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Review

# Review on pre- and post-harvest management of peanuts to minimize aflatoxin contamination

A.M. Torres [a,b,*], G.G. Barros [a,b], S.A. Palacios [a], S.N. Chulze [a,b], P. Battilani [c]

[a] Departamento de Microbiología e Inmunología, Facultad de Ciencias Exactas, Físico — Químicas y Naturales, Universidad Nacional de Río Cuarto, Ruta 36, Km 601 (5800), Río Cuarto, Córdoba, Argentina
[b] Members of the Research Carrier CONICET, Argentina
[c] Institute of Entomology and Plant Pathology, Faculty of Agriculture, Università Cattolica del Sacro Cuore, via Emilia Parmense 84, I-29122 Piacenza, Italy

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ABSTRACT

Peanut or groundnut (*Arachis hypogaea* L.) is cultivated in the tropical and warm temperate regions of the world. Its production reaches approximately 39.9 million metric tons per year. The major producers/exporters of peanuts are the United States, Argentina, Sudan, Senegal, and Brazil. One of the major problems in peanut production worldwide is the contamination with *Aspergillus* section *Flavi* and aflatoxins, being these mycotoxins of great concern due to their toxicological effects to human and animals. Different strategies both at pre-harvest and post-harvest stages have been applied to reduce the entry of aflatoxins to the food and feed chains. Nowadays, no single strategy is enough to solve this problem. An integrate management from the field until food or feed processing is necessary to reduce the impact of aflatoxins. This review summarizes the advance in reducing the impact of aflatoxins in different countries where peanuts are cultivated.



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* Corresponding author at: Departamento de Microbiología e Inmunología, Facultad de Ciencias Exactas, Físico — Químicas y Naturales, Universidad Nacional de Río Cuarto, Ruta 36, Km 601 (5800), Río Cuarto, Córdoba, Argentina. Tel.: +54 3584673429; fax: +54 3584676231.
*E-mail addresses:* atorres@exa.unrc.edu.ar (A.M. Torres), gbarros@exa.unrc.edu.ar (G.G. Barros), spalacios@exa.unrc.edu.ar (S.A. Palacios), schulze@exa.unrc.edu.ar (S.N. Chulze), paola.battilani@unicatt.it (P. Battilani).

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## 1. Introduction

The cultivated peanut or groundnut (*Arachis hypogaea* L.), originated in South America, is now grown throughout the tropical and warm temperate regions of the world. World peanut production totals approximately 39.9 million metric tons per year, China being the world's largest producer, followed by India and the United States (USDA, 2013). The major exporters of peanuts are Argentina, the United States, Sudan, Senegal, and Brazil. These five countries account for 71% of total world exports. Countries such as India, Vietnam and several African countries periodically enter the world market depending upon their crop quality and world market demand. The major peanut importers are the European Union, Canada and Japan. These three areas account for 78% of the world's imports (Cámara Argentina del Maní, 2013).

All parts of the peanut plant can be used. The peanut, grown primarily for human consumption, has several uses as whole seeds or processed seeds to produce primarily peanut butter and oil; in fact, the seed contains 25 to 32% protein (average of 25% digestible protein) and 42 to 52% oil (Woodroof, 1983).

One of the major problems in peanut production worldwide is aflatoxin (AFs) contamination, which is of great concern as these toxins have toxicological effects, which are dose-dependent; at high doses they are lethal if consumed, causing liver, myocardial and kidney tissue damage. Aflatoxins cause chronic toxicity, e.g. liver cirrhosis, and they are potent human hepatocellular carcinogens at sub-lethal or at low-level exposure doses, respectively (Wild & Turner, 2002). The International Agency for Research on Cancer (IARC) has evaluated AFB1 as a Group 1 carcinogen producing liver cancer in humans (IARC, 1993).

Aflatoxins are produced by several species in *Aspergillus* section *Flavi* (Varga, Frisvad, & Samson, 2011). However, as was reported by Richard and Payne (2003), only two of these species, *Aspergillus flavus* and *Aspergillus parasiticus*, are important in the colonization and contamination of agricultural crops, *A. flavus* being the major producer of aflatoxin. The fungus is isolated from a wide range of climate zones, but is more frequently found between latitudes 16° and 35° in warm climate zones and is not common above 45° latitudes (Klich, 2007). Although *A. flavus* appears to be the dominant species of the section invading peanut seeds, *A. parasiticus* is more frequently found in peanuts than in corn and cottonseed (Asis, Barrionuevo, Giorda, Nores, & Aldao, 2005; Barros, Chiotta, Torres, & Chulze, 2006; Barros, Torres, Palacio, & Chulze, 2003; Horn, 2005; Horn & Dorner, 1998) and can also contribute to aflatoxin contamination in a varying degree (Horn, Dorner, Greene, Blankenship, & Cole, 1994).

Because of human health concerns, many countries have set maximum levels of aflatoxin allowed in food and feed (van Egmond, Schothorst, & Jonker, 2007). The maximum tolerable levels for aflatoxin $B_1$ in food have a range from 1 to 20 μg/kg, and 2 μg/kg is a limit in force in at least 29 countries, most of these countries belong to the EU (EC, 2006, 2010). Another major limit is 5 μg/kg, followed by 21 countries, spread over Africa, Asia/Oceania, Latin America and Europe. The USA Food and Drug Administration permits maximum aflatoxin levels of 20 ppb in peanut products destined for human consumption; the European Union allows 4 ppb of total aflatoxin and 2 ppb on aflatoxin $B_1$. The EU regulation standards on aflatoxins have a strong potential impact on nations attempting to export foods that are susceptible to aflatoxin contamination into the EU (Wu, 2008). In a study carried out in 2004, Wu estimated a $ 450 million annual loss, mainly charged to the US, China, Argentina, and sub-Saharan African peanut markets, if the EU aflatoxin standard were adopted worldwide (Wu, 2004).

The relevance of safe peanut production, with low aflatoxin content, is therefore mandatory for all producer countries and prevention of seed contamination during crop production is the suitable approach. Therefore, the aim of this review is to present recent advances in methodologies to prevent aflatoxin contamination in peanuts, recommended by different guidelines and code of practices, focusing mainly on pre-harvest strategies.

## 2. *Aspergillus* section *Flavi* in peanuts

Fungal growth and aflatoxin contamination are the consequences of interactions among the host, the fungus and the environment. The appropriate combination of these factors determines the infection and colonization of the substrate, and the type and amount of aflatoxin produced.

### *2.1. Crop phenology*

Peanut development has been described by Boote (1982) relative to visually identifiable stages, shared between vegetative (V) and reproductive (R), each further subdivided into distinct stages. The V stage is determined by counting the number of developed nodes on the main stem, beginning with the cotyledonary node as zero. The R stages are R1 (beginning bloom), R2 (beginning peg), R3 (beginning pod), R4 (full pod), R5 (beginning seed), R6 (full seed), R7 (beginning maturity), and R8 (harvest maturity). An alternative description is the BBCH scale (edited by the Federal Biological Research Centre for Agriculture and Forestry). The duration of different stage is depending on variety, seasonal conditions and location (Fig. 1).

After aerial fertilization of the peanut flower and gynophore prolongation into the soil, peanuts grow underground. Generally, it is accepted that the peanut plant begins its reproductive stage with the onset of blooms (R1), about 30–45 days after planting. From about 60 days after planting, pods are formed and filled (R3 to R6). Pod weight can increase at a rate of up to 100 kg per hectare per day for the 75–150 days after emergence. Harvest maturity (R8) is reached at 110–170 days (16–24 weeks), and it is also depending on variety, planting time, seasonal conditions and location. The main factor affecting the time to harvest is temperature.

### *2.2. Infection cycle of Aspergillus section Flavi on peanuts*

Soil serves as a reservoir for primary inoculum of *A. flavus* and *A. parasiticus*, and peanut pods are in direct contact with soil populations of aflatoxigenic fungi (Horn & Pitt, 1997). The disease cycle and epidemiology of *A. flavus* were recently reviewed by Amaike and Keller (2011). *A. flavus* lives in soil as conidia or sclerotia and in plant tissues as mycelia. Sclerotia survive in the soil under severe environmental conditions and produce conidia and possibly ascospores (Horn, Moore, & Carbone, 2009), leading to a population increase under hot and drought weather conditions (Payne, 1998; Wicklow, Wilson, & Nelsen, 1993). Sclerotia germinate as mycelium, which then forms conidiophores and conidia.