Economic Anthropology 2017; 4: 200–212 DOI:10.1002/sea2.12088

Risky resources: Household production, food contamination, and perceptions of aflatoxin exposure among Zambian female farmers

Alyson G. Young

Department of Anthropology, University of Florida, Gainesville, FL 32611, USA
Corresponding author: Alyson G. Young; e-mail: alys.yng@ufl.edu

Mycotoxins pose a risk to nutrition security in sub-Saharan Africa, yet research on mycotoxin control pays limited attention to the social context of fungal toxin exposure. In Zambia, groundnuts are considered a "woman's crop," making women's labor central to groundnut production. However, this status does not ensure women control over the groundnut production process—an important distinction when looking at distribution of labor and resources in the household and its implication for aflatoxin reduction. This article uses semistructured interviews and participatory risk assessment techniques with women farmers to examine the relationship between control over groundnut production, risk perception, and aflatoxin mitigation in Eastern Province, Zambia. Interviews were conducted in July–August 2015 in three districts of Eastern Province and focused on knowledge and perceptions of aflatoxin-producing fungi and food contamination and groundnut production practices. Results from this study indicate that gender disaggregated data on ownership and control over production strategies are important for understanding the mechanisms that create variation in household exposure to aflatoxins. Local perceptions of short- and long-term health influence the relationship between knowledge about aflatoxins and practice. Including the social context of decision making into aflatoxin risk assessment and mitigation helps strengthen intervention efforts.

Keywords Risk Perception; Gender; Food Safety; Agricultural Production; Mycotoxins

One of the primary challenges in risk research, whether assessing risks to food, health, or agricultural development, is understanding the mechanisms that link exposure to a hazard, what people know, and what people do. Much of the early work on risk and behavior was centered in technology, statistics, and economics and focused on the gap between expert knowledge and expectations for behavior and "compliance" by communities targeted in intervention campaigns (Lambert and Rose 1996). As social science research gained a foothold in the risk and behavior literature, there was a shift toward understanding how subjective experience mediates the relationship between knowledge and behavior (Peters 2000) and increased dichotomization between studies that quantify differences in behavior and risk and studies that qualify the reasons for that behavior. There is a separation between ecological models of risk that focus on a systems approach to understanding exposure and response (e.g., Turner et al. 2003) and more individually centered psychological models of risk that focus on individual interpretation and lived experience (e.g., Schoon 2006). Few studies work between these lines, although there is demand for multisited, multiscalar research that can address these issues (Brandt et al. 2013; Panter-Brick 2014).

The research on risk has been compartmentalized for a number of reasons—the inertia of differences in intellectual approaches and frameworks, challenges of translating and coordinating research that can bridge disparate approaches, and the practical considerations of the logistics of modeling and testing hypotheses that reasonably speak to complex multiscalar dynamics of risk. In reality, *risk is a process*—it is the biocultural and socioecological dynamic between the physical landscape, the communities dispersed across it (both human and nonhuman), the systems that modify this landscape and its available resources (including who lives on it, who owns it, who gets to use it), and how each of those individuals embodies and modifies the environment, changing it for those around him or her.[1] As Panter-Brick (2014, 433) points out in her work on risk and resilience, "despite some fuzziness, risk and resilience concepts are 'good to think' with: They offer a window onto human biology, behavior, and society and a guide for policy and intervention. They help answer questions regarding why and how health problems do (or do not) emerge, and who is (or is not) affected, by which conditions, when, and where. They offer guidance regarding what we may be able to do, effectively, to mitigate human exposure to adversity and to address the conditions that give rise to health inequities—defined as those health disparities that are demonstrably persistent, preventable, and unfair."

This article uses risk as a concept to "think with" and explore the household context of the relationship between women's knowledge, perceptions of heath and nutrition risks, and decisions about managing aflatoxin contamination in rural Zambian households. The study is situated at the nexus of household decisions about agricultural production and food security and individual perceptions of food safety, nutrition, and health. The goal of the article is to explore the complexity behind the concept of risk and illustrate how individual knowledge, perception, and decisions about managing risk are mediated by the context in which they occur.

Background

Nutrition security is a significant concern in Zambia where rates of stunting for children under five are at 45%. Fungal toxins have drawn increasing attention for their potential impact on child nutrition in the international development literature on nutrition-sensitive agriculture (Williams et al. 2004; Dorward 2014). There are also significant social and health disparities associated with aflatoxin exposure, yet they remain underrepresented in social epidemiology and biocultural research. This article uses data collected among rural smallholder farmers in Eastern Province, Zambia, to outline the links between risk perception, gender, household production, and exposure to aflatoxin contamination; illustrate how these factors shape the context of aflatoxin risk management at the individual and household levels; and explore how biocultural approaches inform our understanding of the relationship between aflatoxins and child health and nutrition.

Aflatoxin exposure and health

Aflatoxins have been under scrutiny since the 1960s because of their widespread occurrence and their impact on crop productivity, nutrition security, and health (Wild and Turner 2002; Shephard 2008; Williams et al. 2004). Aflatoxins are carcinogenic mycotoxins produced by fungi in the *Aspergillus* family (*A. flavus* and *A. parasiticus*). The most toxic metabolite, aflatoxin B_1, is a potent microbial carcinogen. Aflatoxin M_1, a metabolite of aflatoxin B_1, occurs in human milk and milk from livestock that ingest contaminated feed. *Aspergillus* fungi and associated toxins are present in many global food staples (maize, millet, sorghum, groundnuts, cassava, tree nuts, and animal products). The major sources of human and animal exposure are maize and groundnuts because of the widespread consumption of these crops and their susceptibility to contamination.

The highest prevalence of aflatoxin contamination occurs in warmer regions because the tropical conditions in these areas promote fungal proliferation (e.g., high temperatures and humidity, monsoons, unseasonal rains during harvest, and flash floods). Aflatoxin proliferation is mediated by regional climate, the genotype of the crop planted, soil type, minimum and maximum daily temperatures, and daily net evaporation (Bankole and Mabekoje 2004). Aflatoxin contamination is facilitated by stress or damage to the crop from preharvest drought, insects, poor timing of harvest, heavy rains during harvest and postharvest, and inadequate drying of the crop before storage (Hell et al. 2000; Hawkins et al. 2005).

The limited nature of reliable comparative data on aflatoxin contamination and exposure in many countries hampers estimation of the magnitude of health and economic consequences of contaminated foods. In part, this is because technological capacity constrains identification and monitoring of aflatoxin contamination in resource-poor settings (Wild and Gong 2010; Wu and Khlangwiset 2010). Nonetheless, aflatoxin contamination is a crucial issue in arid and semi-arid areas of sub-Saharan Africa (SSA). Rural African households grapple with increased risk of aflatoxin contamination associated with rapid changes in land use, changes in household time and labor allocation, and local effects of global climate change (Williams et al. 2004; Hell and Mutegi 2011; Morton 2007). Chronic exposure to dietary aflatoxins in SSA is evident from the presence of aflatoxin M_1 in human breast milk in Ghana, Nigeria, Sierra Leone, and Sudan and in umbilical cord blood samples from Ghana, Kenya, Nigeria, and Sierra Leone (Gong et al. 2002; Shuaib et al. 2010).

Direct exposure to aflatoxin occurs primarily through the consumption of contaminated agricultural or animal products (Waliyar et al. 2008). Exposure can lead to acute or chronic aflatoxicosis that often compounds existing health issues, including risk for disease transmission (Cullen and Newberne 1994; Williams et al. 2004). Chronic aflatoxicosis is more common than acute aflatoxicosis but no less detrimental to human health. Chronic aflatoxin exposure (particularly exposure to aflatoxin B_1) has multiple negative effects on long-term health, including links to increased risk for hepatocellular carcinoma, growth retardation and stunting in children, and suppression of the immune system (Jolly et al. 2008; Liu and Wu 2010; Wu et al. 2007). Studies have shown that persons with hepatitis B infection who live with chronic aflatoxin exposure have thirty times the risk of contracting liver cancer compared to B- negative individuals. Sub-Saharan African and Asian populations have endemically high hepatitis B and C rates in conjunction with chronic exposure to aflatoxins, putting these populations at increased risk for disease burdens associated with this form of liver cancer (Williams et al. 2004). The limited research that exists also indicates a positive relationship between aflatoxins, risk for stunting, and kwashiorkor in children (Turner et al. 2003; Gong et al. 2002).

At a household level, aflatoxin exposure is mediated through agricultural practices that limit the presence and growth of *Aspergillus* in the environment (such as crop rotation, use of mold-resistant stock, and biocontrol), postharvest practices that promote safe handling practices and limit moisture levels in stored and processed crops, and food preparation techniques that reduce contamination or neutralize aflatoxins in consumed foods (Cotty and Bhatnagar 1994; Cleveland et al. 2003; Lopez-Garcia and Park 1998; Wu and Khlangwiset 2010; Waliyar et al. 2008). However, utilization of best practices for postharvest storage and safe food handling practices can be constrained by food availability and household time and labor demands. For example, adding water to soften peanut shells may decrease the labor associated with hand shelling, but it also significantly increases the risk of mold propagation and aflatoxin exposure.

Risk perception and food safety

Food safety refers to food handling, storage, and preparation practices that prevent foodborne illness (or limit heath risks to the consumer). Food safety is incorporated into water, sanitation, and hygiene (WASH) models in public health and includes practices to reduce risks of exposure to pathogens and chemical and physical contaminants. Individual differences in risk perceptions and their etiology have important implications for efforts to manage food health hazards. While aflatoxins pose an objective risk to health and nutrition, it is the subjective risk perceived by the individual that motivates decision making and behavior that help shape exposure. Much of the work that has been done on risk perception and *food safety* comes from risk analysis and psychometric literature in the health and consumer behavior sciences that often focus on quantitative analysis (Mitchell 1999; Hansen et al. 2003; Finucane and Holup 2005). However, there is a body of literature that focuses on the social context of perceptions of food safety (see, among others, Behrens et al. 2015; Gustafsod 1998; Hansen et al. 2003; O'Shea 2015). This study augments literature on perceptions of food safety by focusing on a non-Western context and examining the intersection of gender, risk perception, and household ecology.

Constraints on risk management and behavior: Gender and agricultural production

Gender norms play an important role in the context and consequences of variation in household food production and contaminant exposure. Gender roles shape the types of risk an individual is exposed to and the range of strategies the individual can employ to cope with risks (Doss 2001; Doss and Morris 2000; Haddad, Hoddinott, and Alderman 1997; Kumar and Quisumbing 2014). It follows that a gender lens has potential for understanding local variability in the success of aflatoxin reduction campaigns — yet, as Christie et al. (2015) note, gender has yet to be systematically integrated into discussions of household food safety. Several studies explicitly examine the role of gender in aflatoxin exposure (Sabuncuoglu et al. 2015; Ghebranious and Sell 1998), but few studies specifically address the role of gender in aflatoxin control (Christie et al. 2015).

Ethnographic context

This study is based on interviews with female smallholders in Eastern Province, Zambia. As of 2010, Eastern Province accounted for 12% of the population and 21% of the cultivated land in Zambia. Chewa/Nyanja compose the largest community in Eastern Province, with Chinyanja as the most widely spoken language next to English. More than 85% of the province is rural, with rural poverty rates of 80% and the lowest literacy rate in the country. Eastern Province has the second highest level of stunting in the country (51.7%), despite a relatively diversified agricultural economy (Mofya-Mukuka and Kulhgatz 2015; Central Statistical Office of Zambia 2016). Aflatoxins are an important health and nutrition concern in the region — Akello et al. (2015) documented high levels of aflatoxins in weaning food samples from Eastern Province.

Methods and study design

Sample selection

The data for this article were collected during focus group and individual interview sessions between July and August 2015. Data collection focused on understanding women's knowledge and perceptions of aflatoxins and the household context of groundnut production. Districts for focus group and individual interviews were chosen after discussions with local government officials and nongovernmental organizations (NGOs) working on aflatoxin reduction and safe harvest practices.[2] Focus group participants were solicited from several districts of Eastern Province (Petauke, Katete, and Chipata). These districts were selected to identify whether there was significant variance in community knowledge about aflatoxins. Individual participants were solicited from Chipata District because of time and resource constraints. Participants were solicited through district women's associations because it was the most effective way to contact local participants. The sample includes women who participated in local aflatoxin trainings and those who had not. Focus group interviews included five groups of ten women between the ages of twenty and fifty (Chipata, $n = 2$ groups; Petauke, $n = 1$ group; Katete, $n = 2$ groups).[3] All interviews and focus groups were conducted in Chinyanja with the help of a local assistant and translator. Individual interviews ($n = 25$) were approximately forty-five minutes in duration, while focus group sessions lasted approximately sixty to ninety minutes.[4]

Interview data

Local awareness campaigns have been effective in sensitizing people to the presence of aflatoxins (*chuku* in Chinyanja), and many community members are already familiar with the concept of aflatoxins as fungal contaminants. Focus group discussions focused on assessing general knowledge about the diversity of pre- and postharvest risks for aflatoxin contamination, signs of aflatoxin contamination in crops and stored foods, strategies for avoiding contamination, perceptions about contamination of different foods, and identifying the relative risk associated with aflatoxins compared to other challenges in the community. The goal of these interviews was to understand how women identify contaminated groundnuts, the factors that influence their ability to mitigate contaminated groundnut stores, and the risks associated with using or consuming contaminated seeds.

The data from focus groups were coded and used to develop questions for assessing individual knowledge, perceptions, and practices regarding aflatoxin contamination.[5] Semistructured interviews with individual women focused on knowledge about aflatoxins, control over household decisions about groundnut production and income use, community participation, access/utilization of extension services, perceptions of household labor, and social support. Individual interview data were used to evaluate women's control over different aspects of groundnut production and inferential analyses of the factors that influence women's knowledge and practice regarding aflatoxins.

Crop production, social support, and labor allocation

Data on crop production, social support, and household labor allocation were collected during individual interview sessions. Participants were asked about the head of household, landownership, involvement in local agricultural training activities (farmer field schools, agricultural extension agents), types of crops planted, and types of agricultural inputs used (fertilizer, pesticide, mechanical labor). Women also estimated the yield of recent groundnut crops, identified how returns from the sale of groundnuts were distributed among household members, and made decisions about using money from groundnut sales. Questions about control over groundnut production focused on which member of the household made primary decisions on the variety of seeds that were planted, how much acreage was devoted to groundnut production, how the groundnuts were chosen and processed for sale, and where the seeds were sold. Social support was self-reported by women and included information on the type of support women received to help with groundnut production (labor, cash, machinery), who provided the support, and how frequently it was provided. Workload was self-identified based on perceived effort on a specific task. Allocation of labor was determined by asking which household members were *most likely* to provide labor for particular tasks (planting, weeding, chemical application, harvest, processing, sales).

Participatory risk assessment

This study employed a participatory risk assessment approach (Grace et al. 2008) to understand how perceived risk of aflatoxins compare to other health and nutrition challenges in the community. Focus group participants were asked to identify and rank the most important health and nutrition challenges in the community. After a discussion of these rankings, the group was asked to situate their perception of the health and nutrition risks associated with aflatoxins relative to these other challenges and explain their rationale for the decision. The same approach was used in individual interviews, and the results were compared to assess individual variation in responses and to better understand local perceptions of health risks. The focus of these activities was not to quantify the subjective assessment of risk; rather, the discussions associated with the ranking activities were used to provide an ethnographic context for understanding how aflatoxins are centered in a larger cultural risk narrative.

Results

General aflatoxin knowledge

Several themes emerged in focus group discussions. Women in focus groups were aware of aflatoxins and their potential health threats, but there was variation in perceptions of the severity of aflatoxin-related health risks. Participants identified lack of access to adequate calories, diversity in diet, and illness as the most important challenges to child health. When asked how most women balance their concerns about aflatoxin exposure with concerns about child nutrition, women indicated both were important—improved access to diverse foods makes it easier to avoid contaminated food. Women also use different food preparation and selection techniques to mitigate the impact of aflatoxins, including avoiding the use of moldy pods or boiling contaminated foods. These strategies have varying levels of effectiveness—while picking out contaminated pods can significantly decrease aflatoxin levels, boiling has no effect on reducing aflatoxin levels.

- *Risks for aflatoxin contamination*. Focus group participants identified several pre- and postharvest factors that increase the risk of aflatoxin contamination. Important preharvest risk factors included seed pod damage (mechanical and insect related) and presence of crop disease. Postharvest risk factors included early/late harvests, pod damage during harvest and storage, and exposure to moisture during storage and processing. Timing of harvest was considered the most important risk factor for aflatoxin contamination.
- *Signs of aflatoxin contamination.* Focus group participants noted that farmers identify aflatoxin contamination by looking at root development, looking for the presence of mold within/on seedpods, and identifying discoloration on groundnut cotyledons. Women identified contamination in food stores and processed foods through the presence of mold and/or a bitter taste in processed foods. There are challenges associated with these methods, however, given that aflatoxins have no discernable taste or smell.
- *Practices for preventing aflatoxin contamination.* Focus group participants noted several important postharvest practices for reducing aflatoxin contamination: harvesting groundnuts at the appropriate level of maturity to avoid issues with moisture, drying the pods appropriately, and maintaining low moisture content during storage and processing. Participants noted that a number of factors influence the ability to follow best practices, including weather conditions during harvest, labor/time available for production activities, and risks from crop damage and theft.
- *Commonly contaminated foods.* All of the focus group participants noted that groundnuts and maize were the most commonly contaminated crops. Several also noted the presence of aflatoxins in animal products, processed foods (flour and oil), and commercially available goods.

Individual aflatoxin knowledge

Aflatoxin knowledge was measured using a set of questions divided into three domains of knowledge based on responses from focus group participants about best practices to prevent aflatoxin contamination. The three domains included signs of aflatoxin contamination in crops and stored foods, factors that increase the risk of aflatoxin contamination, and perceived risk of consuming aflatoxins in different types of food. There was significant agreement among individual women within the different domains of knowledge about aflatoxins (Table 1).

Linear regression was used to explore the relationship between training attendance and the amount of agreement on best practices among participants. Training attendance strongly influenced women's knowledge about aflatoxins, particularly their ability to identify the signs of contamination. Training attendance predicted 27% of the variation in knowledge about food contamination, $F(1, 23) = 10.20$, $p < .004$; 42% of variation in knowledge of risk factors for aflatoxin contamination, $F(1, 23) = 18.38$, $p < .001$; and 80% of the variation in knowledge about signs of aflatoxin contamination in crops and stored foods, $F(1, 23) = 98.44$, $p < .001$. This indicates that education efforts have been more successful in informing community members about identifying contamination in crops and stored food than they have been about food contamination and sources of contamination risk. However, broad extrapolation of these results is limited by the sample size and lack of geographic diversity.

Control over groundnut production, social support, and allocation of labor

The importance of household labor allocation immediately arose when discussing the factors that prevent women from attending trainings and constrain their ability to follow recommended practices to mitigate aflatoxin risks. Despite the level of knowledge about aflatoxins in the community, 64% of women reported harvesting at an improper

Table 1 Aflatoxin Knowledge among Individual Participants

Domain of Knowledge	Agree, *n* (%)	Disagree, *n* (%)	Don't Know, *n* (%)
risk factors for aflatoxin contamination			
mechanical pod damage	21 (84)	3 (12)	1 (4)
insect damage	23 (92)	1 (4)	1 (4)
plant disease	20 (80)	4 (16)	1 (4)
delays in harvest	24 (96)	1 (4)	0
pod damage during harvest	22 (88)	2 (8)	1 (4)
insect damage during storage	22 (88)	2 (8)	1 (4)
moisture damage in storage	24 (96)	1 (4)	0
wetting during shelling	24 (96)	1 (4)	0
most important risk factors			
highest risk from moisture content	5 (20)		
highest risk from harvest timing/conditions	18 (72)		
highest risk from improper processing	2 (8)		
important practices to reduce aflatoxins			
harvest strategies	24 (96)	1 (4)	0
damage avoidance	21 (84)	3 (12)	1 (4)
drying procedures	23 (92)	2 (8)	0
storage procedures	23 (92)	2 (8)	0
signs of aflatoxin contamination			
marks on cotyledons during drought	22 (88)	2 (8)	1 (4)
bitter taste	25 (100)	0	0
white mold inside pod	25 (100)	0	0
underdevelopment of roots	22 (88)	1(4)	2 (8)
foods commonly contaminated by aflatoxins			
staple crops (groundnuts, maize)	25 (100)	0	0
animal products (meat, milk, eggs)	21 (84)	3 (12)	1 (4)
processed foods (flour, oil)	18 (72)	5 (20)	2 (8)
store-bought goods (peanut butter)	15 (60)	8 (32)	2 (8)

Note: $N = 25$.

time, 44% reported adding water when shelling groundnuts, and only 32% think they were able to adequately apply the training they had received on best practices.

The identification of groundnuts as a "woman's crop" in Zambia highlights the importance of understanding the role of gender in household allocation of labor. Men are traditionally identified as the primary decision makers regarding agricultural production in Eastern Province, while women provide labor (Mofya-Mukuka and Shipekesa 2013). This applies to groundnuts as well. As Doss and others point out, the identification of groundnuts (or any other crop) as "women's crops" does not assure women control over decisions about planting, harvesting, processing, or sales (e.g., Doss 2002; Carr 2008). Women contribute a majority of their time and energy to weeding, harvesting, and shelling—three of the most labor-intensive components of groundnut production. Despite this contribution to the labor associated with groundnuts, women may not have full (or any) control over larger-scale decisions about the production and sale of propagated seeds.

There were identifiable gender differences in labor allocation among the households in this study. Distribution of household labor varied across various stages of groundnut production depending on whether the man or the woman had primary control over choices at each stage of production. In households where men controlled more stages in groundnut production, women did a majority of the labor-intensive activities, such as weeding, harvesting, and shelling, while men were more involved in planting and selling seeds. In households where women reported primary control over more stages of groundnut production, these labor-intensive activities were more evenly distributed between men and women (men might take groundnuts to be shelled or contribute labor/resources to groundnut

Table 2 Comparison of Men's and Women's Labor Contribution to Production

Production Activity	Men Control Production,[a] *n* (%)		Women Control Production,[b] *n* (%)	
	Man's Job	Woman's Job	Man's Job	Woman's Job
planting	8 (80)	2 (20)	8 (53)	7 (47)
weeding	1 (10)	9 (90)	6 (40)	9 (60)
harvesting	1 (10)	9 (90)	5 (33)	10 (70)
sales/marketing	9 (90)	1 (10)	6 (40)	9 (60)

Note: In many households, participants identified that they share the labor on all activities; however, "shared" labor is still rarely equitably distributed. We asked participants to sort the activities into "men's jobs" and "women's jobs" based on who was *most likely* to contribute the majority of labor.

[a] $n = 10$.

[b] $n = 15$.

harvesting, while women reported increased involvement in groundnut marketing and sales) (Table 2). Women who controlled more stages of groundnut production were also more likely to report having help with production (OR 2.33, 95% CI 1.13–4.86). Participants identified that increased control over groundnut production meant that women often had access to resources to hire people to help with weeding, harvesting, or processing.

The number of women who reported being in charge of groundnut production was higher than anticipated for the district. The proportion of women in primary control of production activities in this sample is nearly inverse that of larger studies in the region. The difference in this sample is likely a result of sample bias and the prevalence of targeted activities to help facilitate gender equity in Chipata District. Chipata District is at the center of the "zone of influence" for USAID Feed the Future activities and other development initiatives. Consequently, there are a disproportionately high number of development projects focused on sensitizing households to gender/nutrition issues and facilitating women's empowerment compared to other districts in Zambia.

Groundnut production, labor distribution, and aflatoxin mitigation

Variations in control over groundnut production and help with the work associated with agricultural production had important implications for training attendance and household strategies to reduce aflatoxins. Binomial logistic regression indicated a relationship between workload, help with groundnut production, and training attendance, $\chi^2(1) = 18.34$, $p < .001$, accounting for 70% (Nagelkerke R^2) of the variance in attendance. Women with high workloads were less likely to attend trainings, while women who reported help were more likely to attend. Households where women reported being in control of a significant proportion of groundnut production were also more likely to attend training than households where men were primarily in control of production (OR 3.50, 95% CI 1.17–10.4).

The availability of community- and individual-level support had an influence on groundnut production strategies with important implications for aflatoxin risks. Women who were members of several community groups were more likely to report having help with groundnut production (OR 1.51, 95% CI .65–3.5) and utilizing shelling machines or other forms of mechanization in groundnut production (OR 2.43, 95% CI 1.01–5.86). Binomial logistic regression models did not show a significant relationship between perceived workload, support, and either harvest timing or shelling practices. However, women with limited support were more likely to report late harvests (OR 1.73, 95% CI .78–3.84), and women who reported high household labor demands were more likely to wet the shells of groundnuts to soften them, making them faster and easier to process (OR 3.182, 95% CI 1.36–7.43). Forty-four percent of women reported drying groundnuts on racks, 32% dried groundnuts in the field, and 24% dried groundnuts on the bare ground in their compound. There was no relationship between perceived workload, social support, and storage/drying location, although women with no help were more likely to dry groundnuts in piles on the ground (OR 2.35, 95% CI .83–6.6) and store them in sacks in their houses (OR 1.84, 95% CI .74–4.5).

Control over production did not affect decisions about the quality of seeds used for household consumption. All of the women reported using the best-quality seeds for sale and seed stock while retaining the lowest-quality seeds for home consumption. Individual participants acknowledged that using poor-quality seeds for household consumption increased the possibility of consuming aflatoxins. However, aflatoxins were seen as a long-term health risk rather than as an acute problem. When asked about primary risks to child health, 76% of women identified nutrition and 24% of women identified illness as crucial health concerns for children. Thus, although women recognized the aflatoxin risks associated with using poor-quality seed at home, they hoped that by selling the best seed, they could get more money to supplement household nutrition and more money to pay for medical treatment and school needs. This is reflected in household spending patterns—women spent 60% of their earnings from groundnut sales on food, 28% on childcare or treatment, and only 12% on other goods/services.

Discussion

Groundnuts are integral to Zambian livelihoods, particularly among rural households in Eastern Province. Groundnuts are cultivated in half of rural smallholder households, representing the second largest crop, after maize, in production and cultivation (Mofya-Mukuka and Shipekesa 2013). Groundnuts are often identified as a "woman's crop" in Zambia, but this description provides limited information about household allocation of labor and resources to groundnut production or its implication for household strategies to control aflatoxins (Orr, Homann Kee-Tui, and Tsusaka 2014). ICRISAT data from 2010 to 2011 indicate that women contribute significant labor to groundnut production, yet men control a majority (62.4%) of the groundnut fields in Eastern Province (Mofya-Mukuka and Shipekesa 2013; Shipekesa and Jayne 2012). Thus it is important to distinguish between the provision of labor for crop production and control over management and decisions in crop production. Each role in management of agricultural production (control over decisions about land use, control over income from groundnut sales, etc.) situates women differently, relative to decisions about household security and access to resources. In this study, women's control over household production had dual impacts on the risk for aflatoxin exposure. Control over production mediated access to agricultural training, knowledge about aflatoxins, and associated best practices for aflatoxin mitigation as well as the time/energy constraints associated with production and the feasibility of managing aflatoxin risk.

In this study, decreased control over production and associated increases in women's workloads had a negative impact on aflatoxin mitigation because the trade-offs between labor and workload increased the possibility that crops would be harvested with a higher moisture content (because participants had to harvest early or late), dried under less than adequate conditions (piled on the ground rather than being carried back to the homestead to dry), and then exposed to moisture again during processing (e.g., adding water to shells to make processing easier)—all of which foster aflatoxin contamination. Furthermore, because women with limited control over production were also less likely to attend training and be involved in community groups, they had limited access to information and effective resources for reducing aflatoxin risk. Participants indicated that even if men shared the information they received in training, it didn't guarantee that women could access the necessary resources to utilize best practices.

The perception of aflatoxin risk relative to other concerns about household safety and security played an important role in the way women managed constraints on their energetic and monetary resources and perceived trade-offs in health and nutrition between different management strategies. Though all of the women knew and agreed that aflatoxins posed a serious risk to health, they prioritized perceptions of nutritional sufficiency and adequacy when deciding how to allocate household food and monetary resources. This is important for incorporating aflatoxin mitigation strategies into nutrition-sensitive agricultural production strategies because it suggests that market demand may be an important motivating factor for behavior change.

Conclusion

Aflatoxin contamination and exposure are having a disproportionate impact on health and human capabilities in marginalized communities, including poor regions of SSA. The impact of aflatoxin contamination on national trade, household livelihoods, and individual health limits the range of strategies available to help foster adaptability and resilience against other types of shocks. The data from this study highlight the complicated relationship between knowledge and agency in shaping the risks associated with the negative effects of environmental hazards and the importance of examining the mechanisms that link knowledge and behavior. It also brings up several points for further consideration.

First, there is a need for more information on multilevel factors that constrain women's ability to mediate aflatoxin exposure and contamination. The relationship between women's empowerment, control over production, and access to technical capacity needs to be considered when designing strategies for reducing risk of exposure to aflatoxins and other environmental hazards. Although the data from this study indicate that control of production has implications for women's decisions about production strategies, allocation of household labor, and training, it's not clear how much women farmers are constrained by extrinsic factors that limit access to and utilization of agricultural inputs. Women and men navigate different decision landscapes and have different constraints on their decisions from outside the household—increased control of production does not necessarily equal increased capacity to effect change. For example, access to extension services and resources is often spatially constrained for women in SSA because of limits on mobility (Dieterich, Huang, and Thomas 2016). In addition to production constraints, social norms about acceptable forms of transportation and travel for women can constrain women farmers by limiting the number of female extension providers in Zambia and access to other agricultural services and training (Namonje-Kapembwa and Chapoto 2016). Efforts to modify behavior and mitigate aflatoxin contamination at the household level need to consider these interactions between household- and community-level constraints.

Second, it is important to consider how women and men understand and respond to messages about environmental risk—particularly in areas with marginal resources. Women in focus groups and individual interviews acknowledged the gravity of the risk associated with aflatoxins but prioritized concerns about the more immediate consequences of child nutrition and infectious disease. The structural factors that underpin disparities in nutritional status and rates of infectious disease also contribute to variation in aflatoxin exposure—but how do caretakers evaluate and balance these risks? Aflatoxins are almost impossible to detect in soil and processed foods without the use of special laboratory tests. How do people conceive of and compare the risk from a nearly indiscernible toxin against more immediate threats to livelihoods and household health?

Finally, there is a need for further examination of biocultural aspects of resilience (following Panter-Brick 2014) and the feedback between the socioecological and economic structures that influence risk of exposure to aflatoxins and physiological consequences of constant exposure to aflatoxins. Panter-Brick and Leckman (2013, 333) point out that focusing on resilience "shifts the focus of analysis—from asking relatively limited questions regarding health outcomes, such as what are the linkages between risk exposures and functional deficits, to asking more complex questions regarding wellbeing, such as when, how, why and for whom do resources truly matter." We know that aflatoxicosis increases the prevalence of child stunting and liver cancer and that many Zambians are exposed to levels of aflatoxins that have known toxic effects on endocrine and immune function. Yet we have limited knowledge of actual levels of individual aflatoxin exposure on a daily basis and their interactive effects with other stressors. The toxicity of aflatoxin B_1 toward different types of cells varies considerably during development, yet we know little about the socioecology of exposure, how exposure changes across the life course, and the implications of these changes for human well-being.

Notes

1 Panter-Brick (2014), in her *Annual Review of Anthropology* article, does an excellent job of outlining intersections between all of these components, their measurement, and implications of risk and resilience for intervention and practice.

2 Relationships with the NGO and government officials that helped identify study locations and possible participants had been developed as part of Integrating Gender and Nutrition into Agricultural Extension Services (INGENAES), a consortium grant supported by USAID, and a technology assessment of the gender sensitivity of an aflatoxin biocontrol method in Eastern Province. This study was conducted independently of that assessment, however, and was not funded by any associated NGO, government organization, or USAID/INGENAES.

3 We planned two focus groups of ten women for each community; however, a funeral in Petauke District prevented us from holding the second scheduled focus group.

4 The University of Florida provided institutional review board approval, and informed consent was obtained verbally from all participants prior to interviews.

5 Content analysis was done using Dedoose 6.1.8 (SocioCultural Research Consultants 2015); descriptive and inferential analyses were conducted using SPSS v23 (Macintosh) (IBM Corp. 2015).

References

Akello, J., B. Ranajit, M. Mweshi, and H. Njapau. 2015. "Incidence of Aflatoxin Contamination in Locally Processed Complementary and Weaning Foods for Infants in Eastern Province of Zambia." Paper presented at the first African Symposium on Mycotoxicology, May 26–28, Livingstone, Zambia.

Bankole, S. A., and O. O. Mabekoje. 2004. "Occurrence of Aflatoxins and Fumonisins in Preharvest Maize from Southwestern Nigeria." *Food Additive Contamination* 21(3): 251–55.

Behrens, Jorge H., Gabriela M. Vedovato, Ana Maria Cervato-Mancuso, and Deborah H. M. Bastos. 2015. "Social Representations of Safety in Food Services." *Food Research International* 74: 324–28.

Brandt, Patrick, Anna Ernst, Fabienne Gralla, Christopher Luederitz, Daniel J. Lang, Jens Newig, Florian Reinert, David J. Abson, and Henrik von Wehrden. 2013. "A Review of Transdisciplinary Research in Sustainability Science." *Ecological Economics* 92: 1–15.

Carr, Edward H. 2008. "Men's Crops and Women's Crops: The Importance of Gender to the Understanding of Agricultural and Development Outcomes in Ghana's Central Region." *World Development* 36(5): 900–915.

Central Statistical Office of Zambia. 2016. "Zambia Data Portal." http://www.zamstats.gov.zm.

Christie, Maria Elisa A., Peace Kyamureku, Archileo Kaaya, and Alexandra Devenport. 2015. "Farmers, Peanuts, and Aflatoxins in Uganda: A Gendered Approach." *Development in Practice* 25(1): 4–18.

Cleveland, Thomas E., Patrick F. Dowd, Anne E. Desjardins, Deepak Bhatnagar, and Peter J. Cotty. 2003. "United States Department of Agriculture–Agricultural Research Service Research on Pre-harvest Prevention of Mycotoxins and Mycotoxigenic Fungi in US Crops." *Pest Management Science* 59(6–7): 629–42.

Cotty, Peter J., and Deepak Bhatnagar. 1994. "Variability among Atoxigenic *Aspergillus flavus* Strains in Ability to Prevent Aflatoxin Contamination and Production of Aflatoxin Biosynthetic Pathway Enzymes." *Applied Environmental Microbiology* 60(7): 2248–51.

Cullen, John M., and Paul M. Newberne. 1994. "Acute Hepatotoxicity of Aflatoxins." In *The Toxicology of Aflatoxins: Human Health, Veterinary, and Agricultural Significance*, ed. David L. Eaton and John D. Groopman, 3–26. San Diego, CA: Academic Press.

Dieterich, M. Christine, Anni Huang, and Alun H. Thomas. 2016. *Women's Opportunities and Challenges in Sub-Saharan African Job Markets*. Washington, DC: International Monetary Fund.

Dorward, Andrew. 2014. "How Can Agricultural Interventions Contribute in Improving Nutrition Health and Achieving the MDGs in Least-Developed Countries?" In *International Nutrition: Achieving Millennium Goals and Beyond*, ed. B. Black, A. Singhal, and R. Uauy, 93–109. Basel, Switzerland: Karger.

Doss, Cheryl R. 2001. "Designing Agricultural Technology for African Women Farmers: Lessons from 25 Years of Experience." *World Development* 29: 2075–92.

———. 2002. "Men's Crops? Women's Crops? The Gender Patterns of Cropping in Ghana." *World Development* 30(11): 1987–2000.

Doss, Cheryl R., and Michael L. Morris. 2000. "How Does Gender Affect the Adoption of Agricultural Innovations?" *Agricultural Economics* 25(1): 27–39.

Finucane, Melissa L., and Joan L. Holup. 2005. "Psychosocial and Cultural Factors Affecting the Perceived Risk of Genetically Modified Food: An Overview of the Literature." *Social Science and Medicine* 60(7): 1603–12.

Ghebranious, Nadar, and Stewart Sell. 1998. "Hepatitis B Injury, Male Gender, Aflatoxin, and p53 Expression Each Contribute to Hepatocarcinogenesis in Transgenic Mice." *Hepatology* 27(2): 383–91.

Gong, Y. Y., K. Cardwell, A. Hounsa, S. Egal, P. C. Turner, A. J. Hall, and C. P. Wild. 2002. "Dietary Aflatoxin Exposure and Impaired Growth in Young Children from Benin and Togo: Cross Sectional Study." *British Medical Journal* 325(7354): 20–21.

Grace, Delia, Tom Randolph, Janice Olawoye, Morenike Dipelou, and Erastus Kang'ethe. 2008. "Participatory Risk Assessment: A New Approach for Safer Food in Vulnerable African Communities." *Development in Practice* 18(4/5): 611–18.

Gustafsod, Per E. 1998. "Gender Differences in Risk Perception: Theoretical and Methodological Perspectives." *Risk Analysis* 18(6): 805–11.

Haddad, L., J. Hoddinott, and H. Alderman. 1997. *Intrahousehold Resource Allocation in Developing Countries: Methods, Models and Policy*. Baltimore: Johns Hopkins University Press for the International Food Policy Research Institute.

Hansen, J., L. Holm, L. Frewer, P. Robinson, and P. Sandøe. 2003. "Beyond the Knowledge Deficit: Recent Research into Lay and Expert Attitudes to Food Risks." *Appetite* 41(2): 111–21.

Hawkins, Leigh K., Gary L. Windham, and Paul Williams. 2005. "Effect of Different Postharvest Drying Temperatures on *Aspergillus flavus* Survival and Aflatoxin Content in Five Maize Hybrids." *Journal of Food Protection* 68(7): 1521–24.

Hell, K., K. F. Cardwell, M. Setamou, and H. Poehling. 2000. "The Influence of Storage Practices on Aflatoxin Contamination in Maize in Four Agroecological Zones of Benin, West Africa." *Journal of Stored Product Research* 36(4): 365–82.

Hell, K., and C. Mutegi. 2011. "Aflatoxin Control and Prevention Strategies in Key Crops of Sub-Saharan Africa." *African Journal of Microbiology Research* 5(5): 459–66.

IBM Corp. 2015. *IBM SPSS Statistics for Macintosh, Version 23.0*. Armonk, NY: IBM Corp.

Jolly, P., Y. Jiang, W. O. Ellis, J. S. Wang, E. Afriye-Gyawu, and T. D. Phillips. 2008. "Modulation of the Human Immune System by Aflatoxin." In *Mycotoxins: Detection Methods, Management, Public Health and Agricultural Trade*, ed. J. F. Leslie and A. Visconti, 41–52. Oxford: CAB International.

Kumar, Neha, and Agnes Quisumbing. 2014. "Gender and Resilience." *Resilience for Food and Nutrition Security* 2015: 155.

Lambert, Helen, and Hilary Rose. 1996. "Disembodied Knowledge? Making Sense of Medical Science." In *Misunderstanding Science? The Public Reconstruction of Science and Technology*, ed. A. Irwin and B. Wynne, 65–83. New York: Cambridge University Press.

Liu, Y., and F. Wu. 2010. "Global Burden of Aflatoxin-Induced Hepatocellular Carcinoma: A Risk Assessment." *Environmental Health Perspectives* 118(6): 818– 24.

Lopez-Garcia, R., and D. Park. 1998. "Effectiveness of Post-harvest Procedures in Management of Mycotoxin Hazards." In *Mycotoxins in Agriculture and Food Safety*, ed. D. Bhatnagar and S. Sinha, 407–33. New York: Marcel Dekker.

Mitchell, Vincent-Wayne, 1999. "Consumer Perceived Risk: Conceptualizations and Models." *European Journal of Marketing* 33(1–2): 163–95.

Mofya-Mukuka, R., and C. H. Kulhgatz. 2015. "Child Malnutrition, Agricultural Diversification and Commercialization among Smallholder Farmers in Eastern Zambia." Report 198189, Department of Agricultural, Food, and Resource Economics, Michigan State University, Ann Arbor.

Mofya-Mukuka, R., and A. Shipekesa. 2013. "Value Chain Analysis of the Groundnuts Sector of the Eastern Province of Zambia." Working Paper 78, Indaba Agricultural Policy Research Institute, Lusaka, Zambia.

Morton, J. F. 2007. "The Impact of Climate Change on Smallholder and Subsistence Agriculture." *Proceedings of the National Academy of Sciences of the United States of America* 104(50): 19680–85.

Namonje-Kapembwa, T., and A. Chapoto. 2016. "Improved Agricultural Technology Adoption in Zambia: Are Women Farmers Being Left Behind?" Working Paper 106, Indaba Agricultural Policy Research Institute, Lusaka, Zambia.

Orr, A., S. Homann Kee-Tui, and T. W. Tsusaka. 2014. "Gender Tools for Value Chain Analysis: Examples from Groundnuts in Eastern Province, Zambia." *Socioeconomics Discussion Paper 21, International Crops Research Institute for the Semi-Arid Tropics (ICRISAT)*. Lusaka, Zambia.

O'Shea, Paul. 2015. "Dodgy Dumplings and Lethal Liver: Risk, Food Terrorism, and Sino–Japanese Relations." *The Pacific Review* 28(2): 303–21.

Panter-Brick, Catherine. 2014. "Health, Risk, and Resilience: Interdisciplinary Concepts and Applications." *Annual Review of Anthropology* 43: 431–48.

Panter-Brick, Catherine, and James F. Leckman. 2013. "Editorial Commentary: Resilience in Child Development–Interconnected Pathways to Wellbeing." *Journal of Child Psychology and Psychiatry* 54(4): 333–36.

Peters, H. Peter. 2000. "From Information to Attitudes? Thoughts on the Relationship between Knowledge about Science and Technology and Attitudes toward Technologies." In *Between Understanding and Trust: The Public, Science and Technology*, ed. M. Dierkes and C. V. Grote, 265–86. Amsterdam: Harwood Academic.

Sabuncuoglu, Suna, Pinar Erkekoglu, Sevtap Aydin, Gönül Şahin, and Belma Kocer-Gumusel. 2015. "The Effects of Season and Gender on the Serum Aflatoxins and Ochratoxin A Levels of Healthy Adult Subjects from the Central Anatolia Region, Turkey." *European Journal of Nutrition* 54(4): 629–38.

Schoon, Ingrid. 2006. *Risk and Resilience: Adaptations in Changing Times*. Cambridge: Cambridge University Press.

Shephard, Gordon S. 2008. "Risk Assessment of Aflatoxins in Food in Africa." *Food Additives and Contaminants, Part A* 25(10): 1246–56.

Shipekesa, Arthur, and Thomas S. Jayne. 2012. "Gender Control and Labor Input: Who Controls the Proceeds from Staple Crop Production among Zambian Farmers?" Working Paper 68, Indaba Agricultural Policy Research Institute, Lusaka, Zambia.

Shuaib, F. M., P. E. Jolly, J. E. Ehiri, Y. Jiang, W. O. Ellis, J. K. Stiles, N. J. Yatich, E. Funkhouser, S. D. Person, C. Wilson, and J. H. Williams. 2010. "Association between Anemia and Aflatoxin B_1 Biomarker Levels among Pregnant Women in Kumasi, Ghana." *American Journal of Tropical Medicine and Hygiene* 83(5): 1077–83.

SocioCultural Research Consultants. 2015. "Dedoose Version 6.1.18." http://www.dedoose.com.

Turner, Billie L., Roger E. Kasperson, Pamela A. Matson, James J. McCarthy, Robert W. Corell, Lindsey Christensen, Noelle Eckley, J. X. Luers, M. L. Martello, and C. Polsky. 2003a. "A Framework for Vulnerability Analysis in Sustainability Science." *Proceedings of the National Academy of Sciences of the United States of America* 100(14): 8074–79.

Turner, P. C., S. E. Moore, A. J. Hall, A. M. Prentice, and C. P. Wild. 2003b. "Modification of Immune Function through Exposure to Dietary Aflatoxin in Gambian Children." *Environmental Health Perspectives* 111: 217–20.

Waliyar, F., P. L. Kumar, A. Traoré, B. R. Ntare, B. Diarra, and O. Kodio. 2008. "Pre- and Postharvest Management of Aflatoxin Contamination in Peanuts." In *Mycotoxins: Detection Methods, Management, Public Health and Agricultural Trade*, ed. John F. Leslie, Ranajit Bandyopadhyay, and Angelo Visconti, 209–18. Wallingford, UK: CABI.

Wild, C. P., and Y. Gong. 2010. "Mycotoxins and Human Disease: A Largely Ignored Global Health Issue." *Carcinogenesis* 31(1): 71–82.

Wild, C. P., and P. C. Turner. 2002. "The Toxicology of Aflatoxins as a Basis for Public Health Decisions." *Mutagenesis* 17(6): 471–81.

Williams, J. H., T. D. Phillips, P. E. Jolly, J. K. Stiles, C. M. Jolly, and D. Aggarwal. 2004. "Human Aflatoxicosis in Developing Countries: A Review of Toxicology, Exposure, Potential Health Consequences and Interventions." *American Journal of Clinical Nutrition* 80(5): 1106–22.

Wu, F., and P. Khlangwiset. 2010. "Health Economic Impacts and Cost-Effectiveness of Aflatoxin Reduction Strategies in Africa: Case Studies in Biocontrol and Post-harvest Interventions." *Food Additives and Contaminants* 27: 496–509.

Wu, Hui-Chen, Qiao Wang, Lian-Wen Wang, Hwai-I Yang, Habibul Ahsan, Wei-Yann Tsai, Li-Yu Wang, Shu-Yuan Chen, Chien-Jen Chen, and Regina M. Santella. 2007. "Polycyclic Aromatic Hydrocarbon- and Aflatoxin-Albumin Adducts, and Hepatitis B Virus Infection and Hepatocellular Carcinoma in Taiwan." *Cancer Letters* 252(1): 104–14.