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Aflatoxins and fumonisins in rice and maize staple cereals in Northern Vietnam and dietary exposure in different ethnic groups

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A B S T R A C T

Mycotoxins in food are increasingly a food safety hazard concern in particular in developing countries. This study was performed to determine the occurrence and determinants of aflatoxin and fumonisin contamination in rice and maize and to assess health risks through dietary intake exposure among ethnic minority groups in northern Vietnam. A total of 111 rice and 102 maize samples, were tested for occurrence of fungi and mycotoxins, i.e. aflatoxins (AF's) and fuminisin B (FB). Results showed that 107 (96.4%) rice and 84 (82.4%) maize samples were contaminated by fungi. *Aspergillus flavus* was found in 68 (61.3%) rice and 30 (29.4%) maize samples, *Aspergillus parasiticus* in 40 (36.0%) rice and 27 (26.7%) maize samples. AF's - were detected in 27 rice (24.3%) and 27 maize samples (26.4%) at minimum and maximum levels in rice of 2.06 and 77.8 ng/g and 20.5 and 110 ng/g in maize, respectively. Nine (8.1%) rice and 24 (23.5%) maize samples contained FB at ranges of 2.3–624 ng/g in rice and 5.6–89.8 ng/g in maize. Data collected through interviews and observations in households showed that type of crop, storage duration and presence of fungi, particularly mycotoxigenic fungi were important risk factors for AF's and FB contamination. Based on daily food consumption data, the estimated average exposure dose of aflatoxin B_1(AFB_1) from rice was 21.7 ng/kg bw/day for adults and 33.7 ng/kg bw/day for children. For FB, the rice based average exposure amounted to 536 ng/kg bw/day for adults and 1019 ng/kg bw/day for children. The calculated excess risk of liver cancer incidence by ingestion of cereals containing AFB_1 was 1.5 per 100,000 adults and 2.3 per 100,000 children per year. The average intake of FB was calculated to be lower than the tolerable diet intake (TDI). Our findings highlight that rice and maize are contaminated with mycotoxins at levels representing actual health hazards for the ethnic minority groups consuming these stable cereals. Proper drying and storage conditions in households are likely to reduce the mycotoxin contamination.

1. Introduction

Rice (*Oryza sativa* L.) and maize (*Zea mays* L.) are two of the most consumed staple foods worldwide (Kennedy, 2002). Rice contributes worldwide with 20% of total consumed staple food and 40% of energy intake (Latham & Routledge, 1998). The Asian and Pacific regions produce and consume about 90% of the world rice and in several countries, rice contributes with 40–80% of the food energy and protein requirements (Singh, Woodheadb, & Papademetriouc, 2002). Asia contributes about one-third of the world's total maize production and maize is the second most important cereal crop after rice in this region. Vietnam is among the world's top five rice producers and consumers (USDA, 2015) and maize is often a substitute in rural and mountainous areas, especially during periods of rice shortage.

A nutritional surveillance (NIN, 2011) showed that the diet of people in our study area in North West Vietnam is less diverse than in the rest of the country. The different ethnic groups inhabiting this area are all subsistence farmers and most of their daily food

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intake comes from maize and rice with some ethnic groups having maize as their preferred stable crop (Thanh Ha et al., 2004, p. 42). Thus, any hazardous substances in these stable cereals would represent major food safety and health risks. The farmers in the Northern highlands face different climate conditions, e.g. elevated temperatures and higher relative humidity as compared to most other parts of Vietnam (Pandey, Khiem, Waibel, & Thien, 2006). Furthermore, possible different agricultural practices including means of storage and drying harvested cereals, may provide the basis for differences in fungal infestation and associated food safety hazards as compared to those faced by low-land Vietnamese farmers.

Rice and maize are reported as good substrates for fungal growth and production of mycotoxins (Reddy, 2009; Reddy, Saritha, Reddy, & Muralidharan, 2009; Trung, 2008) such as aflatoxins (Reddy et al., 2009; Shephard, 2008) and fumonisins (Domijan, Peraica, Jurjevic, Ivic, & Cvjetkovic, 2005; Nikiema, Worrillow, Traore, Wild, & Turner, 2004). *Aspergillus flavus* shows optimal production of aflatoxins at 28 °C and 8–12% moisture content whereas *Fusarium verticillioides* produce high levels of fumonisins at temperatures between 20 and 26 °C (Folcher et al., 2010; JECFA, 2002; Scott, 1993;; Reid et al., 1999) with toxin often produced pre-harvest when cereals are stored in the field (JECFA, 2002). The growth of fungi and their toxin production is increased by insect damage and post-harvest storage conditions (FAO, 1989).

According to the Food and Agricultural Organization (FAO), 25% of the world's food crops may be affected by mycotoxins each year (Boutrif & Canet, 1998). Amongst the known mycotoxins, aflatoxins, deoxynivalenol and fumonisins pose the greatest threat to human health worldwide (Reddy, 2009). The main producers of aflatoxins are the fungi *Aspergillus flavus* and *A. parasiticus* (FAO, 1989). The International Agency for Research of Cancer (IARC) has classified aflatoxin B_1 and natural mixtures of aflatoxins as group 1 carcinogens. IARC has further classified mycotoxins derived by *F. verticillioides* which mainly are the fumonisins and fusarin C in the group 2B as carcinogenic in animals and possibly also in humans (IARC, 1993). The fumonisins are a group of chemically related mycotoxins mainly produced by *F. verticillioides* (formely *Fusarium moniliforme*). Fumonisins are mainly found in maize, but has also been reported in rice products (Richard, 2007). Previous surveys on mycotoxins in foods in Vietnam are few and with small sample sizes, but they do indicate that aflatoxins are common in maize kernel and maize flour at retail markets in Hanoi (Wang et al., 1995). AFB_1 was found in 10/15 (77%) of maize samples for human consumption coming from different parts of Vietnam with concentrations ranging from 11.3 ng to 126.5 ng/g dry weight while fumonisins were found in 8/25 (32%) samples ranging from 400 to 3300 ng/g (Trung, 2008). Little is known about the occurrence of mycotoxins in stable cereals (rice and maize) produced and consumed by people in the rural and mountainous areas of Northern Vietnam. The Vietnamese standards for maximum content of total aflatoxin and aflatoxin B_1 are 10 μg/kg and 5 μg/kg (Ministry of Health, 2011) as compared to the US standard of 20 μg/kg for any type of food for human consumption (Food Safety Watch, 2013). The EU has lower maximum levels of 10 μg/kg for total aflatoxin in ready-to-eat rice and corn products and as low as 0.1 μg/kg for processed cereal-based baby and infant food (EU, 2010). Both aflatoxins and fumonisins are resistant to processing resulting in a high retention of those mycotoxins in consumed food (Scott, 1993). WHO recently reported a much higher burden of exposure of aflatoxin and fumonisin in low-income regions and also identified priority issues that needed immediately action that is quantifying human health impacts and burden of disease due to the exposure of the mycotoxins and compiling an intervention strategy to control mycotoxins (Strosnider et al., 2006).

The hypothesis of the study was that exposure to and health risks caused by mycotoxins in staple cereals would be different between ethnic groups as well as to farmers in other parts of Vietnam due to the different climatic conditions and agricultural practices. Thus, our study aimed to determine the occurrence and determinants of aflatoxins and fumonisins contamination in rice and maize and assess health risks through dietary intake exposures among ethnic groups in Northern Vietnam.

2. Materials and methods

2.1. Study site and population

The study was conducted in Ta Phoi and Hop Thanh communes in the mountainous province of Lao Cai, Northern Vietnam. These are the poorest communes in Lao Cai district with 40% of households having monthly incomes less than 200,000 Vietnamese Dong (approximately 10 USD per person). Households were mostly located in highland villages and members represented seven ethnic groups, i.e. Dao (18 households), Giay (21), Xapho (20), Tay (18), and Hmong (20) with few Chinese households living there as well (Department of Health Lao Cai district, 2008; Rheinländer, Samuelsen, Dalsgaard, & Konradsen, 2010) (Table 1).

The Giay and Tay ethnic groups live in the lowland about one km away from the center of Hop Thanh commune and typically grow two rice crops per year (Department of Health Lao Cai district, 2008; Rheinländer et al., 2010). In addition, the Giay cultivates two maize crops while one maize crop is produced by the Tay's annually. The Xapho people reside in a highland area of Hop Thanh commune and grow two rice crops and one maize crop every year. The Dao and Hmong people live in highland areas of Ta Phoi commune. The Dao village is located five km from the commune center and inhabitants grow one rice crop and one maize crop per year. Compared with the other ethnic groups, the mountainous Hmong village is the most isolated and least developed with only one maize crop grown annually as the main staple food. The ethnic Vietnamese Kinh group lives in quite developed households in a lowland village in Ta Phoi commune and has a comparable higher income. In contrast to the other ethnic groups which are almost entirely subsistence farmers, the husbands of Kinh households typically work in the local apatite mines and wives take care of household matters. Most Kinh households buy rice and maize at local markets whereas the other ethnic groups in general are self-supplied with home grown rice and maize (Department of Health Lao Cai district, 2008; Rheinländer et al., 2010).

The mean annual temperature is around 20–29 °C, annual rainfall about 1400–1700 mm and the average humidity above 80%.

2.2. Collection of maize and rice samples

A total of 213 samples of dried maize seed and rice were randomly collected from separate purchased batches in October 2009 (Table 1). The samples were collected from three sources: wholesale, retail and household. The "wholesale samples" represent samples purchased at the Coc Leu market, the largest wholesale market in Lao Cai city. Samples purchased at local markets in Ta Phoi and Hop Thanh communes were catalogued as "retail samples". The "household samples" were collected during visits to individual households. Only one rice and/or maize sample were collected from each individual household. Samples were collected from all stands in operation at the wholesale market and retail (local) markets. This sampling strategy was chosen to obtain adequate and representative sample numbers for analysis. Similarly, we collected samples from all households in a particular commune with children less than 5 years old resulting in different