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Factors Influencing Aflatoxin Contamination in Before and After Harvest Peanuts: A Review

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Abstract

Aflatoxin contamination of peanuts has been of worldwide concern since the 1960s. Aflatoxins are fungal secondary metabolites that have been associated with severe toxicological effects to human and animals, which can cause enormous economic loss to producers, handlers, processors and marketers of contaminated peanuts. Aflatoxin contamination of peanuts is unavoidable due to the varied factors in pre-harvest, harvesting, and post-harvest stages of peanuts. The review summarizes the factors influencing aflatoxin contamination in the whole supply chain of peanuts.

Keywords: aflatoxins, influencing factors, peanut, pre-harvest, post-harvest

1. Introduction

Peanut (*Arachis hypogaea* L.) is an important crop in China and other countries in the world due to its nutritional and economic values. About 39.81 million metric tons per year of peanuts are produced in the world, and China and Argentina are the world's largest producer and exporters, respectively (USDA, 2013). In China, peanuts are consumed mainly as whole seeds and pressed oil, which contains 25 to 32% protein and 42 to 52% oil (Woodroof, 1983).

However, peanut is one of the most susceptible host crops to *Aspergillus flavus* resulting in aflatoxin contamination. Aflatoxins have attracted worldwide attention due to their toxicological effects to human and animals. They can cause development defects and immune system suppression, cancer, and even death in severe acute exposure (Shenasi et al., 2002; Proctor et al., 2004; Nakai et al., 2008; Bhat et al., 2010; Michael et al., 2010). *Aspergillus flavus* and *Aspergillus parasiticus* are the major producers of aflatoxins (Richard & Payne, 2003; Klich, 2007; Varga et al., 2011). Aflatoxin contamination in peanuts can occur in the field before harvest, during harvesting, or after harvest, and be affected by many factors. The preharvest factors include peanut cultivars, soil type, species of fungi, climate, weather conditions, agricultural practices, phytoalexin production, water activity and maturity of peanuts; the optimum harvest time and timely drying of peanuts are the main factors during harvesting; the storage and transportation conditions are the main factors resulting in the aflatoxin contamination after harvesting peanuts (Dorner et al., 1989; Cotty & Jaime-Garcia, 2007).

2. Pre-Harvest Factors Influencing Aflatoxin Contamination of Peanuts

2.1 Peanut Cultivars

In the 1980s, many researchers had attempted to find peanut cultivars resistant to *Aspergillus flavus* contamination and aflatoxin formation but failed due to presenting the intricate factors influencing the growth and distribution of the fungus and aflatoxin formation (Blankenship et al., 1985; Azaizeh et al., 1989). In recent years, transgenic technology has been widely used for cultivar improvement. Transgenic peanuts containing the Bt (*Bacillus thuringiensis*) gene had significantly lower levels of aflatoxin than non-Bt peanuts in preliminary analysis of log-transformed data (Ozias-Akins et al., 2002). Guo et al. (2008) identified the resistance-related genes (*iso ara h*3 and LEA 4) in peanut against *Aspergillus parasiticus* infection and subsequent aflatoxin contamination, and then developed a peanut microarray to identify candidate genes that confer resistance to *Aspergillus flavus* infection (Guo et al., 2011). Additionally, cultivar improvement in increasing the resistance of peanut to diseases, can also significantly reduce the incidence of fungal contamination compared to the unimproved varieties (Mutegi et al., 2012).

2.2 Soil Type

It is well known that peanuts can grow in different soil types, such as light sandy soil and heavier soils. Light sandy soil benefits for the rapid proliferation of *Aspergillus flavus*, particularly under dry conditions in the later growth period. On the contrary, heavier soil can reduce the level of aflatoxin contamination in peanut grown because of having a higher water-holding capacity (CAC, 2004; Torres et al., 2014).

2.3 Species of Fungi in Soil

Soil is a reservoir of varied microorganisms including fungi, and peanuts are in direct contact with soil populations of aflatoxigenic fungi (Horn & Pitt, 1997). Common fungal contaminants of peanuts include *Aspergillus*, *Penicillium*, *Rbizopus* and *Fusarium* species (Gachomo et al., 2004; Youssef et al., 2008). Many literatures reported that *Aspergillus flavus* and *Aspergillus parasiticus* are the two closely related species of fungi that invade peanuts and subsequently lead to their contamination with aflatoxins B_1, B_2, G_1 and G_2 (Dorner, 2002; Vaamonde et al., 2003; Mutegi et al., 2012). Presence of other fungi such as *Penicillium* and *Fusarium* species, reduces the aflatoxin production due to competitive inhibition (Horn & Dorner, 1998). Additionally, different morphological types for the same species also affect the aflatoxin contamination of peanuts, such as *Aspergillus flavus*, which has two types, the S- and L-strains. The incidence of *Aspergillus flavus* S-strain has a strong relationship with the peanut contamination with aflatoxin, while L-strain was not positively correlated with the levels of total aflatoxins in peanuts (Mutegi et al., 2012).

2.4 Climate

Marsh and Taylor (1958) reported that aflatoxin contamination was occurred in most growing areas but the highest incidence of aflatoxin was in the warmer, more humid growing regions and followed the same geographical pattern. *Aspergillus flavus* can be isolated from soil in all climatic zones, and it is isolated relatively more frequently in warm temperature zones (latitudes 26-35°) than in tropical or cooler temperature zones. It is quite rare in latitudes above 45° (Manabe & Tsuruta, 1978; Klich, 2002; CAST, 2003). Therefore, the aflatoxin contamination of peanuts is often found in latitudes below 35° (Logrieco & Visconti, 2004).

2.5 Weather Conditions

Sanders and coworkers (1985) found that aflatoxin contamination is not always directly correlated with the incidence of invasion by *Aspergillus flavus*. Cole and coworkers (1985) suggested that after the invasion of aflatoxigenic fungi occurred, growth of the fungi and aflatoxin production could not occur until a natural resistance mechanism broke down as a result of environmental stress (drought and high temperature). Drought and temperature stress are common factors for aflatoxin contamination of peanuts (Cole et al., 1984; Sanders et al., 1993; Craufud et al., 2006). Cole and coworkers (1984) reported that drought stress and soil temperature of 29 ºC for 85-100 days yielded the greatest number of colonized edible grade peanuts and high aflatoxin levels. End of season drought stress and elevated soil temperature are more benefit for promoting aflatoxin contamination (Rachaputi et al., 2002; Bankole et al., 2006). The reason is that drought stress induces a great increase in proline in plants, which can enhance aflatoxin production (Barnett & Naylor, 1966; Payne & Hagler, 1983). Therefore, adequate rainfall can control or reduce aflatoxin production of peanuts. In addition, contamination has been found to be widespread where peanuts are grown under rain-fed conditions compared to those grown under irrigation (Reddy et al., 2003).

2.6 Agricultural Practices

Improper agricultural practices, including crop rotation, tillage, planting date, and irrigation and fertilization, can also increase the incidence of *Aspergillus Flavi* and aflatoxin contamination in peanuts (Torres et al., 2014).

The continued cultivation of peanuts on the same land may result in the high infection of fungi and aflatoxin contamination (Ortiz et al., 2011). Crop rotation may lower the rate of between-season survival of different species/strains, especially if it involves crops that are non-host to *Aspergillus* species (Middleton et al., 1994; Mutegi et al., 2012). However, the effects of crop rotation on aflatoxin contamination depend on the planting environment, for example, in a semi - arid environment, populations of *Aspergillus* may be very high, and crop rotation may have little influence on the fungal activity (CAC, 2004).

In noninoculated, non-insecticide-sprayed areas, dense population of plants or reduced fertilization, appear to have a positive influence on the incidence of contamination by aflatoxin (Anderson et al., 1975).

Insects might play an important role in the aflatoxin contamination of crops since nearly all aflatoxins were found in areas damaged by insects. The insect damage peanut tissue, thereby creating entry portals for the fungus, and then lead to the high aflatoxin production in peanuts (Anderson et al., 1975; Waliyar et al., 2008). Many literatures reported that some insecticides and fungicides can inhibit aflatoxigenic fungi growth and subsequent aflatoxin biosynthesis in field (Dorner et al., 1992; Bowen & Mack, 1993; D'Mello et al., 1998; Lee et al., 2001; Dorner et al., 2003). Bowen and Mack (1993) used the insecticide to treat peanuts during cultivation, and reduced the levels of *Aspergillus flavus* infection and aflatoxin contamination.

In addition, early-sowing in optimum time, rational planting, scientific fertilizing, strong field management were needed in reducing the aflatoxin contamination of peanuts.

2.7 Phytoalexin Production

Phytoalexins are antimicrobial substances synthesized by plants that accumulate rapidly at areas of pathogen infection. Although the chemical nature of the phytoalexins was not determined, it was shown that peanuts produced phytoalexins when challenged by several species of fungi, including *A. flavus*. (Keen, 1975; Ingham et al., 1976; Keen et al., 1976; Aguamah et al., 1981; Wotton & Strange, 1985). It was verified as early as 1972 that the resistance of immature peanut pods to fungi was due to phytoalexins produced in high quantities in response to fungal infection (Vidhyasekaran et al., 1972). As long as peanuts had the capacity for phytoalexin production, they were not contaminated with aflatoxins (Dorner et al., 1989). In immature peanuts, aflatoxin did not form until phytoalexin production ceased in drought stressed plants (Dorner et al., 1989).

Water activity (a_w) of peanut kernels appeared to be the most important factor controlling the capacity of kernels to produce phytoalexins. Peanuts produce sufficient phytoalexins at high a_w (>0.97) to inhibit growth of *Aspergillus flavus* and subsequent aflatoxin contamination. As kernel a_w decreases, as a result of prolonged drought, the capacity of those kernels to produce phytoalexins also decreases and eventually is lost ($a_w<0.95$) (Dorner et al., 1989) .

2.8 Maturity

Preharvest' contamination appears first, and is more concentrated in smaller, immature kernels. Several studies have shown consistently that levels of both *Aspergillus flavus* invasion and aflatoxin contamination are higher in smaller, more immature kernels than in mature kernels (Sanders et al., 1981; Cole et al., 1982; Hill et al., 1983; Cole et al., 1985; Sanders et al., 1985). Immature peanuts lose the capacity to produce phytoalexins faster than that of mature ones, leading to earlier contamination. In addition, the mature peanuts have sustained resistance to aflatoxin contamination well, even after the disappearance of phytoalexin production (Dorner et al., 1989).

3. Factors During Harvesting

Aflatoxin contamination can occur if peanuts are not timely harvested, or mechanically harvested (Heathcote & Hibbert, 1978; Cole et al., 1995; Torres et al., 2014). The harvest time depends on the maturity of peanuts and weather conditions during harvesting. Overmature or immature pods at harvest can all lead to the high contamination of aflatoxins in the final product. Harvesting in the dry weather, aflatoxin contamination does not occur but often present in very humid weather (Kabak et al., 2006). Mechanical damage to kernels during digging and threshing peanuts makes them much more vulnerable to the invasion of molds and subsequent aflatoxin contamination (Heathcote & Hibbert, 1978).

4. Post-Harvest Factors Influencing Aflatoxin Contamination of Peanuts

Generally, kernel moisture contents of 10% or higher post-harvest peanuts are prone to producing aflatoxins. Timely drying and maintaining at safe moisture level can effective control aflatoxin contamination of peanuts after harvest (Torres et al., 2014). Diener and Davis (1970) found that aflatoxin production can be prevented by rapidly drying to or below a a_w of 0.83 for post-harvest peanuts. Before-storage segregating to remove contaminated peanuts is the most effective way to reduce aflatoxin production (Cole et al., 1995; Dorner, 2008).

To prevent an increase in aflatoxin contamination occurring during storage and transportation, it is important to control the moisture content, the temperature in the environment, and the hygienic conditions (Dickens, 1977; CAC, 2004). Inappropriate kernel moisture during storage can proceed from leaky roofs, condensation because of improper ventilation in the warehouse, high-moisture foreign material associated with stored peanuts, and high-moisture peanuts initially going into storage (Davidson et al., 1982). Therefore, the storage and transportation conditions are the most important factors in controlling aflatoxin contamination of peanuts.

5. Conclusion

Aflatoxin contamination of peanuts is a worldwide problem, which poses a risk to human health and has been identified as a major constraint to trade in the world. It is not avoided dues to the effects of interactions among many factors. These factors presents in pre-harvest, during harvesting, and post-harvest processes, especially pre-harvest management and storage conditions of post-harvest are the main factors. These factors can vary considerably from one location to another, and between seasons in the same location. Some environments may be particularly favorable to fungal infection and subsequent aflatoxin contamination of peanuts, and in these circumstances it would be necessary to consider whether or not the peanuts should be grown in such areas.

According to the factors influencing aflatoxin contamination of peanuts before and after harvest stages, the corresponding strategies to prevent the growth of aflatoxigenic fungi as well as to inhibit aflatoxin biosynthesis have been studied. For these strategies, only one strategy can not completely prevent and control aflatoxin contamination of peanuts, it is necessary to use two or more methods in the whole supply chain of peanuts based on the guide of total quality management.

Since aflatoxin contamination of penauts can not be prevented completely, it is necessary to develop new methods for detoxification in process. The research in detoxification of aflatoxins in peanuts is till a hotspot, and physical, chemical, and biological methods have been used to remove or degrade aflatoxins in foods. Presently, there is no one method to effective degrade aflatoxins and maintain the quality of treated products. In addition, aflatoxin risk forecasting based on the influencing factors is also a hotspot in the future study, which can assist in preventing and minimizing pre-harvest contamination and especially in optimizing harvest post-harvest management.

Conflict of Interest

The authors declare that there are no conflicts of interest.

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