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Review Article

Aflatoxin Reduction Mechanism of Probiotics

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ABSTRACT

Mycotoxins are secondary metabolites produced by various toxigenic fungi produced by *Aspergillus*, *Fusarium*, and *Penicillium*. They have mutagenic, teratogenic, carcinogenic effects for both humans and animals. Among the different mycotoxins, aflatoxins (AFs) are the most potent and it is a secondary metabolite produced primarily by *Aspergillus flavus* and *Aspergillus parasitic* in agricultural food staff such as peanuts, maize grains, cereals, and animal feed. The most abundance and heat stability of these mycotoxins during food and feed processing pose serious health problems in humans and animals. Therefore, to overcome this problem using biological detoxification method is the best. So, this review aims to see the effectiveness of the biological detoxification methods of aflatoxin, and reduction mechanisms. Probiotics are one of the biological control of mycotoxin and which are regulated as dietary supplements and foods, consist of yeast or bacteria. Using different probiotics aflatoxin can reduce its bioavailability and absorption in the gut. The action of microorganisms on mycotoxins and their mechanism of action has based the competition for nutrients with entering pathogens, interactions, the competitive exclusion for adhesion sites (barrier function of the intestinal epithelium), by binding with the cell wall of the bacteria and by changing its toxicity to non-toxic substances. The ability of aflatoxin reduction potentials of probiotics bacteria is different depending on the type of the bacteria, the concentrations of the bacteria, and the PH conditions. It is important to study the chemical interactions between the cell wall of probiotic bacteria, and its related components with aflatoxin molecules that could be satisfied to provide further justification of probiotics as adsorbent of aflatoxin. The best way to prevent the aflatoxin prevalence in agricultural products are making suitable conditions of harvesting and storage but if that could be impossible, could be better to eat fermented foods (yogurt or dairy drinks) or taking probiotics since they are available as capsules, tablets, packets, or powders to reduce the toxicity of the toxin.

Keywords: Action of mechanism; Aflatoxin; Probiotics; Lactic acid bacteria; Mycotoxin

INTRODUCTION

High amounts of the world's food and feed production are spoiled due to the contamination by several foodborne mycobiota [1]. One of the major causes that spoiled food and bring unhealthy system for the human being is a fungus. Molds play a major role in the spoilage of food products since it is estimated that 5% to 10% of the world food's production is lost due to fungal contamination [2]. The growth and survival of these fungi cause losses in dry matter, quality, and economic value of the stored food and feed products [3]. When the fungus grows on a food product, it might produce a toxic substance called mycotoxins, which are harmful to human and animal health. As a result, reducing or eliminating either fungus or toxic substances are a critical issue, besides reducing the health problem aspect, will also help the world to reduce food loss and food insecurity.

There are many biological toxins present in the natural environment, which may be dangerous for human and animal health. But mycotoxins are currently considered to be among the most dangerous ones, which can cause various diseases and death in animals and humans. It is a secondary metabolite of

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fungal origin, and some of the species filamentous fungi, mainly belonging to the genera *Aspergillus*, *Penicillium*, and *Fusarium* [4].

Probiotics a biological control of mycotoxin and which are regulated as dietary supplements and foods, consist of yeast or bacteria. They are available as capsules, tablets, packets, or powders and are contained in various fermented foods, most commonly yogurt or dairy drinks. Probiotic products may contain a single microorganism or a mixture of several species. According to the World Health Organization (WHO) working groups, probiotics are defined as "live microorganisms which when administered in adequate amounts confer health benefits on the host". Probiotic bacteria used for food applications may have a human origin (feces, breast milk) or they can be derived from food (artisanal fermented products) [5]. There are many microorganisms used as probiotics are listed below in Table 1.

Bacteria			Yeast
Lactobacillus species	*Bifidobacterium* species	Other bacteria	
L. acidophilus	*B. adolescentis*	*Bacillus cereus*	
L. bulgaricus	*B. animalis*	*Enterococcus faecalisa*	
L. casei	*B. bifidum*	*Enterococcus faeciuma*	
L. crispatus	*B. breve*	*Escherichia coli Nissle*	*Saccharomyces boulardii*
L. fermentum	*B. infantis*	*Streptococcus thermophilus*	
L. gasseri	*B. lactis*		
L. johnsonii	*B. longum*		
L. lactis			
L. plantarum			
L. reuteri			
L. rhamnosus			

Table 1: Microorganisms Used as Probiotics.

HEALTH BENEFITS OF THE CONSUMPTION OF PROBIOTIC

Probiotics have many beneficial health effects, for example, several studies have shown that probiotic treatment can improve intestinal functions and integrity, relieve constipation-related symptoms, and improved the microbiota environment [6]. The other beneficial modulation of the gut microbiota activity by the reduction of the risk-associated with mutagenicity and carcinogenicity, alleviation of lactose intolerance, reinforcement of gut mucosal immunity, acceleration of intestinal mobility, prevention of colon cancer [7]. Furthermore, it is also believed that the application of probiotics in the area of detoxification and decontamination has recently been studied. Its application in the food industry is of great significance. So, in addition to their health, probiotics have a significant application on the toxin reduction potentials in agricultural products. This thing makes interesting and the attentions of probiotics towards toxin reduction is increasing and it is the current researchable area. Therefore the present review aims to assess the effectiveness of probiotics on the mycotoxin reduction potential and its reduction mechanism of aflatoxin.

LITERATURE REVIEW

Biological detoxification of mycotoxins in food, raw material, and concentrated feed, as well as inhuman and animal organisms, is a new and very useful method. In this method, the way that the probiotics entering into the aflatoxin infected host is by ingestion. Ingestion of probiotics exerts a beneficial effect on the host organism beyond inherent general nutrition and holds great promise for reducing the bioavailability of consumed AFs. For this, the specific strain, the food matrix used as a vehicle, the dose, the period, and the way of administration (continuous or in a cyclical way) seems to be crucial for the achievement of the desired health benefit. Different organisms, including bacteria especially, probiotics and dairy strains of Lactic Acid Bacteria (LAB), yeast strains of *Saccharomyces cerevisiae*, and non-toxigenic *Aspergillus fungi*, have been tested for their ability the control of AFs contamination [8]. Among them particular attention paid to lactic acid bacteria because of their favorable influence on human organisms (probiotic bacteria), the widespread use in the production of fermented foods, and the ability to inhibit the growth of molds as well as mycotoxins production.

The effective performance of the probiotic depends on their strong adherence and colonization of the human gut, which in turn improves the host immune system. Accordingly, Kabak et al. research report has been conducted *in vivo* methods on aflatoxin B1 (AFB1) and ochratoxin A (OTA) in the gastrointestinal tract in the absence and presence of probiotics, a possible adsorbent [9]. In this research finding average bio accessibility of AFB1 and OTA without probiotics was found to be 90% and 30%, but in the presence of six probiotic bacteria showed a reduction to a maximum of 37% and 73%, respectively. The bacterial strains' binding capacity to AFB1 and OTA were different. In Gratz et al. research report also using Lactobacillus and *Propionibacterium* strains of probiotic bacteria in chicken duodenum the aflatoxin B1 reduction covered from 57-66% [10]. In another research report in *Lactobacillus fermentum*, *Lactobacillus easel*, *Lactobacillus plantarum* in Liquid media the aflatoxin B1 was reduced from 25-61%. Accordingly, Abdelmotilib et al. research report on aflatoxin M1 reduction in milk in both probiotic bacterial and yeast species (*Lactobacillus Plantarum*, *Lactobacillus acidophilus*, *Bifidobacterium bifidum*, *Kluyveromyces lactis*, and *Saccharomyces cerevisiae*) found that the highest AFM1 removal was 80.56%, 86.64%, 88.60% and 90.88% in the treated milk samples in a respective manner [11]. This probiotic bacteria binding capacity is different from each other due to different reasons. It is also interesting to note that the toxin-removal capacity of the combination of the 4 strains was not the sum of their individual capacities. The removal of

other mycotoxins beyond AFB1 by lactic acid bacteria and bifido bacteria was studied as well. AFB1, removal capacity was variable among strains (reduction in the supernatant ranged from 2% to 82%) and depending on the strain-mycotoxin considered as well, but not too much on PAT or OTA concentration. For instance, *B. animalis* VM12 reduced 82% of PAT and 22% of OTA whereas *B. animalis* LA17 reduced less than 12% of both toxins. On the contrary, some *B. longum*, *L. acidophilus* and *L. plantarum* strains reduced much more OTA than PAT. The strain-specific capacity to bind AFB1 was confirmed by Hernandez-Mendoza et al., where the removal capacity ranged from 14-50% among 8 strains of *L. casei* assessed [12].

MECHANISM OF BINDING

To date, several studies have demonstrated that the structure and components of the cell wall are responsible for the microbial binding of aflatoxins, though the mechanism of binding by a specific strain is still unclear. Accordingly, these LAB can reduce the aflatoxins through the two main degradation mechanisms including an enzymatic pathway-dependent reaction or a physical binding process. Further investigations showed that some LAB strains reduced aflatoxins uptake, hydrolyzed the toxin with no new toxic products formed, along protected themselves against membrane and DNA damage during these reactions. But some researchers stated that the esterified glucomannan (EGM) and mannooligosaccharide (MOS) have been proposed to be responsible for yeast cell walls. While in LAB, for AFB1 binding suggested a physical union, an adhesion to bacterial cell wall components (polysaccharides and peptidoglycans) instead of covalent binding or degradation [13]. But cell wall components of probiotic bacteria such as peptidoglycans and polysaccharides have been proposed to be the most crucial elements responsible for Aflatoxin binding. The main mechanism of action for the majority of the health benefits attributed to probiotic bacteria is perhaps the adequate activation of the gut-associated immune response. It is said that probiotics remove aflatoxin by binding to the bacterial cell wall. For example, Shetty et al. stated that mycotoxin removal is by adhesion to cell wall components, rather than by covalent bindings or metabolism, as non-viable and dead bacteria do not lose their binding ability [14]. Moreover, Hernandez-Mendoza et al. showed that AFB1 binding to the bacterial cell wall involved a physical interaction [15]. However, the mechanism by which aflatoxin binds to the bacterial cell wall is unclear. The binding and interaction of AFB1 molecule to the bacterial cell wall using a computer-generated simulation model was assessed in a study by Yiannikouris et al. The authors examined the interaction between β-D-glucan structures of *Saccharomyces cerevisiae* and AFB1 molecules found that the binding involved a 2-step mechanism process. Firstly, the AFB1 molecule is trapped inside the single helix of the (1-3)-β-D-glucan chain, then the AFB1 molecule is covered by the branched (1-6)-β-D-glucan chain, where it is maintained inside the helix. Hydrogen bonds only account for a small portion (-3.8 kcal/mol) of the docking energy for the binding, therefore finally the authors concluded that Van der Waals interaction plays a major role in the binding of AFB1.

CONCLUSION

Probiotic bacteria have many beneficial health effects, and one of them is their ability to bind aflatoxin. Evidence from *in vitro*, animal studies have supported the potential ability of probiotic bacteria as adsorbent of aflatoxin. The ability of aflatoxin reduction potentials of probiotics bacteria is different depending on the type of the bacteria, the concentrations of the bacteria, and the PH conditions. Even if some kinds of literature are described the mechanism slightly detailed mechanism of which probiotic bacteria bind to aflatoxin is unclear and literature on the mechanism is scarce.

RECOMMENDATION

It is important to study the chemical interactions between the cell wall of probiotic bacteria, and its related components with aflatoxin molecules that could be satisfied to provide further justification of probiotics as adsorbent of aflatoxin. The best way to prevent the aflatoxin prevalence in agricultural products are making suitable conditions of harvesting and storage but if that could be impossible and assuming that consuming toxin foods, it could be better to eat fermented foods (yogurt or dairy drinks) or taking probiotics since they are available as capsules, tablets, packets, or powders.

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