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Prevalence and importance of the mycotoxin and ochratoxin A (OTA) in coffee: A review

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Abstract

Coffee is one of the world's most significant agricultural crops. The goal of this review is to illustrate the presence and importance of Ochratoxin A (OTA) in coffee. Mycotoxins, such as Ochratoxins A (OTA), are crucial for the coffee industry. Coffee producers and merchants are concerned about their personal health as well as the economy of coffee consumers. Ethiopia is the birthplace and genetic diversity hub for Arabica coffee, and over half of the coffee produced is consumed domestically. According to various studies, the presence of Ochratoxins A (OTA) in distinct coffee beans in Ethiopian domestically consumed coffee varies by place, particularly beans picked from soil. The presence of Ochratoxine A (OTA) in green, roasted, and instant coffee is substantial, and it is also affected by different coffee roasting, processing, drying, and storage methods. Finally, Ethiopia's Food and Drug Authority officials should, for example, set the maximum allowable level of OTA in roasted and ground coffee at 5 g/kg in ground coffee and 10 g/kg in instant coffee, and they should assess and monitor mycotoxins in local coffee in a timely and consistent manner. Educate and train coffee farmers and distributors on mycotoxins, especially Ochratoxins A (OTA), their effects, and potential mitigation strategies.

Keywords: Coffee, Ethiopia, Ocratoxine A (OTA), Quality.

Introduction

Food contamination is a global hazard at all phases of agricultural and processed food production, distribution, and consumption (FAO, 1996). Failure in any of these areas results in food insecurity and malnutrition, which have a negative impact on human health and the socioeconomic side of society. Micro-fungi such as *Penicillium, Fusarium* and *Aspergillus* that grow on food and feed when conditions are suitable, can release secondary metabolites that endanger the health of humans and animals after being consumed (Dipendra *et al*., 2019).

According to the Centers for Disease Control and Prevention (CDC), 4.5 billion individuals are chronically exposed to mycotoxins (Emmott *et al*., 2013). According to the Food and Agriculture Organization (FAO) and the Centers for Disease Control and Prevention (CDC), microfungi can infect 25% of the world's food crops (Kumar *et al*., 2017; Amirhossein *et al*., 2020).

Mcotoxins are classified into different groups depending on their molecular structure, producer fungus, and toxicity: Trichothecenes, which comprise nivalenol , deoxynivalenol , diacetoxyscirpenol and T-2 and HT-2 Toxini, are molecules that produce the inhibition of protein synthesis (García *et al*., 2015). Aflatoxin-related contamination by fungi can occur in food and feed products (e.g., coffee, cocoa, spices, figs, rice, wheat, maize, sesame seeds, millet, and groundnuts) during the processes before and after harvesting. AF can contaminate commercial products such as cosmetics, cooking oil, and peanut butter (Amirhossein *et al*., 2020).

Coffee is one of the most widely consumed beverages in the world because of its pleasant taste, its pharmacological effects, and its stimulatory effects on mental and physical activity (Soliman, 2002) In the field and after harvest, a variety of biotic and a biotic variable have an impact on coffee output and quality. One of the post-harvest issues that affects the quality of coffee beans is fungus infestation and the formation of mycotoxins (Malaker *et al*., 2008). Filamentous fungi can contaminate coffee at different phases, including harvesting, preparation, transportation, and storage, as well as fermentation and drying, particularly when the water activity is low (Silva, Batista, & Schwan, 2008)

The European Commission's coffee law sets OTA maximum limits at 5.0 µg/kg for roasted and ground coffee and for soluble coffee 10.0 µg/kg, respectively (Paterson, Lima, & Taniwaki, 2014). According to Geremew *et al.* (2016) showed a total fungal incidence of 87 percent in coffee samples collected from six major coffee-growing districts in Ethiopia's Jimma zone of Oromiya regional of state in Ethiopia. However, this high occurrence is due to the location of the coffee sample collection as well as the processing procedures specified and required to support it. According to Legese *et al.,* 2020, Aspergillus niger was the most prevalent species detected in most coffee samples, followed by Aspergillus ochraceus and Fusarium spp (Legese *et al.,* 2020).

According to a new study on mycotoxins and climate change, mycotoxins in coffee should be examined as soon as feasible. To the best of our knowledge, no comprehensive research on coffee growing and processing techniques have been undertaken in Ethiopia on the incidence and relevance of mycotoxins in locally consumed Ethiopian coffee (Geremew *et al.,* 2016; Legase *et al*., 2020). The presence of different mycotoxins generated by Fusarium and/or Aspergillus in coffee needs intervention in the future. As a consequence, the goal of this review is to concentrate on the presence and prevalence of mycotoxin in coffee in order to ensure food safety and security for healthy people.

An Overview of Mycotoxins in Foods and Feeds: Most mycotoxins remain chemically and thermally stable during various food processing methods such as heating, boiling, baking, frying, baking, and pasteurizing. Contaminated feed results in the presence of mycotoxins in animal consumables like as meat, eggs, and milk, contaminating the human plate (Alshannaq *et al.*, 2017). Regulatory limits on significant levels of mycotoxins in food and feed are set by various authorities around the world, including the Food and Drug Administration (FDA) of the United States (US), the World Health Organization (WHO), the Food Agriculture Organization (FAO), and the European Food Safety Authority (EFSA)(Bennett *et al.,* 1987).

The International Agency for Research on Cancer (IARC) categorizes several significant mycotoxins by reviewing toxicological studies for the presence of substantial human evidence for carcinogenicity (Marin *et al*., 2013).

Table 1 summarizes the principal mycotoxins, their IARC number, the major producers, and some often contaminated commodities, as well as the European Union (EU) and United States Food and Drug Administration (FDA), while IARC is for International Agency for Research on Cancer regulation limitations for mycotoxin levels in food and animal feed (Marin *et al*., 2013; Alshannaq *et al.*, 2017).

Mycotoxin (IARC Number *)	Fungal Species	Food Commodity	US FDA (µg/kg)	EU (µg/kg)	References
Aflatoxins B1, B2, G1, G2 (1*)	*Aspergillus flavus, Aspergillus parasiticus*	Maize, wheat, rice, peanut, sorghum, pistachio, almond, ground nuts, tree nuts,figs, cottonseed, spices	20 for total	2–12 for B 14–15 for total	(EC, 2006)
Aflatoxin M1 (2B*)	Metabolite of aflatoxin B1	Milk, milk products, and meat	0.5	0.05 in milk 0.025 in infant formulae & infant milk	(EC, 2006)
Ochratoxin A (2B*)	Aspergillus ochraceus, Aspergillus carbonarius Penicillium verrucosum, Penicillium nordicum	Cereals, dried vine fruit, wine, grapes, coffee, cocoa, cheese	Not set	2–10	(EC, 2006)
Fumonisins B1, B2, B3 (2B*)	Fusarium verticillioides, Fusarium proliferatum	Maize, maize products, sorghum, asparagus	2000–4000	200–4000	(EC, 2007)
Zearalenone (3*)	Fusarium graminearum (F. roseum), Fusarium culmorum Fusarium equiseti, Fusarium cerealis, Fusarium	Cereals, cereal products, maize, wheat, barley	Not set	20–100	(EC, 2007)

	verticillioides, Fusarium incarnatum				
Trichothecenes (type B: deoxynivalenol)	Fusarium graminearum, Fusarium culmorum, Fusarium cerealis	Cereals, cereal products	1000	200–50	(EC, 2007, Piacentini et al., 2019)
Patulin (3*)	*Penicillium expansum Bysochlamis nívea, Aspergillus clavatus, Penicillium patulum Penicillium crustosum*	Apples, apple juice, and concentrate, pears,peaches, grapes, apricots, olives lowacid fruit juices	50	10–50	(EC, 2006) Ünüsan,2019)
Trichothecenes (3*)	*Fusarium langsethiae*	Maize, wheat, barley, oat, rye	15	25–1000	[EC,2013]
Trichothecenes (type A: T-2 toxin) (3*)	Fusarium langsethiae, Fusarium sporotrichioides	Maize, wheat, barley, oat, rye	15	25–1000	[EC,2013]
Ergot alkaloids	Claviceps purpurea, Claviceps fusiformis, Claviceps africana, Neotyphodium spp	Rye, rye-containing commodities, wheat, triticale, barley, millet and oat	Not set	Not set	(Marin *et al*.,2013; Debegnach eta l., 2019)
Enniatins	*Fusarium tricinctum,*	Corn	Not set	Not set	(Ben et al., 2019)
Alternariol	Alternaria alternata	Grain and grain-based products, vegetables and vegetable products, fruits and fruit products, wine and beer, oilseeds and vegetable oils	Not set	Not set	[EC,2016]

IARC number definitions: 1, the mycotoxin is carcinogenic to humans; 2B, the mycotoxin is possibly carcinogenic to humans; 3, the mycotoxin is not classifiable as to its carcinogenicity to humans.

Mycotoxins in food must be dealt with by the agriculture industry since they are a global concern and a big hazard (Lee et al., 2017). Factors such as inadequate food quality management, hot environment, poor production technology, and poor crop storage conditions enhance the development of fungus and the generation of mycotoxins in developing nations, resulting in the more frequent occurrence of mycotoxin-contaminated foods (Al-Jaal,et al., 2019). Annual agricultural and industrial losses in the billions of dollars occur because mycotoxins infect 25% of the world's harvested crops (Marin *et al.,* 2013).

Some of the important factors are increasing production costs, decreasing animal output, decreased market prices, irregular production (Temba *et al*., 2019), regulatory enforcement, and testing and other quality control procedures (Winter *et al*., 2019). In a recent press release issued by the IARC and WHO in 2016, calls for action on mycotoxin contamination in developing countries were made because, according to the report, 500 million people in developing countries who are exposed to financial burdens are exposed to natural toxins, including mycotoxins, on a daily basis, and 160 million children under the age of five are stunted globally (WHO, 2016). A search for the presence of significant mycotoxins was conducted. A search for the occurrence of major mycotoxins was undertaken using published articles between 2014 and 2019.

Ocratoxins A (OTA), Its Occurrence, and Properties: OTA was discovered in South Africa in the fungus A.

ochraceus, from whence it gets its name. It is a phenylalanyl derivative of a substituted iso-coumarin (R)-N-[5-chloro-3,4-dihydro-8-hydroxy-3-methyl-1H-2-benzopyran-7-y1]carbonyl]-l phenylalanine (Alhamoud et al., 2019). OTA is the most prevalent and dangerous mycotoxin that contaminates foods in the ochratoxin categories A, B, and C (Temesgen 2018). The two most important genera of OTA makers are Aspergillus and Penicillium (Alhamoud et al., 2019).The two most important genera of OTA makers are Aspergillus and Penicillium. Aspergillus section Circumdati, Aspergillus section Nigri, P. verrucosum, P. thymicola, and P. nordicum are the principal generating species (Marin *et al*., 2013). The far less hazardous non-chlorinated counterpart, ochratoxin B, occasionally co-occurs with OTA in food and feed (Udovicki, et al., 2018). Although Aspergillus-produced OTA is likely to occur before to harvest, recent investigations (Limay-Rios et al., 2017) have identified OTA in grains as primarily a storage concern.

Despite the fact that OTA degrades in the rumen, it has been identified in cow's milk (Zhao et al., 2020). When AFB1 co-occurs with OTA in particular crops, its mutagenesis capability may be amplified (Sofia et al., 2020).The Joint FAO/WHO Expert Committee on Food Additives (JEFCA) suggested a preliminary tolerated weekly intake (PTWI) of 112 ng/kg body weight (b.w.) (JECFA, 2001).

Ochratoxin production occurs in the 0.92–0.99 water activity (aw) range, with maximal concentrations ranging from 0.95 to 0.99 depending on the strain. The ideal temperature for OTA production is 20 degrees Celsius, followed by 15 degrees Celsius, and drastically decreased production at 30–37 degrees Celsius (EFSA, 2006). Because the Aspergillus and Penicillium that create OTAs have a temperature range of 12–37°C for A. ochraceus and 0–31°C for P. verrucosum, OTA may be produced in any agricultural area of the world (Lee *et al.,* 2017).

Ochratoxin has been associated to immunotoxic, genotoxic, neurotoxic, carcinogenic, nephrotoxic, and teratogenic effects, and is thought to be the most toxic member of the ochratoxin family. Ochratoxin has been found in grains, species, alcoholic drinks such as wines and beer, dried vine fruits, coffee, cocoa and chocolate, meat, and mil. Cereals are top in overall OTA exposure among foods, accounting for 60% (Sofia et al., 2020). The European Commission (EU) has established maximum limits of 5 ng/g OTA in raw cereal grains, 3.0 ng/g in cereal-processed goods, 10 ng/g in coffee and dried fruits, 2 g/L in wine, and 0.5 ng/g in cereal-based infant meals (Sofia et al., 2020).

Risk evaluations were conducted in Brazil (Franco et al., 2019), Benin, Cameroon, Mali, Nigeria (Ingenbleek et al., 2019), and Paraguay (Naz et al., 2017) using OTA incidence data. The majority of the population, according to these researches, did not surpass the TDI. Recent study on the influence of OTA demonstrates the need of strengthening OTA control measures in food production. Although mycotoxins are very stable throughout food processing, there are a number of conditions that might compromise their stability. OTA cannot be entirely deactivated at many phases of food preparation, including baking, roasting, frying, brewing, canning, and peeling (Sadiq et al., 2019).

Furthermore, OTA has been observed to be transmitted into beer and wine samples from infected grains (Bullerman et al., 2007). When animals are fed OTA-infected bread, it can accumulate in the flesh of animals meant for human consumption (Perši et al., 2014).

Factors Influencing Mycotoxin Growth and Production: Temperature, humidity, environment, pH, water activity (aw), nutrients, amount of inoculation, substrate nature, physiological condition, and microbial interactions all influence the development and synthesis of mycotoxins in many species of fungus. This is why describing the set of ideal circumstances for development and output under physiological settings is challenging (Aldars-garcía, et al., 2018. Fungi thrive in temperatures ranging from 10 to 40 degrees Celsius, pH 8.4, and aw levels greater than 0.70 (Lacey et al., 1991). For active growth, field fungi require 70%–90% relative humidity, a temperature of 20–25°C, aw > 0.85, and aw for optimum growth of 0.99. The period of active growth occurs when the fungus develops rapidly in the mycelium. Storage fungi, on the other hand, have evolved to reduced humidity and higher temperatures. A minimum of 0.75–0.85 aw is required for most Aspergillus and Penicillium species, and 0.93–0.98 aw is ideal. For active growth, Aspergillus species need water activity of 0.73, while Penicillium species need aw of at least 0.78–0.80. Furthermore, Aspergillus species adapt to temperatures of 30–40 degrees Celsius, but Penicillium species thrive well at temperatures of 25–30 degrees Celsius (Rodrigues et al., 2014).

Overview mycotoxine (OTA) of coffee in Ethiopia: Ethiopia is the origin of Arabica coffee, and coffee production is essential to countries' economy, with around 15 million people relying on it either directly

or indirectly (Petit, 2007). However, coffee can be damaged by pests and diseases, which can lead to fungal contamination and the production of mycotoxins. Coffee beans can be tainted by a variety of mycotoxins, but the most common is OTA, which was recently discovered in Ethiopia (Geremew et al., 2016).

The quality of coffee is determined by a number of factors, ranging from the field through post-harvest processing and secondary processing (Musebe et al., 2007). As a result, quality control is required at all stages of production and processing, as the final quality determines the market price. There is a significant difference between coffee meant for the domestic market and coffee destined for export, since the former must fulfill the strictest criteria imposed by many regulatory bodies. Quality controls are carried out on farms and at the district level by several agricultural authorities, the Ethiopian Commodity Exchange and the Ministry of Agriculture. Visual inspection and liquor analysis by experienced experts are used to determine quality. Any coffee product that fails to pass a series of stringent tests is routed to the local market (Abu and Teddy, 2013).

Fungi contamination is a major limitation in coffee bean producing. Temperature, moisture content, storage conditions, and storage durations can all play a role in mold formation (Amezqueta et al., 2009). Furthermore, field-related variables such as insect infestation, vulnerability of coffee varieties, and crop nutrient composition are risk factors for fungal invasion (Amezqueta et al., 2009). Fungi in coffee beans not only influence the sensory quality of the coffee beverage, but they also pose a health concern due to the formation of mycotoxins by some of these fungal taxa (Rezende, et al., 2013). Mycotoxins found in coffee include aflatoxins (AFs) B1, B2, G1, and G2, OTA, patulin, and sterigmatocystin (Soliman, 2005; Bokhari and Aly, 2009). A recent coffee analysis, however, demonstrated convincingly that coffee can be contaminated by a much broader range of mycotoxins, including trichothecenes, nivalenol, deoxynivalenol, T-2 and HT-2 Toxin, diacetoxyscirpenol, fumonisins B1 and B2, and the emerging mycotoxins cyclodepsipeptides enniatin A, enniatin A (Moraleja et al., 2015).

To far, OTA is the most prevalent mycotoxin detected in coffee, but due to climate change, other mycotoxins, such as AFs, are expected to become a concern in a variety of geographic regions in the next decades (Paterson et al., 2014). Several Aspergillus and Penicillium species produce ochratoxin A, which has been proven in animal models to be nephrotoxic, hepatotoxic, genotoxic, immunosuppressive, and carcinogenic (Pfohl-Leszkowicz et al., 2007; Reddy and Bhoola, 2010). OTA is produced in coffee by members of the Aspergillus sections Circumdati and Nigri, including A. OTA is produced in coffee by members of the Aspergillus sections Circumdati and Nigri, including sulphureus, A. carbonarius, A. niger, A. ochraceus, A. Westerdijkiae, and A. sclerotiorum (Paterson et al., 2014).

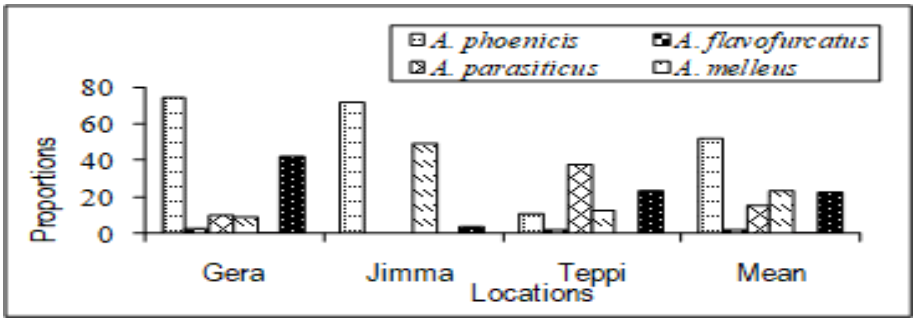
The first report of OTA in green coffee beans was made by Levi et al., (1974), and the generation of ochratoxin by Aspergillus ochraceus was first documented in South Africa (Hunter, 1998), while the presence of OTA in commercial roasted coffee samples was discovered by Tsubouchi et al., (1998) .OTA is named after the mold Aspergillus ochraceus, from which it was initially isolated (Naidu, et al., 1997). It is a species complex with nine species (Hudler, 1998). These species are prevalent in soil, decaying vegetation, and microbially deteriorated stored seeds and grains. It is more abundant in the soil around the roots of coffee plants than in other soils, and exposure of coffee blossoms to fungal spores can lead to bean infection (FAO, 2007a). However, Manter and Vivanco, (2007) proposal that ochratoxin A in coffee beans may come from ochratoxin A absorption in soil by coffee tree roots and later translocation is unproven (JECFA, 2001). OTA has been proven to be nephrotoxic, hepatotoxic, immunosuppressive, carcinogenic, and teratogenic in all monogastric mammalian species examined so far (Peraica et al., 2008). The most significant OTA-producing species or groupings of species in coffee are A.ochraceus, A. carbonarius, and strains of A. niger. A. ochraceus is widely present in coffee production systems and appears to be the most common source of ochratoxin A in coffee (Taniwaki et al., 1999). The fungus thrives at temperatures ranging from 8 to 37 °C, with the optimal range being 24 to 31 °C. Its presence or absence in any sample is most likely related to storage time rather than geographical location or other considerations (Pitt et al., 2000). A. carbonarius is uncommon and was just recently identified as a source of ochratoxin A. (Wicklow et al., 1996). The most notable difference between A. carbonarius and A. niger is the development of bigger spores, while other minor morphological changes occur. According to preliminary research (Heenan et al., 1998), A. carbonarius develops at

lower temperatures than A. niger, with a maximum temperature of roughly 40 °C and ideal circumstances of 32–35 °C. The A. niger complex is by far the most widespread, especially in Coffea caneophora (Robusta), but OTA production is uncommon and frequently insufficient. These three types of organisms differ in their biological niches, commodities impacted, and frequency of occurrence in various geographical locations (JECFA, 2001).

OTA has been found in raw coffee in several investigations. According to research conducted in Thailand (Bucheli et al., 2000) on the drying of Robusta coffee, OTA is generated during sun drying in the coffee cherry pericarp. According to the Finnish Customs Laboratory, the overall mean OTA content for raw coffee samples was 1.6 ppb, with over 85 percent of the samples falling into the lowest category (undetectable up to 2 ppb) and 1 – 2 percent of the samples being highly contaminated and having a large effect on the overall mean value (FAO, 2005). Abraham (2006) conducted research on the relationship of ochratoxicogenic fungus on Arabica coffee samples obtained from three locations in south west Ethiopia, which revealed a high occurrence of A. ochraceus. Abraham (2006) found a higher occurrence of A. ochraceus on dry processed coffee dried on the bare floor than on washed coffee dried on drying beds in his study of the connection of ochratoxicogenic fungus on Arabica coffee samples taken from three locations in south west Ethiopia.

According to Girma and colleagues (2007) identified six fungal species from the genera Aspergillus and Penicillium while researching the occurrence and distribution of mould species associated with Ethiopian dried coffee cherry samples collected from the ground and those picked from coffee trees, as well as parchment coffee samples taken from drying tables in the Gera, Jimma, and Teppi areas (south western Ethiopia). As a result, the distribution and proportions of these mycofloral communities differed greatly between sample groups and coffee-growing regions throughout the country. At Gera and Jimma, A. phoenicis was the most common mould species isolated (65–75%) from coffee cherries that had fallen to the ground and dried on the tree. When compared to washed parchment coffee, A. melleus had the second largest mould population (10–50%) in the dried coffee samples collected on the ground and selected on the tree (Fig. 1). However, no OTA-forming species, A. ochraceous, A. carbonarius, or A. niger, were isolated from all samples in this investigation.

Figure 1 depicts the geographic distribution of mycofloral species linked with Arabica coffee beans in southern Ethiopia (Girma et al., 2007)



According to Legese et al. (2020), who studied the percentages of fungal species discovered on Arabica coffee samples obtained from three locations in West Wollega, Ethiopia districts of Haru, Homa, and Nedjo were 84.67 percent, 7.37 percent, 6.74 percent, and 1.5 percent of Aspergillus spp, Fusarium spp, Penicillium spp, and Rhizopus spp, respectively (Legese et al., 2020). As a consequence, Aspergillus spp. were the most common fungal genera, with Rhizopus being the least common. (See Figure 2)

Figure 2 shows the percentage of total coffee bean associated fungal genera (Legese et al., 2020).

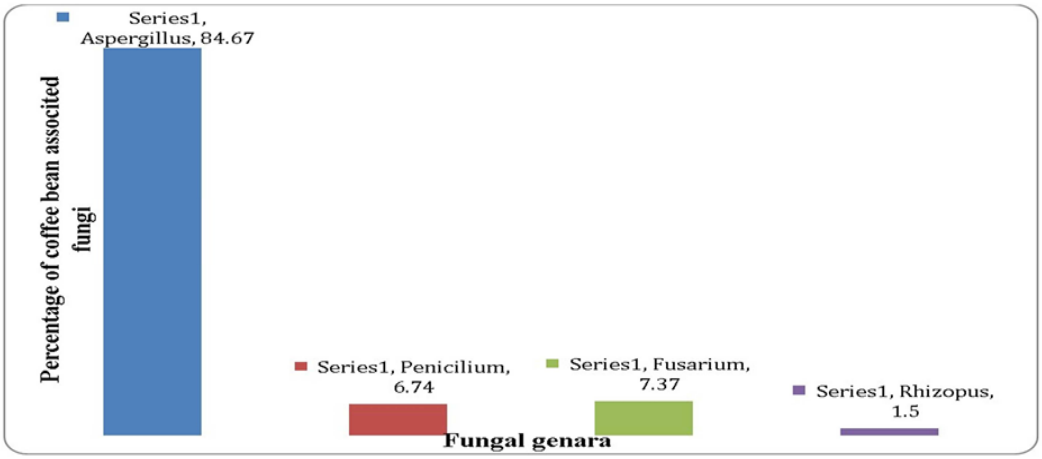


Figure 3 Percentage of coffee bean associated fungi from different district. (Legese et al., 2020).

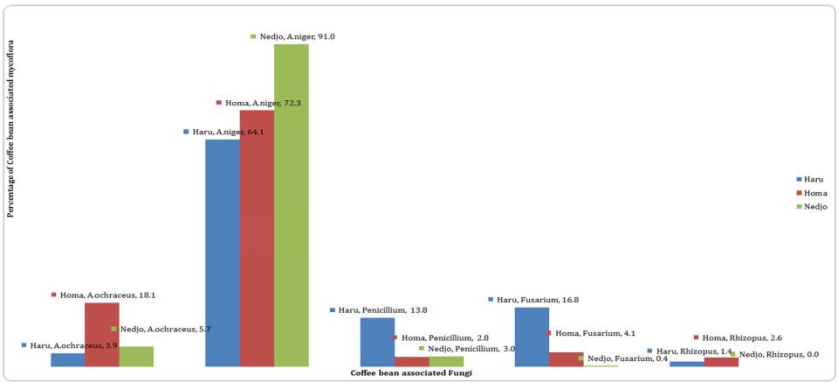


Table 2 Determination of Ochratoxin A concentration by the ELISA kit. (Legese et al., 2020).

	A.ochraceus	***A.niger***	**Ochratoxin A**	**Moisture content**
A.ochraceus		0.14	0.31**	0.25*
A.niger	0.14		0.12	0.10
Ochratoxin A	0.31**	0.12		0.23*
Moisture content	0.25*	0.10	0.23*	
Mold condition	0.11	0.27*	0.20	0.44***

Where: *A.niger=Aspergillus niger, A.ochraceus=Aspergillus ochraceus* *** Significant at P<0.001, ** Significant at P<0.01, * Significant at P<0.05

According to Legese et al. (2020), who studied the relationship of ochratoxicogenic fungus on Arabica coffee samples obtained from three locations in West Wollega, Ethiopia, the mycotoxigenic fungi Aspergillus, ochraceus, and Aspergillus niger were discovered as mycotoxigenic fungi linked with coffee beans. Aspergillus niger accounted for 73.3 percent of the total, whereas Aspergillus ochraceus accounted for 11.37 percent. Similarly, the most prevalent mycotoxigenic fungi detected at the district level in Haru, Homa, and Nedjo were A. ochraceus, A. niger, Penicillium, Fusarium, and Rhizopus (figure 3). Aspergillus ochraceus is found in all regions, with Homa having the highest occurrence, followed by Nedjo and Haru. There is a relationship between mycotoxigenic fungi and ochratoxin A, according to Legese et al. (2020).The results of this study revealed a substantial difference and a modest positive relationship between Aspergillus ochraceus and ochratoxin A (r = 0.31), on the one hand, and Aspergillus ochraceus and ochratoxin A (r = 0.31), on the other (Table 2).

There is a link between mold condition and moisture content, according to Legese et al. (2020), and there was a very significant differential positive intermediate correlation between moisture content (r = 0.44) on the one hand and mold condition (r = 0.44) on the other (Table 2). On the other hand, there was a substantial positive weak association between ochratoxin A and moisture content (r = 0.23).

The amount of ochratoxin A in raw coffee varies from district to district, according to Legese et al., 2020 results. Haru district had no detectable amount, but Homa had a mean OTA level of 1.23 g/kg and Nedjo had a mean OTA level of 2.03 g/kg. Although the presence of Aspergillus ochraceus does not always imply the presence of ochratoxin A, environmental factors such as moisture content may influence the development of the toxin. Although we found Aspergillus ochraceus in the Haru samples, we were unable to find any ochratoxin A in the district. (See Table 3).

Table 3 shows the concentrations of ochratoxin A. (Legese et al., 2020).

Districts	№ of sample analyzed	Average OTA concentration in µg/kg (ppb)
Haru	25	0 (ND) Not detected
Homa	25	1.23 µg/kg (1.23 ppb)
Nedjo	25	2.03 µg/kg (2.03 ppb)
Mean		1.08 µg/kg (1.08 ppb)

*****ppb=part per billion

The moisture content of the coffee bean is critical for the production of OTA as well as the formation of mold on the coffee cherry. Mold growth in coffee cherries was likewise strongly associated to Aspergillus niger. This suggests that coffee may create ochratoxin A even in the absence of mold development, and moisture content is the most essential factor in OTA production. According to Legese et al. (2020), OTA content in green coffee was ND (not identified), 1.23 g/kg, and 2.03 g/kg for Haru, Homa, and Nedjo, respectively. A. niger, Penicillium sp., Niger, and Penicillium sp., Homa treatments all exhibited significant differences. There were no statistically significant changes between Fusarium spp. and Homa, Rhizopus spp., and Penicillium spp. treatments. The findings of Legese et al. (2020) are congruent with those of Geremew et al. (2016), who discovered 1.5g/kg of OTA in locally consumed Ethiopian coffee.

On the other side, Demelash and Ashenafi (2019) revealed that OTA is labile, but that it is more quickly degraded by high temperatures than aflatoxin and sterigmatocystin. Toxin levels were reduced by 70% to 96% during coffee bean roasting, according to Heilmann and colleagues (1999), who showed similar reductions during roasting. After an incubation time, the beans were roasted to three levels (light, medium, and dark) and milled into three types (fine, medium, and coarse), according to Oliveira et al. (2013). High-performance liquid chromatography was used to measure OTA levels. The lowest concentration of OTA was found when dark roast and coarse particle size were combined, at 3.06 mg/kg, a decrease of 97.17 percent. The findings of Oliveira et al., (2013) reveal that the residual concentration of OTA in roasted and ground coffee beans is determined by roasting and particle size rather than roasting alone (Table 4).

Table 4 Mean OTA values detected in the samples, percent reduction, residual value, temperature and roasting time Oliveira et al., (2013)

Temperature and roasting time	Sample types	Mean OTA concentration (mg/kg)	Standard deviation	OTA reduction	Residual value
205 °C in 13.5 (min)	Green coffee without inoculation	5.41	-	-	
	Inoculated green coffee	108.33	-	-	
	Light roast/fine particle size	47.41	1.97	56.25%	43.77%
	Light roast/medium particle size	40.78	1.07	62.36%	37.64%
	Light roast/coarse particle size	28.24	3.60	73.93%	26.07%
217 °C in 14 (min)	Medium roast/fine particle size	16.81	1.04	84.48%	15.52%
	Medium roast/medium particle size	10.75	0.69	90.01%	9.93%
	Medium roast/coarse particle size	8.43	0.89	92.22%	7.78%
224 °C in 14 (min)	Dark roast/fine particle size	4.97	0.18	95.41%	4.59%
	Dark roast/medium particle size	3.73	0.36	96.55%	3.44%
	Dark roast/coarse particle size	3.06	0.16	97.17%	2.83%

OTA is so harmful that FAO/WHO scientists have declared a maximum tolerated limit of 100 billionths of a gram per kilogram of body weight every week for people. Similarly, the EU established maximum permitted levels for OTA in roasted and ground coffee of 5 ppb and 10 ppb in instant coffee. However, no restriction has been imposed for green coffee beans thus yet (FAO, 2007b).

According to Culliao and Barcelo, 2003, OTA was more typically discovered in Robusta coffee (37 percent) than in Arabica coffee (26 percent). The maximum level of OTA was discovered in Arabica dried whole cherries at 97 g/kg, whereas Robusta had the highest level of OTA at 120 g/kg. In addition, Romani et al., (2000) found that the observed OTA from green coffee beans in Congo was 18–48 g/kg.

The present review found that mycotoxins in coffee should be examined as soon as feasible, according to a recent study on mycotoxins and climate change. There have been no significant studies on coffee cultivation and processing methods in Ethiopia to assess the prevalence and importance of mycotoxins in locally consumed Ethiopian coffee (Geremew et al., 2016; Legasse et al., 2020). The presence of numerous mycotoxins generated by Fusarium and/or Aspergillus in coffee will require extensive intervention in the future.

Conclusion

We may deduce from public health and economic concerns that the presence and severity of mycotoxins in food and feed systems is critical nowadays. Mycotoxins, on the other hand, have been categorized based on their frequency and significance. Ethiopia is an African country that produces and consumes coffee (*Coffea Arabica*). The country consumes over half of the coffee produced domestically. The intervention on mycotoxin, especially Ocratoxine A (OTA), in green coffee evaluation based on diverse coffee processing and different coffee drying materials (raised on mesh wire, polished cement floor, or locally accessible materials) appears promising. Coffee growers, local coffee buyers and dealers, research organizations and universities, and coffee and tea authorities should all be involved in the production, quality, and processing of coffee. Ethiopia's Health Minister and

food and drug regulatory officials should establish the maximum permitted level of OTA at 5 g/kg for roasted and ground coffee and 10 g/kg for ground coffee and instant coffee, and they should evaluate and monitor mycotoxins in local coffee in a timely and reliable way.

Recommendation

Further research is needed in Ethiopia on the prevalence and relevance of mycotoxins, particularly ochratoxin A, in green, different roasting types, and instant coffee for household consumption. The majority of the research focused on the existence and importance of mycotoxins in Ethiopian raw coffee. So far, in roasted coffee, including diverse roasting techniques, a future line of inquiry can be investigated. Future research directions Educate and train coffee producers and dealers on the prevalence of mycotoxins, their impact, and potential mitigation techniques. Permeation of that mycotoxin, in particular, Ocratoxine A, into coffee has been reported in Ethiopia in this review, and additional evaluation of different agro-ecological systems in the treated areas is needed, while analysis of green coffee using different coffee processing and drying materials may yield better results. Raising knowledge of mycotoxins' occurrence, import, and potential mitigation techniques for coffee growers and traders through training on coffee pre- and post-harvest handling; coffee quality handling and suitable processing are critical.

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