Minimizing Aflatoxin Production in Grains in the Tropics

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Abstract

Aflatoxins are secondary metabolites of the fungi *Aspergillus flavus* and *A. parasiticus* produced in agricultural commodities. Acute diseases in humans and animals, as well as chronic diseases such as primary liver cancer, have been linked to aflatoxin consumption. International Agency for Research on Cancer placed aflatoxin B_1 on their list of human carcinogens. Aflatoxin contamination has posed serious problems in commerce and international trade but information about regulations on aflatoxins in some 60 countries could be found only for 17 countries from Asia and Africa.

The incidence of aflatoxins has been reported in over 50 countries in the world especially in tropical and subtropical countries of Asia and Africa. Various foods and feeds are contaminated with aflatoxins. The high-risk commodities are maize, peanuts, parboiled rice, cottonseed, copra and various other nut species. Aflatoxins occur before and after harvest, but particularly when harvesting takes places under high humidity weather conditions followed by improper storage of insufficiently dried commodities.

Recognition of the problems due to aflatoxin is the first step to implement appropriate programs for the prevention and control, including the flow of aflatoxin-contaminated commodities, prevention of aflatoxin formation and detoxification or decontamination. Besides, routine surveillance, regulatory measures, information, education and communication activities are required. Development of postharvest practices, such as drying of the produce to safe moisture levels, improvement of storage structures and practices including storage under modified atmosphere, appear to be more practical solutions.

Introduction

Aflatoxins are secondary fungal metabolites. They are produced primarily by some strains of *Aspergillus flavus* and most strains of *A. parasiticus* and *A. nomius* (Kurzman *et al.*, 1987). There are four major aflatoxins, B_1, B_2, G_1 and G_2 plus two additional metabolic products, M_1 and M_2, that are of significance as direct contaminants of foods and feeds.

Most foods and feeds are susceptible to fungal invasion during some stage of production, processing, transport and storage. Aflatoxins may be produced when fungal growth occurs. However, the presence of the fungi in or on a food product does not automatically mean the presence of aflatoxins but, rather, that a potential for aflatoxin contamination exists. On the other hand, the absence of the fungi does no guarantee that the commodity is free from aflatoxins.

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Occurrence

Aflatoxins can be found in the field prior to harvest and contamination can increase during postharvest activities if crop drying is delayed and during storage of the crop, if the water activity is allowed to exceed the critical value for mold growth. Fungal growth and aflatoxin contamination are the consequence of an interaction among the fungus, the host, and the environment. The appropriate combination of these factors determines the infestation and colonization of the fungi, and the amount of aflatoxins produced.

Aflatoxins have been reported from over 50 countries in the world. The African and Asian countries from which aflatoxins have been reported include Bangladesh, Bhutan, The People's Republic of China, Egypt, Ethiopia, Gambia, Ghana, Hong Kong, India, Indonesia, Iran, Iraq, Japan, Kenya, Republic of Korea, Malaysia, Mozambique, Nepal, Nigeria, Pakistan, The Philippines, Senegal, Singapore, Sri Lanka, Sudan, Swaziland, Taiwan, Tanzania, Thailand, Turkey, Uganda, Vietnam, Zambia and Zimbabwe (FAO, 1990 a,b; ICRISAT, 1989).

Various foods and feeds contaminated with aflatoxins are listed in Table 1. Among these, high-risk commodities for aflatoxin are maize, peanuts, parboiled rice, cottonseed, copra and various other nut species (Jelinek *et al.*, 1989).

Table 1 Occurrence of aflatoxins in foods and feeds

Cereal grains	Maize, rice, wheat, sorghum
Oilseeds	Groundnut, cottonseed, coconut, soybean, sunflower
Vegetable oils	Groundnut oil, coconut oil, cottonseed oil, olive oil
Pulses	Various beans (Africa)
Root crops	Cassava, sweet potato
Tree nuts	Pistachio nuts, almonds, walnuts, peanuts
Vegetable products	Coffee, cocoa, figs, peaches, spices
Animal products	Milk, cheese, fish, shrimps
Fermented products	Alcohol, beer, sauces, wines

Health problems

Of all the mycotoxins presently known, the aflatoxins have been a cause for major public health concern because of their widespread occurrence in several dietary staples (peanut, maize and milk) and their potential as human carcinogens. In 1988, the International Agency for Research on Cancer (IARC) placed aflatoxin B_1 on their list of human carcinogens.

The aflatoxins caused liver damage, decreased milk and egg production, and suppression of immunity in animals consuming low dietary concentrations. Generally, young animals of any species are more susceptible than older animals. Clinical signs include gastrointestinal dysfunction, reduced reproductivity, decreased feed utilization and efficiency by exposure to aflatoxin metabolites secreted in the milk.

Aflatoxin effects in animals vary with the dose, length of exposure, species, breed, and diet or nutritional status. The toxins may be lethal when consumed in large doses. Sublethal doses lead to a chronic toxicity, and low levels of chronic exposure can result in cancer and primarily liver cancer in some animal species. The affected animals are birds and poultry (duckling, turkey, pheasant chick, mature chicken and quails), mammals (young pig, pregnant pig, dog, cat, mature cattle, sheep and fishes) (Bullerman, 1979, 1981, 1986).

Humans are exposed to aflatoxins by consuming foods contaminated with products of fungal growth. Aflatoxins have been linked with the occurrence of various chronic diseases in humans. However, the major concern has focused on the possible contribution of aflatoxins to the development of liver cell cancer. Surveys of human population conducted in Africa and Asia have revealed a positive association between estimated exposure to aflatoxins and incidence of liver cell cancer. Primary liver cancer (PLC) is one of the leading causes of cancer mortality in Asia and Africa. Studies carried out in The People's Republic of China, Thailand, the Philippines, Kenya, Swaziland, Mozambique and Uganda, provide evidence for the involvement of aflatoxin consumption in the cause of PLC. A major variable in many of these studies has been the role of chronic hepatitis B virus infection which may inherently predispose individuals to the cancer-inducing effects of aflatoxin (Groupman *et al.*, 1988).

Economic impact

Economic losses due to aflatoxins occur at various levels, including lower earnings from reduced export, costs incurred in control, surveillance, preventive and training measures, as well as cost of detoxification. Subsidies for producers (farmers) cover outright food or feed losses, reduced prices for selling commodities, and reduced productivity of livestock leading to lower income. The middlemen experience losses due to product refusal, lowered prices, loss of reputation, and losses due to litigation and compensation to be paid. The consumers incur costs due to impaired health and productive capacity, and possibly medical and veterinary costs (FAO, 1977).

International regulatory standards have critical economic implications. Since 1973, aflatoxins in finished products of commercial feed manufacturers have been controlled by legislation in the European Community (EC), with maximum possible levels of aflatoxins prescribed. The maximum levels of aflatoxin B_1, in unfinished feed may not exceed 0.05, 0.03 and 0.01mg/kg, the actual level depending on the animal to be fed and the nature of intended produce i.e. milk, eggs, or meat. To increase the level of control, in 1985, the regulations were extended to raw materials such as maize, cottonseed, copra. If the materials contain a level above 0.2mg/kg of aflatoxin, the importer is compelled to have the goods returned to their origin, destroyed, or sold outside the EC (Bhat, 1991).

Obviously, many developing countries where aflatoxin problems may be severe had no aflatoxin regulations. Some Asian countries (Table 2) and African countries (Table 3) were reported to have regulations, in particular for aflatoxin B_1.

Very few countries have enacted a legislation for the control of aflatoxins in animal feeds in Asia and Africa. The downward trend of the EC limits for aflatoxin B_1 in animal foodstuffs will lead to increasing problems for the Asian and African countries.

Table 2 Maximum tolerance levels for aflatoxins in foodstuffs in Asian countries

Country	Commodity	Tolerance ($\mu g/kg$)	
		B_1	$B_1+B_2+G_1+G_2$
People's Republic of China	Maize and maize products	20	–
	Peanut and peanut products	20	–
	Peanut oil	20	–
	Rice, other edible oils	10	–
	Other cereals, legumes, fermented food	5	–
	Infant milk substitutes	Not detectable	
Taiwan	Cereals (rice, maize, peanuts, sorghum, legumes, wheat, barley, oats, etc.)	50	–
Hong Kong	Peanut and peanut products	20	(including aflatoxins M_1, M_2, P_1, and aflatoxicol)
India	All foods	30	
Japan	All foods	10	
Jordan	Almonds, cereals, maize, peanuts, pistachio nuts, rice	15	30
Malaysia	All foods		35
Nepal	Cereal grains, legumes	30	
Philippines	Coconut, peanut products	20	
Singapore	(export)	Zero	Zero
Thailand	All foods		20
Vietnam	All foods		
	Peanuts	Zero	–

Source: Van Egmond (1989), FAO (1990), Stoloff *et al.* (1991).

Control and management

Various agronomic approaches, such as proper crop water management, use of pesticides, soil amendments, crop rotation practices, control of insect pests, appropriate harvesting practices, sowing in the correct season and early harvesting have been advocated. Use of resistant cultivars of peanut and maize seem to show initial promise but has not yet been widely accepted as a safe means of preventing aflatoxin contamination.

Sophisticated innovative solutions based on genetic engineering for aflatoxin prevention have been suggested. One is to alter the fungus to make it non-toxic and another is to alter plants to make them more resistant to the fungus. However these techniques are still in preliminary stages and practical application requires time.

A variety of natural plant extracts (such as those from herbs and spices) and industrial chemicals (such as volatile fatty acids) have been reported to be effective in minimizing aflatoxin contamination. However, widespread use of these substances at the field level and

Table 3 Maximum tolerance levels for aflatoxins in foodstuffs in African countries

Country	Commodity	Tolerance ($\mu g/kg$)	
		B_1	$B_1+B_2+G_1+G_2$
Malawi	All foods		35
Mauritius	Peanuts	5	15
	Other products	5	10
		6	(including aflatoxins M_1, and M_2)
Nigeria	Infant foods	Zero	–
	All foods	20	–
South Africa	All foods	5	10
Zimbabwe	Peanuts, maize, sorghum, peanut butter, cereals, flour and bread	5	20

Source: Van Egmond (1989), FAO (1990), Stoloff et al. (1991).

their efficacy for adoption by farmers need to be studied and confirmed.

Since aflatoxin contamination can not be completely prevented, detoxification of commodities contaminated with aflatoxins appears to be the ideal approach. Segregation of aflatoxin-contaminated peanuts by visual or mechanical method is a practical means. Detoxification of aflatoxin-contaminated peanuts, oil seed cakes and maize by ammonia and formaldehyde is considered to be practical and effective but the method is useful only for animal feeds (Bhat, 1990). Another way of minimizing aflatoxin toxicity is to use dietary supplements such as hydrated sodium calcium aluminosilicate or various vitamins in the feed to prevent the harmful affects of aflatoxins (Kubena *et al.*, 1990; Johri *et al.*, 1990).

Among the measures aimed at minimizing aflatoxin contamination, more practical approaches that are successfully adopted in developing countries are as follows:

1) improved postharvest practices; 2) drying the produce to safe moisture levels; 3) scattering of small silos throughout the production sites; 4) storage under modified atmosphere and/or hermetic storage; 5) segregation of contaminated peanuts; 6) use of field aflatoxin detection kit; 7) regulations relating to food, animal feed ingredients; 8) education and extension activities on prevention of aflatoxin contamination.

Recognition of the problems due to aflatoxins is the first step to implement appropriate programs for their prevention and control. These include not only the prevention of aflatoxin formation in agricultural commodities but possibly also their removal through detoxification or decontamination. In addition, routine surveillance, regulatory measures to control the flow of aflatoxin-contaminated commodities in national and international trade, as well as information, education, and communication activities are required. Each of these approaches forms a part of overall strategies to minimize the problems of aflatoxin contamination.

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