africa herbs and spices have faced rejection a number of times at the EU and US borders due to their non compliance with product standards. Failure to meet the conditions required for market access by some African countries has led to rejection of herbs and spices in huge amounts. Figure 4 represents the EU border rejection of herbs and spices for selected years in terms of the number of exports that were prevented from accessing its market. The primary reason for border rejections of third countries' exports has been violation of food safety requirements especially by countries with limited technical and institutional capacity to comply with EU and US standards (Kareem et al., 2015).

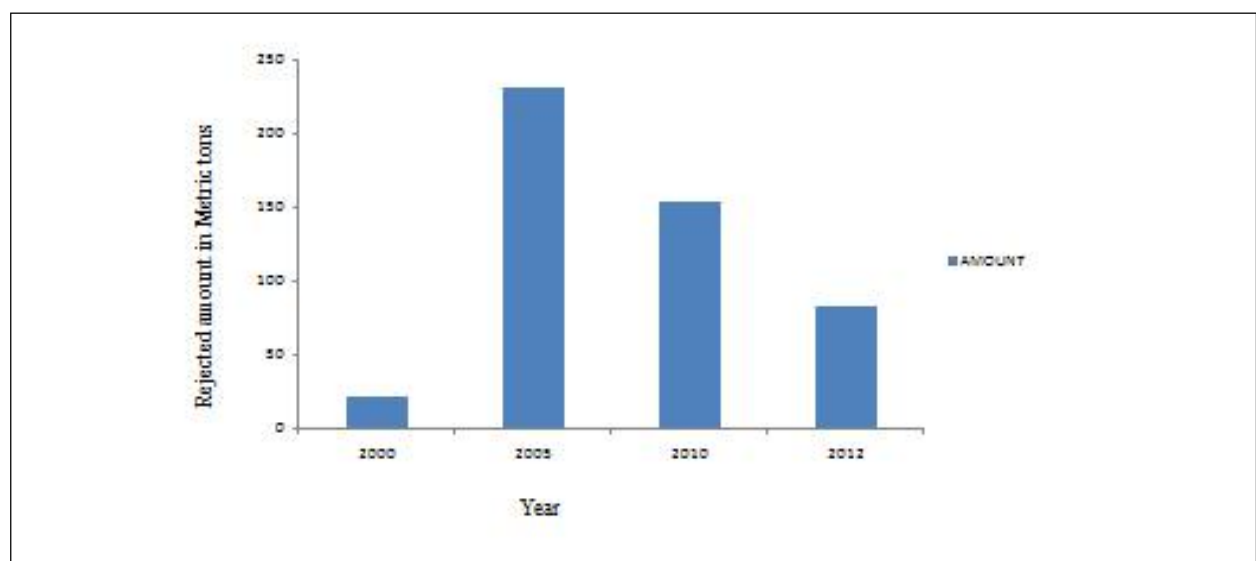


Figure 4: EU's rejection of herb and spice products (selected years)

Source: Authors' compilation from Rapid Alert System for Food Feed (RASFF) and United Nations Industrial Development Organization

Mycotoxins and microbial contaminants are the major hazards that account for herbs and spice rejection and they vary depending on the products point of entry. For example, an Online Database report by RASFF for the period of 2002-2008 indicates that mycotoxins were the main reasons for rejection of herbs and spices from Ghana by EU while microbial contaminants dominated the 'hurdles to pass' list set by EU in Morocco and Egypt (Figure 5).

Import bans and border restrictions come with enormous and costly consequences among them being ruining of the affected country's reputation and reduced export competitiveness. For instance Tanzania which produces over 30 spices for local and foreign market has experienced a decline in export from 0.5% (\$38 mn) to 0.12% (\$12.4 mn) from 2012 to 2016 (Mordor Intelligence, 2017). This decline is attributed to failure in meeting

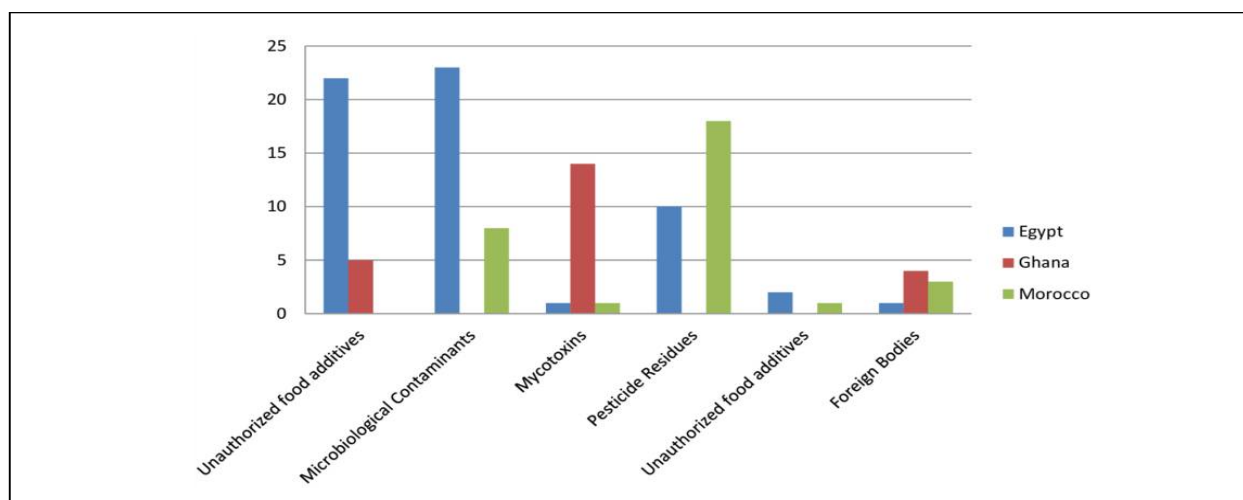


Figure 5: EU reasons for rejections of herbs and spices

Source: RASFF statistics online Data Base; https://ec.europa.eu/food/sites/food/files/safety/docs/rasff_annual_report_2008_en.pdf

product quality standards, low value processing and production and trade capacity constraints (REPOA, 2018). With an increasing demand for African herbs and spices by the global markets comes prospect for successful development, poverty reduction and economic growth hence the need for strict adherence to policies and regulations set up for mycotoxin surveillance in herbs and spices.

Since herbs and spices are organic foods, they are grown without synthetic fungicides and thus more vulnerable to mold contamination and high mycotoxin production (Winter and Davis, 2006). Disparity in agronomic practices, environmental conditions and post harvest handling of herbs and spices across Africa results into a huge variation of mycotoxin contamination levels (Ashiq, 2015). A summary of the main herbs and spices found in Africa together with the amount of mycotoxin levels detected in each product is given in Table 3. Extremely high or low levels of mycotoxins on herbs and spices and reports of undetectable levels as indicated in the table can be attributed to interferences in the various analytical methods used (HPLC, TLC or mini column) and lack of validation (Ali et al., 2005). In Kenya, undetectable levels of AFs were reported on nutmeg (Mwangi et al., 2014) while different reports in Nigeria shows high levels of AFs on nutmeg and garlic beyond permissible limits (Ezekiel et al., 2013; and Haruna et al., 2017). In their study, Haruna and associates could not detect AFs presence in garlic while Singh and Cotty (2017), recorded a 3.3 $\mu\text{g}/\text{kg}$ of the same toxin in garlic (Table 3). High mycotoxin levels in herbs and spices are possible if safe levels of moisture content are not observed or presence of faults in the analytical techniques used (Ali et al., 2005).

The use of validated analytical methods that are safe with efficient sample clean up and low detection limits in other studies have resulted to relatively low levels of mycotoxins (Ali and Watt, 2019). Samples collected from bare grounds and bags have a significantly high occurrence of mycotoxins in comparison with those from glass, wooden boxes and metal containers (Hun Do et al., 2015). Hence, there exists an association of processing and storage conditions, collection and analytical techniques and source of sample with levels of mycotoxin production. For instance samples taken from an Ethiopian market recorded high levels of AFs up to 500 $\mu\text{g}/\text{kg}$ from chili spice while Singh and Cotty (2017) reported 156 $\mu\text{g}/\text{kg}$ of AFs from the same spice in

Nigeria. In Morocco, a study carried out on mycotoxin contamination of spices revealed 100% incidence rate of aflatoxin contamination (Zinedine et al., 2006) on cumin and ginger. In Kenya, cayenne, paprika and cumin sampled from Nyahururu market were found to be contaminated by AFs at levels as high as 99 µg/kg and 98 µg/kg with chillies recording a 31.5 µg/kg (Mwangi et al., 2014).

Zaied et al. (2010) in Tunisia reported high levels of OTA contamination on selected spices which were above the permissible levels of 10 µg/kg by European commission. Ochratoxigenic fungi thrive well at room temperature in tropical climates and thus prolonged storage of spices under such conditions contributes to high levels of OTA (Ribeiro et al., 2006; and Passamani et al., 2014). Such observations imply that consumers need to store their purchased herbs and spices below room temperatures if they intent to use them for long periods of time without mould contamination. Some methods applied by consumers such as drying and washing of spices before use cannot reduce OTA and AFs content since they are thermally stable up to 180 °C and slightly soluble in water (Raters and Matissek, 2008; and El Khoury and Atoui 2010). Cloves and cinnamon sampled from Tanzania, Nigeria and Egypt have reportedly shown low levels of aflatoxins while Nguegwouo et al. (2018) did not report any presence of OTA on cloves sampled from Cameroon. In a study carried out by Reddy et al. (2010) clove extracts were reported to completely inhibit mycelia growth of *A. ochraceus* an aflatoxin and ochratoxin producing species while garlic completely inhibited OTA production (Anjorin et al., 2013) hence part of the reason for undetectable levels on samples analyzed by Haruna et al. (2017) in Nigeria. Such findings are attributed to the antifungal activities of secondary metabolites found in cloves (Liu et al., 2017).

Mycotoxins exposure usually results from their high concentrations in the foodstuffs and the amount of food that is consumed by the exposed population (Marin et al., 2013). Herbs and spices constitute an important part of day to day menus which are consumed regularly and therefore their contribution to health hazards as a result of mycotoxin contamination is inevitable (Shirima et al., 2013; and Milicevic et al., 2010). Dietary habits of communities serve as most important factors in determining human exposure to mycotoxins (Al Jabir et al., 2019). For example the Asian communities in Kenya and Nigerians at large consume large amounts of hot chili and raw pepper compared to other spices such as cumin and thus chances of mycotoxin exposure from pepper among such a population is high compared to exposure levels from other culinary herbs and spices. Contamination levels also vary from different populations or individuals within a population depending on storage time, location and seasons (Wagacha and Muthomi, 2008). For an exposure assessment to be achieved there is need to estimate frequency, intensity and duration under which human beings are exposed to toxins from herbs and spices (Agriopoulou, 2020).

Tolerable daily and weekly intakes are values used to assess the risks involved when it comes to human exposure to toxins in food and feed. The TDI values vary from country to country in relation to the type of mycotoxin and the organization mandated with the task of establishing the tolerable values. In an effort to regulate mycotoxins in feed and food and their effect on human population, TDI levels for fumonisins and ochratoxins have been set by the FAO/WHO Joint Expert Committee on Food Additives (JECFA) at 2000 ng/kg bw and 14 ng/kg bw respectively (JECFA, 2011). A lot of these studies have not been achieved in African herbs and spices hence scarce data is available for the same. In a recent study, Nguegwouo et al. (2018) reported high consumption frequency of white pepper in Cameroon compared to black pepper. Based on OTA contamination data analysis for the two spices, the daily intake levels were 0.182 ng/kg bw/day for black pepper, and 0.699 ng/kg bw/day for white pepper. Despite the low levels, below the 14ng OTA/kg bw/day recommended by JECFA; the daily intake of the toxin in pepper in the long run exposes consumers to the associated risks considering a direct relationship between consumption frequency and toxin levels (Nguégwouo et al., 2018). Unlike OTA, the proposed tolerable daily intakes for AFB1 have been set as low as 1ng/kg bw/day in chilli and pepper and these levels have been exceeded in other parts of the world with Sri Lanka having an exposure of upto 3.49 ng/kg bw/day (Yongendrarajah, 2015). In Africa such information is limited and most consumers are not aware of the tolerable daily intakes of AFs and OTA in herbs and spices.

Regardless of low and undetectable levels of mycotoxins reported in some herbs and spices below provisional tolerable daily intake as indicated by research (Azzoune, et al., 2016; and Nguegwouo et al., 2018) the health risks associated with mycotoxicoses should not be underestimated. This is because same samples could be contaminated with other mycotoxins that interact toxicologically eliciting synergistic and additive effects on consumers (Cheli et al., 2017).

Table 3: Toxin levels in different herbs and spices within African countries				
Country	Spice/herb sample	Toxin	Mycotoxins ($\mu\text{g}/\text{kg}$)	References
Egypt	Red Pepper	AFB1	10	Selim <i>et al.</i> , 1996
	Black Pepper	AFs	33	
	Cinnamon	AFB1	10-42	
	Black Pepper	AFB1 and AFG1	28-35	El-Kady <i>et al.</i> , 1995
	Cumin	AFB1	8.2	El-Dawy <i>et al.</i> , 2019
	Ginger	OTA	6.7	
Algeria	Saffron	AFs	26.50	Azzoune, <i>et al.</i> , 2016
	Sweet Cumin	AFs	19.07	
	Sweet Pepper	AFs	0.10-3.17	
	Red Pepper	AFs	3.44	
	Cumin	AFs	ND	
	Aniseed	AFs	0.66	
Morocco	Cumin	AFs	0.18	Zinedine <i>et al.</i> , 2006
	Black Pepper	AFs	0.55	
	Ginger	AFB1, AFs	3.50, 9.10	
	Paprika	AFB1, AFs	2.8, 5.23	
Nigeria	Ginger	AFB1, AFG1,	2.9, 3.2	Tančinová <i>et al.</i> , 2014
	Ginger	OTA	>0.2	
	Nutmeg	AFs	11.4	Haruna <i>et al.</i> , 2017
	Thyme	AFs	0.6	
	Chilies	AFs	2.7	
	Garlic	AFs, OTA	ND	
	Clove	AFs	>20	
	Pepper	AFs	7.3	
	Ginger	AFs	11.6	Haruna <i>et al.</i> , 2016
	African nutmeg	AFs	9.9	
	Thyme		2.6	
	Garlic		ND	
	Chilies	AFB1	156	Singh and Cotty, 2017
	Garlic	AFs	3.3	

Table 3 (Cont.)				
Country	Spice/herb sample	Toxin	Mycotoxins ($\mu\text{g}/\text{kg}$)	Reference
	Nutmeg	AFB1	20	Ezekiel <i>et al.</i> , 2013
Kenya	Cayenne	AFs	99.6	Mwangi <i>et al.</i> , 2014
	Paprika	AFs	99	
	Cumin	AFs	98	
	Nutmeg	AFs	ND	
	Chili	AFs	31.5	
Tanzania	Cinnamon	AFs	0.13-11.22	Fundikira, 2018
	Ginger	AFs	0.55-9.66	
	Cloves	AFs	0.23-11.23	
	Cardamom	AFs	0.23-11.90	
Tunisia	Caraway	OTA	244	Zaied <i>et al.</i> , 2010
	Coriander	OTA	206	
	Curcuma	OTA	290	
	Black Pepper	OTA	274	
	Red Pepper	OTA	203	
Ethiopia	Red Pepper	AFs	250-525	Fufa and Urga, 1996
Benin, Togo, Mali	Hot Chilli	AFs	3.2 AFs	Hell <i>et al.</i> , 2009
South Africa	Ginger	OTA	3.625-411.1	Omotayo <i>et al.</i> , 2019
	Ginger	AFs	0.096-3.395	
Cameroon	White pepper	OTA	4.89	
	Black pepper	OTA	1.91	Nguegwouo <i>et al.</i> , 2018
	Cloves	OTA	ND	
Note: Limit of detection 0.05, limit of quantification 0.1, ND (Not Detectable).				

Quantification of mycotoxins in herbs and spices in Africa is based on relatively old methods such as use of ELISA kits and thin layer chromatography (Azzoune, *et al.*, 2016; Fundikira, 2018; and Haruna *et al.*, 2017). Analytical methods that are more sensitive for detection of extremely lower levels of mycotoxins should be used to ensure safe produce is available on the local and international markets and to earn African countries international recognition of their commercialized herbs and spices by the Association of Official Analytical Chemists (Ali and Watt, 2019). There is need for consumers to pay attention on some indicators of mycotoxin presence in herbs and spices while purchasing. The most pertinent indicator is the presence of moulds while change of odor and color are considered secondary as they result from mould presence (Nguégwouo *et al.*, 2018). There is low awareness and knowledge among the public on mycotoxin contamination of herbs and spices and the associated problems in the diets (Mohd *et al.*, 2013; Mohd *et al.*, 2012; Ilesanmi and Ilesanmi 2011; and Jolly *et al.*, 2009). According to findings by Nguégwouo *et al.* (2018), 88% of the study population in Cameroon is not aware of mycotoxin presence in spices. Therefore it's necessary to enhance public knowledge

and awareness of mycotoxins in herbs and spices, their associated health risks and implement preventive measures by government bodies and research institutions (Zain, 2011).

5. Conclusion

Herbs and spices have been used for culinary and medicinal purposes in the African continent for a long period of time. Mycotoxin contamination represents one of the most critical toxicities present in herbs and spices and is of global concern by health organizations such as WHO. Most of the commercial herbs and spices have been reported to have high levels of aflatoxins and ochratoxins beyond permissible limits. This is an indication of possible human exposure to mycotoxin contamination. Mycotoxicoses is a threat to human health in the African continent that is already facing an increase in cases of life threatening illnesses such as cancer and kidney failures. The main purpose of mycotoxin mitigation in herbs and spices is to prevent adverse health effects caused by foodborne exposure to mycotoxins while preserving the nutritional and organoleptic quality of food. Some biotechnological and chemical techniques aimed at reducing mycotoxin content have been approved with many remaining at experimental stages. Development of mitigation strategies should prioritize aflatoxins and ochratoxins that occur at high levels in herbs and spices and whose health effects have been termed carcinogenic and life threatening in cases of chronic exposure. It's rare to achieve complete elimination of mycotoxins from herbs and spices; however, to lower the risks from sanitary incompatibility of herbs and spices there is need to upgrade the processing conditions. This in turn reduces exposure to mycotoxin contamination by eliminating toxigenic fungi and transforming mycotoxins into less toxic derivatives.

Conflicts of interest

The authors of this review paper declared no conflicts of interest.

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