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Mycotoxins Contamination in Tea and Herbal Infusion: A Mini-Review

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A B S T R A C T

Consumption of tea and herbal teas is increasing worldwide due to their beneficial substances and daily antioxidant properties. However, in unfavorable environmental conditions, biological contamination can occur and cause a variety of diseases in humans and animals. In the meantime, fungal infection is of special importance as it produces secondary metabolites (mycotoxins). Mycotoxins affect various tissues of the body and their acute and chronic toxic effects can have serious problems for public health. Health risk varies in terms of mycotoxins and depends primarily on the geographical area and economic status of the population. This review examines the published articles about determining the presence of mycotoxins in herbal teas and teas and transfer to infusions 1997-2019 using high technique apparatus. The collected information was obtained from PubMed, Science Direct, Scopus, and Web of Science. This review decided to investigate the mycotoxins levels in tea and herbal tea and then consider different and effective proposed methods of removing or reducing mycotoxins.

1. Introduction

Tea and herbal teas are one of the most widely consumed beverages, a long tradition, and part of today's lifestyle. It is estimated that nearly 18-20 billion cups of tea are consumed daily all over the world [1]. Today China, India, Kenya, Sri Lanka, and Turkey (86.5%) are the largest tea producers in the world [2]. In terms of tea consumption, Turkey and China are the world's two largest tea consumers. It is estimated that tea consumption has increased by 4.5%annually over the past decade [3]. Although, there are different types of tea on the market, they all come from the leaves of *Camellia Sinensis*. Famous brands of black tea include *Darjeeling*, *Assam*, *Turkish*, and *Ceylon* tea [3]. There is, however, evidence that all varieties of tea (white, yellow, green, black) originate from the leaves of the camellia tree [4, 5]. Generally made by drying parts of the harvested plant at 60°C in specific ovens with microwave irradiation or further valid techniques that decrease moisture and let valuable biomass be concentrated [6]. Consumption of tea and herbal teas has been proven to be beneficial to health, especially in the treatment of cardiovascular diseases, immune disorders, and low blood cholesterol [5]. There are many useful compounds in tea and herbal teas including phenolic compounds, and flavonoids (catechin and anthocyanin), which have antioxidant properties [7]. However, adverse environmental and biological parameters (such as temperature, humidity, air quality, and insects) can be effective in contaminating herbal

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teas with mycotoxins during post-harvest growth and processing. Fungal contamination of agricultural products is one of the main challenges in analytical chemistry, which has contributed to serious efforts in analytical development and preventive measures [8]. Mycotoxins are natural, secondary metabolites produced by certain filamentous fungi on most agricultural products. Mycotoxins enter the body through contaminated foods (Figure1) which damage vital organs such as the liver, kidney brain, reproductive system, and immune system and results in toxicity [9]. Several comprehensive studies have highlighted issues related to the prevalence of mycotoxins in tea and herbal teas. Each will be discussed separately [10].

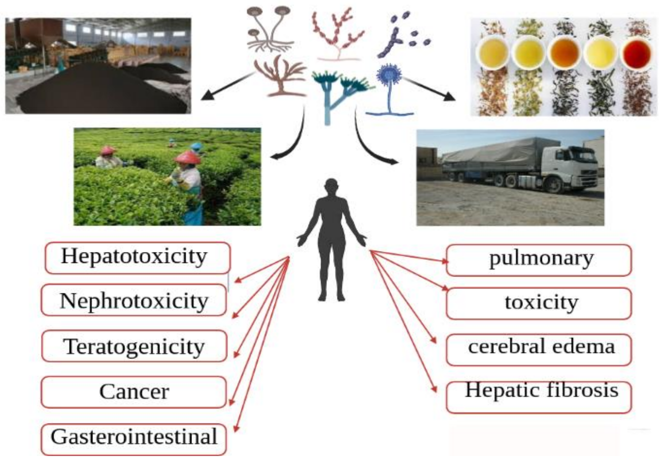

Figure1: Mycotoxin pathways during transport and storage in herbal teas and teas and their effects on different organs in the body

1.1.1 Aflatoxins:

Aflatoxins are the most toxic mycotoxins [11]. Among natural aflatoxins, aflatoxin B_1 (Figure 2a) is included in the list of human carcinogens (group I carcinogens) according to the International Agency for Research on Cancer (IARC) [12]. Epidemiological studies have shown a significant relationship between human liver cancer and dietary aflatoxin levels [13]. It is confirmed that aflatoxins cause liver cancer in humans [14].

1.1.2 Ochratoxin:

It is produced universally in foods such as cereals, cocoa, soybeans, nuts, spices, grapes, beer, and coffee [15]. Ochratoxin A (OTA) is the most well-known and toxic type produced by *Penicillium verrucosum*, *Aspergillus ochraceus*, and *Aspergillus carbonarius* [16]. It has been reported a maximum residual level of 5 µg/kg OTA (Figure 2b) in cereals recommended by the Joint FAO/WHO Expert Committee on Food Additives (JECFA) [17]. The carcinogenic effects of OTA have been listed in group II_B by the IARC [18]. The tolerable daily intake (TDI) level of OTA was determined 5 ng/kg/bw/day [19]. The maximum tolerable daily intake (MTDI) for OTA has been reported by the World Health Organization (WHO) to be 14.3 ng /kg/day [20]. It is supposed that OTA is a nephrotoxic and carcinogenic mycotoxin implicated in the etiology of Balkan endemic nephropathy [21].

1.1.3 Fumonisin:

It has been suggested as a toxic metabolite and carcinogen [22]. It is mainly produced by fusarium fungi and is involved in the development of nephrotoxicity and hepatotoxicity and hepatocarcinoma in animals [23]. According to the IARC, Fumonisin B_1 (Figure 2c) is categorized as carcinogen II_B. It can act as a promoter of cancer, but not as a genotoxic agent [24]. The maximum tolerable daily intake of fumonisin recommended by the WHO is 2 µg/kg/day [17]. Martin et al. (2000) investigated the occurrence of FB_1 in commercial medicinal plants in Portugal [25].

1.1.4 Zearalenone (ZEA):

It is produced by different species of Fusarium (Figure 2d), and can be found in a variety of food products including corn, wheat, and oats. This mycotoxin has been reported to be associated with deoxynivalenol (DON) [26]. The WHO's maximum tolerable daily intake of zearalenone is 0.5 µg/kg per day [27].

1.1.5 Citrinin:

It was first identified as a major cause of yellow rice disease in Japan. Kidney is the main target organ of citrinin (Figure 2e). To date, there is no specific global standard for determining citrinin levels in foods. The European Union has set the limit for citrinin in food products at 50-5000 ng/g [28].

1.1.6 Trichothecene:

This mycotoxin (Figure 2f) is produced by Fusarium species [29]. It is found mainly in cereals (e.g. wheat, corn and barley) in North America, Europe, and Asia [30]. The prevalence of infertility has been steadily increasing worldwide, and some of these effects are related to the contamination of food and animal feed with trichothecene [31]. According to WHO, the maximum tolerable daily intake of the T-2 toxin is 0.06 µg/kg/day [32].

1.2 Strategies to prevent fungal growth and mycotoxin production:

Despite the development of many strategies to prevent mycotoxins from contaminating food and animal feed, virtually no effective and reliable strategy has been reported to prevent food contamination with these microscopic fungal toxins [33]. Mycotoxins can contaminate agricultural products, both on the farm and during storage. In order to prevent and control mycotoxin-producing fungi, field management, the use of biological and chemical materials, harvest management, and post-harvest measures such as drying and storage conditions can be implemented. Natural materials and chemical and radioactive radiation can also be used to inhibit their growth [34]. The significance of drying and controlling moisture during storage is well understood in terms preventing fungal contamination in the food industry. There have been fascinating results presented on the possibility of using biological agents to prevent aflatoxin contamination before harvesting crops like peanuts, rice, corn, and cotton. The combination of toxic fungus-resistant crops and biochemical technologies of non-mycotoxin-producing fungal strains may be one of the most effective ways to prevent mycotoxin contamination [34]. Several natural plant extracts and spice oils, such as eugenol, cinnamon, oregano, onion, and lemongrass, are excellent at detoxifying mycotoxins similar to chemicals such as sodium bisulphite and chlorine [31]. Unfortunately, the proposed methods significantly reduce the nutritional value of foods or lead to toxic derivative products. Chemical treatment is permissible in animal feeds, but not admissible in the human diet. The recently published study revealed a lot of interest in using bacteria, yeasts, and molds for mycotoxin detoxification in food only in *in vitro* conditions [35, 36]. In addition, none of the physical or chemical detoxification methods have shown effective performance in reducing mycotoxins, including physical separation, extraction with adsorbents, and adsorption [37]. Although the efficacy of the detoxifying procedure depends on the nature of the food, environmental conditions like humidity, temperature, also the kind and concentration of mycotoxins, and the degree of binding between mycotoxins and their compounds should also be considered [38].

1.2.1 Physical solutions:

Mechanical separation based on density and colour significantly reduce mycotoxin levels in the seeds. Simple washing by aqueous solution or sodium carbonate can reduce ZEN and FB_1 concentrations in cereals or corn. Gamma radiation has been successfully used to control ochratoxin levels in feed [39]. Although the levels of mycotoxins in animal feed are unknown, dilution by mixing is associated with a decrease of mycotoxins below a critical level with restrictions on usage in several countries [40].

1.2.2 Chemical solutions:

It is effective against mycotoxins detoxification such as alkalis (ammonia, sodium hydroxide), oxidizing reagents (hydrogen peroxide, ozone), reducing agents (bisulphite), chlorinated substances (chlorine), salts, and formaldehyde [41]. Ammonization is the most widely used method in mycotoxin detoxification in several countries [42]. In another study, sodium bisulphite was also found to be effective in detoxifying aflatoxin and trichothecene levels from food samples. Some data revealed that treatment with sodium hypochlorite and heat could significantly reduce the OTA level in food samples following 24-30 hours of exposure. Also, the other study showed the treatment with sodium bicarbonate and Hydrogen peroxide alone or with calcium hydroxide totally excluded FB_1 in contaminant maize [43].
Calcium hydroxide mono methylamine has been used for purifying T-2 toxin and Diacetoxyscirpenol in animal feed [44].

1.2.3 Physicochemical solutions:

Numerous reports indicate that phyllosilicate clay can chemically adsorb aflatoxin from aqueous solutions. Hydrated Sodium calcium aluminosilicate (HSCAS) and montmorillonite are other sorbents, which form a more stable complex with AFB_1 in *in vitro* conditions [45]. All of the proposed chemicals are the most effective processes in animal food detoxification [46]. A prophylactic drug such as Oltipraz and Chlorophylline in some countries with high levels of food contamination with mycotoxins may reduce the biological dose of these compounds in crops [47]. Unfortunately, the long-term medical budget is impossible in developing countries. Therefore, the focus in animal feed industries is to reduce mycotoxin levels and the use of esterified glucomanoses and yeast in animal feeds [48]. It has been reported that certain minerals, such as clay can selectively absorb aflatoxins from the gastrointestinal to the point of hampering their absorption [45]. While charcoal is effective in the treatment of some chemical poisoning, it is often not effective in preventing the absorption of the digestive system [49]. It revealed that hydrated HSCAS is an effective method in contaminated feed in hampering aflatoxicosis in lambs, calves, turkeys, chickens, pigs and goats with low absorption of micronutrients [50]. Biological detoxification methods, such as enzymatic degradation or biological transport, are new and effective in reducing mycotoxins, but they may not be suitable for all foods when it comes to preventing fungal contamination and mycotoxins [51].

2. Discussion:

The Contamination of tea and herbal teas with toxin-producing fungi is a current problem, which has become one of the most important challenges worldwide. Unwanted environmental and biological conditions such as temperature, humidity, air quality, and insects during growing, processing, transportation, and storage can lead to the contamination of tea and herbal teas with mycotoxins [52]. Mycotoxins as carcinogenic compounds by IARC can cause harmful effects on humans and animals. We need to be aware of the level of contamination of mycotoxins in food and feeds. The conducted investigation showed the contamination in the analyzed samples ranged from 0.12 ng/g to 280 µg/kg in black tea [53-59]. The contamination level of AFs by HPLC-FD in 129 samples of green tea in Morocco showed 59% of positive samples were contaminated with AFs. In positive samples, the AFB_1 level was reported between the range of 1.8-6.7 ng/g in tea samples, while the maximum amount of total AF was 116.2 ng/g [60]. The AFB_1 level in green tea samples was reported at lower than LOQ ((1ng/g) in Brazil) [61]. There is only one report from Iran about AF contamination of tea samples. Among 40 samples, about 25% of black tea (including domestic and imported tea) was contaminated with AFB_1 (10

ng/g) [54]. In Turkey, the levels of AFB_1 in 62 various food samples (including dried vegetables, tea, spices, instant soups, snacks) showed only two positive samples contaminated with AFB_1 (1 µg/kg) [53]. PallaréS et al. (2017) investigated several types of mycotoxins in 44 samples of commercial black, green, and red tea, and peppermint tea in Germany. The results showed that AFB_2 and AFG_2 levels in several samples were higher than 14-32 µg/l. Also, a higher level of AF in green tea was seen compared with black and red tea [55]. It was found that the AF levels of several beverage products derived from herbal tea ranged from 2-13.5 µg/l in Spain [56]. In Argentina, 152 samples of medicinal plants showed that the AF level was determined between 10-2000 ng/g, and 26% of the fungal strains were Aspergillus. Moreover, the OTA level was reported in the range of 0.12-9 ng/g [57]. The AF level in 48 herbal teas in Italy confirmed that none of the herbal teas was contaminated with AF in tropical countries [58]. Based on AF levels in 28 medicinal plants in Thailand, 18% were contaminated between 2-14 ng/g [59]. Besides, only one out of 10 green tea samples was contaminated with AFB_1 (5.4 µg/kg) in Spain [62]. Another study from Indian markets showed that 26% of black tea samples were contaminated with Aspergillus fungi and the highest AFB_1 was 19.2 µg/kg [63]. The contamination of 36 Puerh tea samples in Yunnan, China showed that AFs and fumonisin were not found in the samples, but ochratoxin A was found in 4 of 36 tea samples [64]. The results of another study in China revealed that AFs, especially AFB_1, exceeded 20 µg/kg in several samples [65].
In Croatia, 62 samples of 11 herbal teas, showed that ochratoxin A was found in only tested samples [22]. The content of OTA and its transfer to hot beverage tea was determined in 50 samples in Turkey. The results revealed that OTA concentrations in 92% of black tea samples were lower than 0.35 ng/g. In addition, 4 out of 40 black tea samples were contaminated with OTA higher than 0.35ng/g. The OTA level in positive samples was 19.6-56.7 ng/g. The average transfer of OTA to beverage tea was 41.5%. It seems that the transfer rate also depends on the origin of the tea, fermentation, pH of drinking water, and the process of beverage tea [23]. In another study, the OTA level in 24 samples (including 12 black tea and 12 fruit tea samples) was analyzed in Czech. The proposed study showed that 33% of black tea samples were contaminated by OTA more than the permissible allowable level (between 1.85-250 ng/g). In fruit tea samples, the OTA level in 4 samples was 0.35 ng/g and the OTA level was reported between 1.1-104 ng/g, respectively. The mean transfer of black tea and fruit tea beverage was 34.8% and 4.1%, respectively. We supposed that the low level of OTA transfer is attributed to organic acids [66]. The fumonisin content (FB_1 & FB_2) in herbal tea and medicinal plant samples in Turkey revealed that FB_1 was found only in two of 115 samples (0.16 and 1.487 µg/g) with no FB_2 contamination in 115 samples [25]. A study in Portugal found FB_1 in 88% of black tea samples and 44% of chamomile tea samples [67]. Additionally, a similar study in Portugal found that, in 88% of black tea, FB_1 levels ranged between 80-280 µg/kg [26]. An analysis of 91 black and herbal tea samples collected from supermarkets in China and Belgium revealed that only one sample was contaminated with 76 µg/kg of FB_1 [68]. Another study in Latvia showed that FB_1 and deoxynivalenol (DON) were found in 55 and 45% of the samples (n = 60), respectively. In the present study, the OTA and AFB_1 were reported in 10 and 20% of the samples in the concentration range between 3.3-99.2 µg/kg and 3.4-23.7 µg/kg. Also, it was observed that the transfer rate of DON and zearalenone in tea samples were reported to be between 32-100% [69]. The incidence of mycotoxins in 84 medicinal plant samples in Spain showed that 98% of the samples were contaminated with ZEA, 96% with AF, 63% with OTA, 13% with FB62% with DON, and 61% of the samples with citrinin [70]. Evaluation of 108 samples of black tea in China showed 5% of samples were contaminated with ZEN (5.29 µg/kg). The incidence of OTA was 2% with a mean concentration of 0.66 µg/kg. In addition, none of the samples does observe AF, DON, and FB contamination [71]. Based on the conducted study all over the world, different strategies were used to remove or reduce mycotoxins. Unfortunately, the proposed solutions have limitations that make it impossible to use them on a large scale. In addition, none of the proposed methods can remove 100% of contamination effectively. As mentioned by the present data, the best way is the prevention of products from contamination during crop cultivation, storage, and processing.

3. Conclusion:

Mycotoxins are toxic metabolites of filamentous fungi, which can cause irreparable financial damage and incurable disease in humans. The increasing consumption of tea and herbal teas requires that we have sufficient and necessary knowledge about the contamination level of tea and herbal beverage, which is a crucial issue in maintaining the health of consumers. The main strategic method of preventing large amounts of crops from being contaminated by fungi and their metabolites (mycotoxins) is through controlling products before, during, or after harvest.

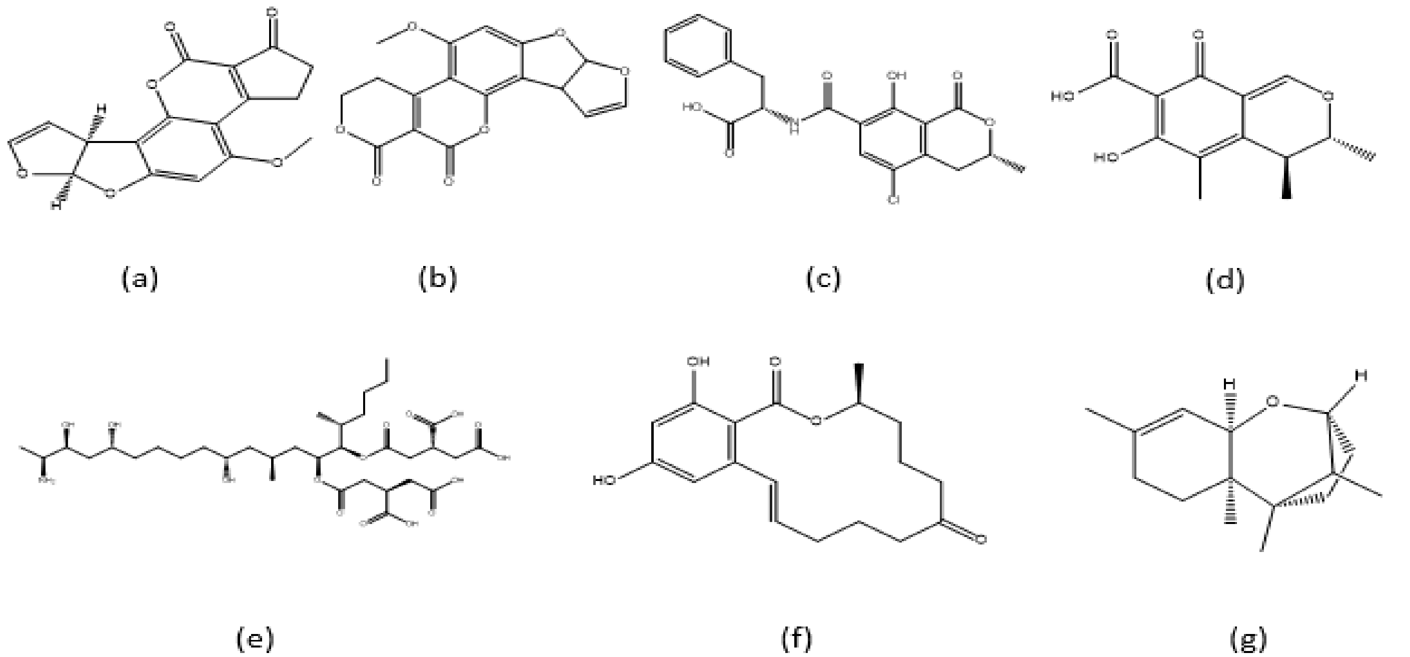

Figure 2: Mycotoxins structure: (a). aflatoxin B1, (b). Ochratoxin A, (c). Fumonisin B1, (d). Zearalenone, (e). Citrinin, (f). Trichothecene

Authors' Contributions

Asma Ghasemi, Mohammad Reza Mehrasebi, Mir Jamal Hosseini: Searching; writing Draft; reviewing; editing.

Conflicts of Interest

The Authors declare that there is no conflict of interest.

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