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Kinetics of aflatoxin degradation during peanut roasting

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ABSTRACT

This study investigated aflatoxin degradation during peanut roasting. First, peanuts contaminated with three initial aflatoxin concentrations (35, 332 and 695 μg/kg) were roasted at 180 °C for up to 20 min. The percentage of aflatoxin degradation after 20 min were 55, 64 and 81% for peanuts contaminated with aflatoxin at 35, 332 and 695 μg/kg, respectively. This difference was statistically significant ($p < 0.05$), showing that initial concentration influences aflatoxin reduction. Thereafter, peanut samples contaminated with an initial aflatoxin concentration of 85 μg/kg were roasted at 160, 180 and 200 °C for 5, 10, 15, 20 and 25 min, then residual concentrations of aflatoxin were determined. Roasting at 160, 180 and 200 °C resulted in an aflatoxin reduction of 61.6, 83.6 and 89.7%, respectively. This study has provided quantitative data reinforcing the fact that roasting alone is not enough to control aflatoxins in peanuts.

1. Introduction

Aflatoxins are secondary metabolites produced principally by *Aspergillus flavus*, *A. parasiticus* and *A. nomius* (Pitt & Hocking, 2009). These mycotoxins are the most potent liver carcinogens known and are currently classified by the International Agency for Research on Cancer as Group 1 carcinogens, i.e. known human carcinogens (IARC, 2002). Moreover, aflatoxins have acute, chronic, genotoxic and immunosuppressive properties (ICMSF, 2002; Williams et al., 2004).

Aflatoxins have been found in a wide range of food commodities, including cereals (EFSA, 2013), dairy products (Campagnollo et al., 2016) spices (Hammami et al., 2014) and even in meat and eggs (Abd-Elghany & Sallam, 2015; Herzallah, 2009; Oliveira et al., 2000). However, oilseeds including peanuts (Martins et al., 2017; Mutegi, Ngugi, Hendriks, & Jones, 2009; Mutegi et al., 2013; Oliveira, Gonçalves, Rosim, & Fernandes, 2009), pistachios (Georgiadou, Dimou, & Yanniotis, 2012; Molyneux, Mahoney, Kim, & Campbell, 2007; Set & Erkmen, 2010), hazelnuts (Baltaci, Ilysaglu, & Cavrar, 2012; Ozay, Seyhan, Pembeci, Saklar, & Yilmaz, 2008), walnuts (Molyneux et al., 2007), cocoa (Copetti, Iamanaka, Pereira, Fungaro, & Taniwaki, 2011; Turcotte, Scott, & Tague, 2013), almonds (Gürses, 2006; Molyneux et al., 2007), and sesame (Hosseininia, Vahabzadeh, Rashedinia, Riahi-Zanjani, & Karimi, 2014; Kollia, Tsourouflis, & Markaki, 2016) are more likely to be highly contaminated. Peanuts are one of the most susceptible crops because peanut kernels can be invaded by *A. flavus* or *A. parasiticus* in soil (Horn, Greene, & Dorner, 1995). After fungal invasion, aflatoxin can formed in peanuts before harvest, during drying and during storage under poor conditions (Horn et al., 1995; Pettit & Taber, 1968; Pitt, Taniwaki, & Cole, 2012).

Peanuts are therefore an important source of aflatoxin in the human diet (Mutegi et al., 2009, 2013; Oliveira et al., 2009). Various approaches have been studied to control the contamination of peanuts by aflatoxins (Pitt et al., 2012). However, for control to be effective, quantitative data on the effects of processing are needed to assist in effective management of aflatoxins. Aflatoxin degradation has been reported by microwaves (Luter, Wyslouzil, & Kashyap, 1982; Mobeen, Aftab, Asif, & Zuzzer, 2011), heating in oil (Lee, Cucullu, Franz, & Pons, 1969) and roasting (Arzandeh & Jinap, 2011; Ogunsanwo, Faboya, Idowu, Lawal, & Bankole, 2004). However, the roasting temperatures studied by these authors were different from those commercial roasting conditions in Brazil and other countries that usually are from 160 to 200 °C. Additionally, Ogunsanwo et al. (2004) and Arzandeh and Jinap (2011) did not focus on the analysis of the degradation kinetics of aflatoxins. Therefore, the aims of this study were to investigate the influence of initial aflatoxin concentration on aflatoxin degradation in raw peanuts, evaluate the aflatoxin degradation kinetics during peanut roasting and to evaluate the effect of roasting time and temperature on peanut colour.

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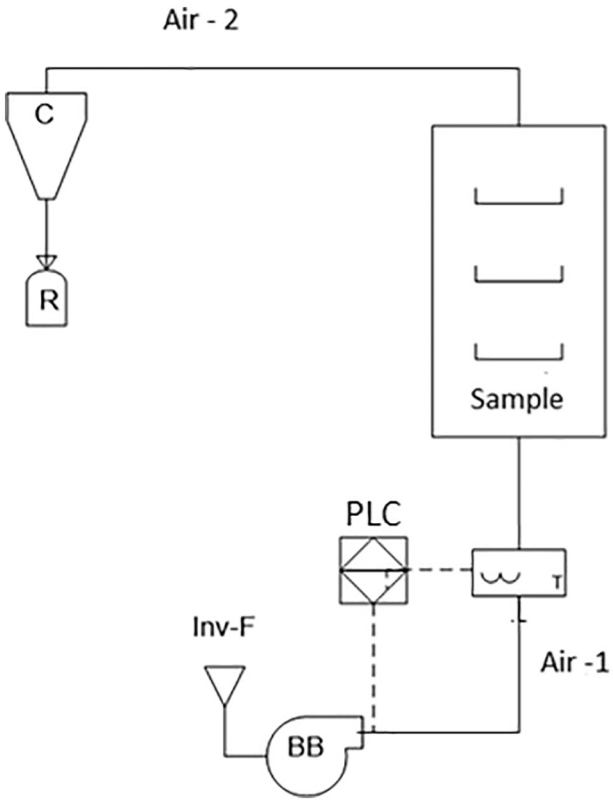

Fig. 1. Spouted bed roaster equipment.The figure shows the air dryer scheme set for roasting peanuts. The sample was placed in the dryer bed (ϕ 104, 1 mm) on a perforated screen. The fan air speed is controlled by a frequency inverter (Inv-F). The air velocity, provided by centrifugal fan (BB), was previously set with the amount of peanut sample (100 g) in order to establish a spouted bed, without dragging off the sample to the cyclone (C), which directs possible entrained particles into the container (R). A proportional control strategy tuned through a PLC controller maintained the drying temperature in the set point values. Air-1 represents cold air before passing through the resistor, and Air-2 represents the warm air after passing through the sample.

2. Material and methods

2.1. Peanut samples

Approximately 20 kg of raw shelled peanuts with intact skins were obtained directly from a peanut cooperative in São Paulo State, Brazil. The nuts were surface disinfected and plated on Dichloran 18% Glycerol agar (Pitt & Hocking, 2009) to assess infection by species from *Aspergillus* section *Flavi*. After five days at 25 °C, 100% of the fifty nuts examined were infected, so this batch provided samples naturally contaminated with aflatoxins.

2.2. Roasting conditions

Peanut samples (100 g) were roasted in a vertical spouted bed roaster (104 mm diameter, 590 mm height, 20 mm screen, 45°) (Fig. 1), designed in the Process Engineering Laboratory at the Institute of Food Technology.

2.3. Influence of initial concentration on aflatoxin degradation

A first study was conducted to determine whether initial concentration of aflatoxin influenced its degradation. The water activity of peanuts (10 kg) were increased to 0.9 by addition of 10 mL/g of sterile water and incubated at 25 °C. In order to obtain samples with different initial aflatoxin concentrations, subsamples were removed over several days and dried to 0.5 water activity in an incubator at 55 °C for 10 h. After skins were removed, peanuts were homogenized and portions (100 g) roasted at 180 °C for 5, 10, 15 and 20 min in duplicate.

2.4. Kinetic of aflatoxin degradation in peanuts during roasting as influenced by temperature

Samples (100 g) were roasted for 5, 10, 15, 20 and 25 min at 160, 180 and 200 °C. The roaster was preheated until the roasting temperature (160, 180 or 200 °C) was achieved and after the roasting time the heater was turned off and air passed through each sample to accelerate cooling. The temperature and time values used were defined according to the range used by Brazilian industries for roasted peanut production. The roasted peanut samples were ground using a laboratory mill (Model A11, IKA, Staufen, Germany) for colour and aflatoxin analyses. Each time and temperature study was replicated, and means and standard deviations calculated.

The aflatoxin degradation kinetic parameters were determined by fitting the Weibull model to the data as shown in Eq. (1) (Mafart, Couvert, Gaillard, & Leguerinel, 2002):

$$\log_{10}\frac{C}{C_0} = -\left(\frac{t}{\delta}\right)^p \quad (1)$$

where C_0 and C represent the initial and final concentrations of aflatoxin (μg/kg), t the roasting time (min), δ treatment time for the first decimal reduction, and p represents the shape parameter.

2.5. Aflatoxin analysis

Aflatoxin analyses were carried out according to Stroka, Anklam, Jorissen, and Gilbert (2000) with modifications, as follows.

2.5.1. Clean-up

Twenty-five grams of ground peanuts were added to 2.5 g of NaCl and extracted with 100 mL of methanol: water (8:2, v/v) for 30 min using a horizontal shaker (New Brunswick Scientific Company, New Brunswick, NJ, USA). After filtration through quantitative filter paper (Nalgon, Brazil), and a glass microfiber filter (Vicam, Milford, MA, USA), filtrate (4 mL) was diluted in phosphate buffered saline (60 mL; pH 7.0) and applied to an immunoaffinity column (Aflatest WB, Vicam) at a flow rate of 2–3 mL/min. The column was then washed with 30 mL of distilled water and aflatoxins eluted with methanol (1250 μL) followed by Milli Q water (1750 μL).

2.5.2. Chromatographic conditions

The HPLC system (Model 1260 Infinity, Agilent, Santa Clara, CA, USA) was used with fluorescence detection (362 nm excitation and 455 nm emission), C18 column, and an isocratic and reverse phase system, associated with a Kobracell electrochemical reactor (R-Biopharm, Darmstadt, Germany) connected to a current of 100 μA for post-column derivatization of aflatoxins B_1 and G_1. The mobile phase was water:acetonitrile:methanol (6:2:3, v/v/v), with potassium bromide (119 mg/L and nitric acid (4 M, 350 μL) at a flow rate of 1 mL/min. The injection volume was 20 μL and the limit of detection (LOD) and limit of quantification (LOQ) were 0.05 and 0.17 μg/kg respectively. Aflatoxin standards were obtained from Sigma-Aldrich (St Louis, MO, USA). Each 100 g peanut sample was analyzed as a single lot.

2.6. Colour analysis

Samples were ground and the colour reflectance values (CIELAB L*) were measured in duplicate at ambient temperature using a Konica Minolta CM-5 spectrophotometer (Konica Minolta, Chiyoda, Japan). A reflectance specular method was used with a 3 cm area view, illuminant D65 and 10° standard observer angle (Smith, Perry, Marshall, Yousef, & Barringer, 2014). Two samples of roasted peanuts were purchased in the market for comparison with colours of the peanuts roasted in this work. Colour values were checked for significant