International Journal of Food Microbiology 251 (2017) 24–32

Contents lists available at ScienceDirect

International Journal of Food Microbiology

journal homepage: www.elsevier.com/locate/ijfoodmicro

Mycotoxin risk assessment for consumers of groundnut in domestic markets in Nigeria

Oluwawapelumi A. Oyedele [a], Chibundu N. Ezekiel [a,b,*], Michael Sulyok [b], Modupeade C. Adetunji [c], Benedikt Warth [b,d], Olusegun O. Atanda [c], Rudolf Krska [b]

[a] Department of Microbiology, Babcock University, Ilishan Remo, Ogun State, Nigeria
[b] Center for Analytical Chemistry, Department of Agrobiotechnology (IFA-Tulln), University of Natural Resources and Life Sciences Vienna (BOKU), Konrad Lorenzstr. 20, A-3430 Tulln, Austria
[c] Department of Biological Sciences, McPherson University, Seriki Sotayo, Ogun State, Nigeria
[d] Department of Food Chemistry and Toxicology, Faculty of Chemistry, University of Vienna, Waehringerstr. 38, 1090 Vienna, Austria

ARTICLE INFO

Article history:
Received 23 September 2016
Received in revised form 2 March 2017
Accepted 27 March 2017
Available online 28 March 2017

Keywords:
Aflatoxin
Consumer safety
Fungi
Groundnut
Mycotoxins
Trade
Risk assessment

ABSTRACT

The fungal and multi-mycotoxin profiles of groundnuts sold in domestic markets in Nigeria as well as the associated risk to consumers were assessed in the present study. Four hundred fungal isolates representing mainly *Aspergillus* [58.6%: *Aspergillus* section *Flavi* (37.1%) and *A. niger*-clade (21.5%)], *Penicillium* (40.9%) and *Fusarium* (0.5%) were isolated from 82 (97.6%, $n = 84$) groundnut samples collected from four agro-ecological zones (AEZs) of Nigeria. The incidence of aflatoxin-producing *A. flavus* isolates (71%) was significantly ($p < 0.05$) higher in the groundnuts than that of the non-aflatoxigenic isolates (29%). Fifty-four fungal metabolites [including aflatoxins (AFB_1, AFB_2, AFG_1, AFG_2 and AFM_1), beauvericin (BEAU), cyclopiazonic acid (CPA), moniliformin, nivalenol and ochratoxin A] and four bacterial metabolites were detected in the groundnuts by liquid chromatography tandem mass spectrometry. Aflatoxins (39%; max: 2076 μg/kg; mean: 216 μg/kg) were detected in more samples than any other mycotoxin. About 25, 23 and 14% of the samples respectively were above the 2 μg/kg AFB_1, 4 and 20 μg/kg total aflatoxin limits of the European Union and US FDA respectively. The mean margins of exposure of AFB_1 and total aflatoxins for adult consumers were 1665 and 908, respectively, while mean estimated daily intake values for infants, children and adults were <0.1% for BEAU and 4% for CPA. Consumers of mycotoxin contaminated groundnuts in Nigeria may therefore be at a risk of liver cancer in addition to other combinatory effects of mycotoxin/metabolite cocktails. There is need for increased targeted interventions in the groundnut value chain in Nigeria for public health benefits.

1. Introduction

Groundnut forms a major part of the diet of many Nigerians. It is also one of the most important oil seed crops with high economic potential and usefulness in animal and human nutrition worldwide. Groundnut offers a rich source of protein, fat, minerals and vitamins in the diet (Bankole et al., 2005). Nigeria ranks third among the global leading producers of groundnut and produced 3.07 million metric tonnes in 2012 (FAOSTAT, 2014). About one-third of Nigeria's groundnut production is consumed directly as food while the other two-thirds are used for making oil for domestic consumption and export, meat and confectionary items. The abundant protein-rich haulms serve as a feed ingredient (Ashley, 1993). In spite of the quantity of groundnut produced in Nigeria, the groundnut export trade is far less significant than other commonly consumed crops owing to several factors including microbial infestation and toxin accumulation. Consequently, large amounts of groundnut and groundnut products (e.g. oil) are concentrated in the domestic markets targeted for household consumption and local feed industry sourcing.

Pre-and post-harvest colonization of staples by fungi leads to mycotoxin accumulation and constitutes a major threat to food safety, food security and consequently, public health (Shephard, 2008). The contamination is largely influenced by a variety of factors ranging from climatic and farm practice, handling and storage to processing and distribution of food. Previous studies on aflatoxin contamination of groundnuts in Nigeria have focused more on determining the prevalence of fungi and/aflatoxins in groundnut products (e.g. roasted groundnut, peanut cake and other groundnut-based snacks) (Afolabi et al., 2015; Akano and Atanda, 1990; Bankole et al., 2005; Ezekiel et al., 2013a; Ogunsanwo et al., 2004) than in raw groundnuts (Afolabi et al., 2015; Ifeji et al., 2014; Jimoh and Kolapo, 2008). Furthermore these studies assessed a very limited number of samples (Afolabi et al., 2015; Jimoh and Kolapo, 2008), or were restricted to one state when sample size was large (Ifeji et al., 2014). In addition to aflatoxins,

* Corresponding author at: Department of Microbiology, Babcock University, Ilishan Remo, Ogun State, Nigeria.
E-mail address: chaugez@gmail.com (C.N. Ezekiel).

http://dx.doi.org/10.1016/j.ijfoodmicro.2017.03.020
0168-1605/

Ezekiel et al. (2012) and Kayode et al. (2013) reported the presence of other mycotoxins (e.g. beauvericin and ochratoxin A (OTA)) and >15 microbial metabolites in groundnut-based snacks analyzed by a liquid chromatography tandem mass spectrometry (LC-MS/MS) while Ifeji et al. (2014) recently documented the presence of OTA in addition to aflatoxins in raw groundnuts from Niger state determined by a high performance liquid chromatographic method.

Surveillance of fungi and mycotoxins in food commodities (e.g. groundnuts) from several agro-ecological zones (AEZs) and risk assessment is required to monitor the current food safety situation in the country as well as identify hotspot regions of toxin contamination to facilitate targeted interventions. In view of the paucity of such comprehensive data for groundnut in Nigeria, this study assesses the distribution of moulds and >300 microbial secondary metabolites (including mycotoxins and metabolites previously reported to contaminate foods (Malachová et al., 2014; Sulyok et al., 2007; Warth et al., 2012)) in groundnuts available for sale in domestic markets in four AEZs of Nigeria and also to determine the risk associated with consumption of mycotoxin contaminated groundnuts.

2. Materials and methods

2.1. Survey and sampling

Four of the six AEZs in Nigeria where groundnuts are produced and largely consumed as well as regions that could easily be accessed for sampling were purposely selected for this study. These included: Northern Guinea Savanna (NGS), Southern Guinea Savanna (SGS), Derived Savanna (DS) and Humid forest. The geography and rainfall patterns of the zones has been previously documented (Adetunji et al., 2014; Atehnkeng et al., 2008). A survey was then conducted in 11 states across the four AEZs between May and July 2015 for the sampling of raw shelled/decorticated groundnuts (Fig. 1). A maximum of three states per AEZ were selected based on accessibility to large groundnut markets. In each state, 3–4 major markets where groundnuts are sold in bulk quantities were purposely selected except for Kogi state where only two markets were sampled due to fewer markets with groundnut vendors who had the required quantities for sampling at the time of survey. In each market, 2–3 groundnut vendors who wholesale or retail groundnuts in quantities of at least 500 kg (ten 50 kg bags) were selected. A total of 84 samples (i.e. an average of 8 samples per state for 10 states and 4 samples from Kogi state) were thus collected in this study between late May and early July 2015 as described below. The distribution of samples across the AEZs were NGS = 16, SGS = 20, DS = 32 and HF = 16.

Sampling and sample preparation were carried out as described by Ezekiel et al. (2012). One bag or storage bin was sampled per 5 bags available in a vendor's store. About 500 g was taken from each of three parts of one bag or storage bin and combined with other sampled portions from one other bag or bin to give a total of 3 kg bulk per sample. Each bulk sample was collected into a sterile polyethylene bag and transported to Babcock University for further analysis. Each bulk sample was quartered repeatedly to give subsamples weighing about 50 g each. Three representative subsamples were taken per bulk sample, mixed together and divided into two parts: part A, for moisture content analysis and isolation of moulds; part B, for the multi-mycotoxin analysis using liquid chromatography tandem mass spectrometry (LC-MS/MS). All part A and B samples were ground separately in a Waring blender and stored at 4 °C and −20 °C, respectively, prior to further analysis.

2.2. Moisture content determination of groundnut samples

The moisture contents of the groundnut samples were determined using an OAHUS MB25 MC-173467 moisture analyzer (Ohaus Corp.

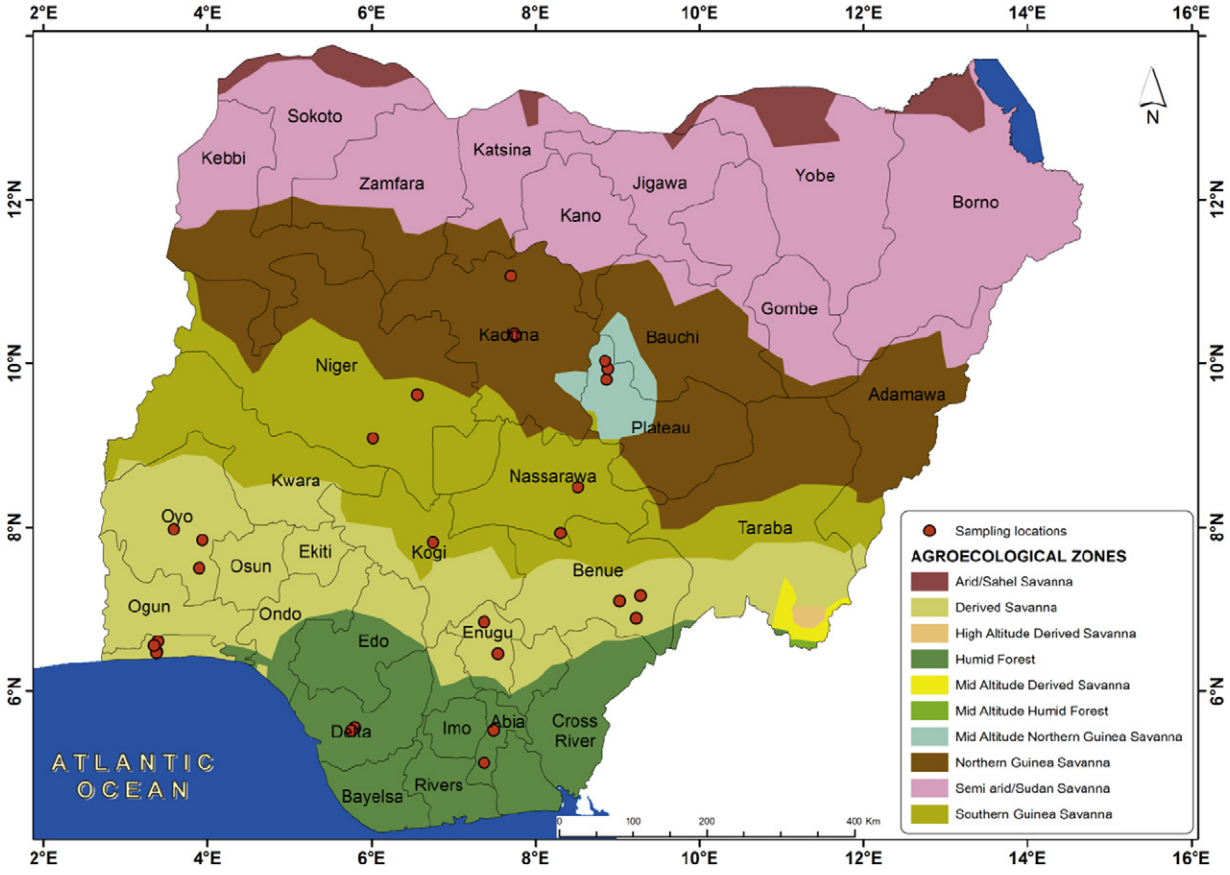

Fig. 1. Sampling locations of groundnuts in Nigeria.