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Risks of Ingestion of Aflatoxin-Contaminated Groundnuts in Benin: Scale Measurements, Beliefs, and Socioeconomic Factors

C. M. Jolly,[1]* B. Bayard,[2] and S. Vodouhe[3]

This study evaluates farmers' beliefs and perceived risks of aflatoxin (AF) on the consumption, production, and marketing of groundnuts. A survey was conducted with 181 farmers in Benin to assess their beliefs of AF effects on the marketing of groundnuts, and finally human and animal health. Awareness and action factors were also evaluated. Relationships of the belief and action factors with socioeconomic variables were evaluated using multiple indicators and multiple causes (MIMIC) models within a socioeconomic framework using a health belief model (HBM). The results indicate that the scale of the various constructs is reliable and the validity conforms to expectations. The unifactorial models developed in this study provide a satisfactory fit with NFl, CFI, and GFI exceeding 0.90. The results reveal that gender, age, and years of experience in farming significantly impact farmers' action regarding the reduction of AF in groundnut production and marketing. Male farmers are more likely to be aware of AF problems in groundnuts and feel more susceptible to the problems than their female counterparts. Gender and education seem to be dominating factors in the perception of barriers to mitigating the effects of AF, and male and older farmers are more likely to perceive the benefits of producing and marketing good quality groundnuts.

KEY WORDS: AF; belief; equation; groundnuts; health; model; structural

1. INTRODUCTION

AF presents a major financial and health risk to West African populations. AF contamination of grains inflicts annual losses of over $750 million in Africa,[1] and is a major economic and health concern for Benin groundnut (peanut) and maize producers, consumers, and policy decisionmakers. Two of the basic staples, groundnut and maize, consumed in Benin are usually highly contaminated with the fungus. Groundnuts are consumed throughout the country, though consumption varies with zone, with families reporting all-year consumption of 7–89%.[2] Continued consumption of low to moderate levels of AFs may result in chronic aflatoxicosis.[3] Jolly *et al.* reported from information from the Center of Disease Control that an outbreak of acute aflatoxicosis in Kenya resulted in deaths of 125 of 317 patients (39.4%).[3]

The basic staples, corn and groundnuts, are usually contaminated with levels of AF that far exceed the 20 ppb contamination level considered safe by the World Health Organization and Food and Agriculture Organization (FAO).[4,5] AFs are a group of extremely toxic metabolites produced by the fungi

[1] Auburn University, Auburn, AL, USA.
[2] Centre de Planification et d' Economie Appliqué, Haiti.
[3] University of the Republic of Benin, Cotonou, Benin.
* Address correspondence to C. M. Jolly, 202 Comer Hall Auburn, AL 36849, USA; tel: 334 844 5583; fax: 334 842 2577; cjolly@auburn.edu.

Aspergillus flavus and *A. paraticus*.[6] The risk of ingestion of AF-contaminated food products is serious in Benin where AF–albumin adducts were detected in 99% of 479 children.[2] Hell *et al.*[7] found that maize samples in southern Guinea and Sudan savannas were associated with higher AF levels and the forest/savanna mosaic was associated with lower toxin levels. Bouraima *et al.*[8] found AF B1 levels up to 14 μg/kg and AF G1 levels up to 58 μg/kg in stored maize from Benin. AF was detected in 98% of samples of dried yam chips examined in Benin, with levels ranging from 22 to 220 μg/kg and a mean value of 14 μg/kg. AFs cause carcinoma of the liver in a number of animal species[9] and have been associated with hepatocellular carcinoma in humans,[10,11] especially in people with hepatitis B infection. AFs also act as immunosuppressive agents[12–15] and increase susceptibility to infectious diseases in animals.[13,14]

AF contamination in groundnuts and grains is fostered by hot humid climate and by improper postharvest handling and storage practices.[16] The fungus is naturally occurring, and it is difficult to completely eliminate it, but it can be definitely controlled. Control of the fungus by developed countries to an acceptable level, according to the U.S. Food and Drug Administration, is achievable through some costly practices beyond the financial scope of limited-resource African farmers. However, the fungus can be controlled and reduced to an acceptable level by proper FAO recommended production and postharvest handling practices. Yet it is not known whether groundnut producers of Benin are aware of those recommended practices, and still more, of the endemic problem, the perceived seriousness, susceptibility, barriers, and benefits that influence their decisions to adopt measures to reduce the associated risks of AF groundnut contamination. In this article, we examined the factors that influence producers' awareness, the perceived health risks of AF groundnut contamination, and farmers' beliefs and attitude toward adoption of management practices to reduce AF contamination.

2. THEORETICAL FRAMEWORK

Social scientists, including economists and psychologists, have realized that a holistic approach is needed to understand producer and consumer decisions to adopt recommended food safety measures to reduce health and financial risks. They perceive the problem as unsolvable using a simple linear equation model, but believe that in order to explain individuals' decision-making processes they must attempt to decipher the relationships between attitudes and behaviors and how these influence economic choice.[17,18] These choices must be placed in a conceptual framework that considers the social, psychological, environmental, and economical context of individuals' risk avoidant behaviors. Lynne *et al.*[19] discussed the absence of a cohesive conceptual framework for linking psychological processes to economic decisions. They suggested a framework that provides a link between the psychosocial and economic variables. This economic decision model is based on the theory of reasoned action by Azjen and Fishbein.[20]

Based on the theory of reasoned action[21] and social cognitive theory,[22] we developed a framework to examine Benin farmers' behavior, knowledge, awareness, and attitude toward adopting hygienic and postharvesting practices to reduce AF in groundnuts. We borrowed from the Health Belief Model (HBM), widely employed to assess individuals' health behavior, to develop a framework incorporating psychosocial, physical, and economic constructs to evaluate how physical, demographic, and socioeconomic factors influence farmers' decisions to alter their production and marketing practices to reduce risks associated with production and marketing of groundnuts contaminated with AF. The HBM is widely used in nutritional intervention[23,24] and in agriculture by Lichtenberg and Zimmerman[25] to evaluate choice decisions. The HBM consists of four dimensions perceived: susceptibility (feelings of personal vulnerability); severity (the seriousness leading to the force behind changed behaviors); benefits (financial, economic health, or effectiveness that actions taken will reduce vulnerability); and barriers (the potential negative aspects of the costs of a particular health action).[26] The final component of the HBM is self-efficacy, which is one's perceived ability to modify a particular behavior. The construct of self-efficacy expands the model to what we call the Expanded Health Belief Model (EHBM).

We propose a structural model of farmers' consumption behaviors that integrates perceptual variables, attitude, awareness, and behavior. The model can be formed as follows:

$$\text{Perceptions} \Rightarrow \text{Awareness and attitudes} \quad (1)$$

$$\text{Awareness and attitude} \Rightarrow \text{Behavior.} \quad (2)$$

The motivational variables, susceptibility, seriousness, benefits, barriers, awareness, and knowledge, that persuade individuals to take action are not directly measured and must be determined. We used factor analysis to isolate those constructs. The relationship between the observed and latent variables can be represented by the following equations:

$$\boldsymbol{x} = \boldsymbol{\Lambda}_{\boldsymbol{x}}\xi + \boldsymbol{\delta} \quad (3)$$

$$\boldsymbol{y} = \boldsymbol{\Lambda}_{y}\boldsymbol{\eta} + \boldsymbol{\varepsilon} \quad (4)$$

where $\boldsymbol{x}$ and $\boldsymbol{y}$ are $q \times 1$ and $p \times 1$ vectors of observed variables, respectively; $\boldsymbol{\xi}$ is the $n \times 1$ matrix of a random vector of the latent exogenous variables; $\boldsymbol{\Lambda}_{\boldsymbol{x}}$ is a $q \times m$ matrix of regression coefficients relating the observed variables to the underlying factors; $\boldsymbol{\eta}$ is the $m \times 1$ matrix of a random vector of latent endogenous variables; $\boldsymbol{\Lambda}_{\boldsymbol{y}}$ is a $p \times m$ matrix of coefficients of the regression relating $\boldsymbol{y}$ to $\boldsymbol{\eta}$; and $\boldsymbol{\delta}$ and $\boldsymbol{\varepsilon}$ are $q \times 1$ and $p \times 1$ vectors of measurement errors in $\boldsymbol{x}$ and $\boldsymbol{y}$, respectively.

Structural equation modeling and path analysis are used to examine how the motivational variables influence the decision by individuals to take action by developing the awareness and attitude that lead to the engagement in proper AF-reduction activities. The hypothesized structural model is mathematically represented by the following equations:

$$\xi_1 = \alpha_{11}\text{age} + \alpha_{12}\text{gen} + \alpha_{13}\text{profes} + \alpha_{14}\text{educat} + \alpha_{15}\text{inc} + \alpha_{16}\text{mktdep} + \zeta_1 \quad (5)$$

$$\xi_2 = \alpha_{21}\text{age} + \alpha_{22}\text{gen} + \alpha_{23}\text{profes} + \alpha_{24}\text{educat} + \alpha_{25}\text{inc} + \alpha_{26}\text{mktdep} + \zeta_2 \quad (6)$$

$$\xi_3 = \alpha_{31}\text{age} + \alpha_{32}\text{gen} + \alpha_{33}\text{profes} + \alpha_{34}\text{educat} + \alpha_{35}\text{inc} + \alpha_{36}\text{mktdep} + \zeta_3 \quad (7)$$

$$\xi_4 = \alpha_{41}\text{age} + \alpha_{42}\text{gen} + \alpha_{43}\text{profes} + \alpha_{44}\text{educat} + \alpha_{45}\text{inc} + \alpha_{46}\text{mktdep} + \zeta_4 \quad (8)$$

$$\eta_1 = \gamma_{11}\xi_1 + \gamma_{12}\xi_2 + \gamma_{13}\xi_3 + \gamma_{14}\xi_4 + \gamma_{15}Z + \zeta_5 \quad (9)$$

$$\eta_2 = \gamma_{21}\xi_1 + \gamma_{22}\xi_2 + \gamma_{23}\xi_3 + \gamma_{24}\xi_4 + \gamma_{25}Z + \zeta_6 \quad (10)$$

$$\eta_3 = \beta_{31}\eta_1 + \beta_{32}\eta_2 + \beta_{32}Z + \zeta_7 \quad (11)$$

where ξ_1 = perceived susceptibility, ξ_2 = perceived seriousness, ξ_3 = perceived benefits, ξ_4 = perceived barriers, η_1 = awareness, η_2 = knowledge, and η_3 = action. Age = age of the respondent, gen = sex, profess = type of profession, educat = education level, inc = income level, and mktdep = market dependency on groundnut consumption. Z represents all the variables used in Equations (4) through (6); β and γ are matrices of coefficient estimates.

The model posits that awareness and attitude affect farmers' behaviors. Awareness of and attitudes toward AF contamination are influenced by local people's perceptions of the problem. Individuals who perceive the seriousness of the risks associated with AF contamination, and perceive themselves susceptible to the negative impacts, are likely to become aware of the magnitude of the problem, develop positive attitudes toward it, and change their behavior by adopting sustainable agricultural practices to reduce the risks. However, their levels of awareness and attitudes will be based on a cost-benefit analysis of the perceived barriers to and perceived benefits of their actions.

The HBM was chosen as the basis of the theoretical framework based on its proven ability to successfully predict health behaviors.[23] The HBM is employed to assess the value the experts place on attaining the goal of reduction of the risks due to AF-contaminated groundnuts and the likelihood that the actions taken will reduce the risks.

The actions taken to reduce risks are greatly influenced by a number of enabling sociodemographic variables, such as gender, age, income, education, and professional and nonprofessional activities.[27] Davidson and Freudenburg[28] noted that an individual's gender, role in the household, level of employment, and the number of children at home may be interrelated and may influence the individual's perception of risks. Age may play an important part in how individuals perceive food risks. Krewski *et al.*[29] reported that respondents in higher age categories (55 years of age and older) were more likely to rate risks than those less than 30 years old. Research has shown that as the level of income increases, the overall perception of the world as a risky place decreases. Dosman *et al.*[27] suggest that this phenomenon exists because individuals with higher income are able to purchase products to minimize their exposure to, or mediate the level of, risk. McDaniels,[30] on the other hand, found that household income level was significantly influenced by the willingness to pay to avoid risks. Krewski *et al.*[29] also found that educated individuals also had a better understanding of hazard. The educational level influenced their professional and nonprofessional activities.

3. METHODOLOGY

3.1. Research Area

A survey was administered to 181 farmers in three agro-ecological zones in Benin (Fig. 1). Benin is a narrow strip of land in West Africa sandwiched between Nigeria on the east, Togo on the west, and

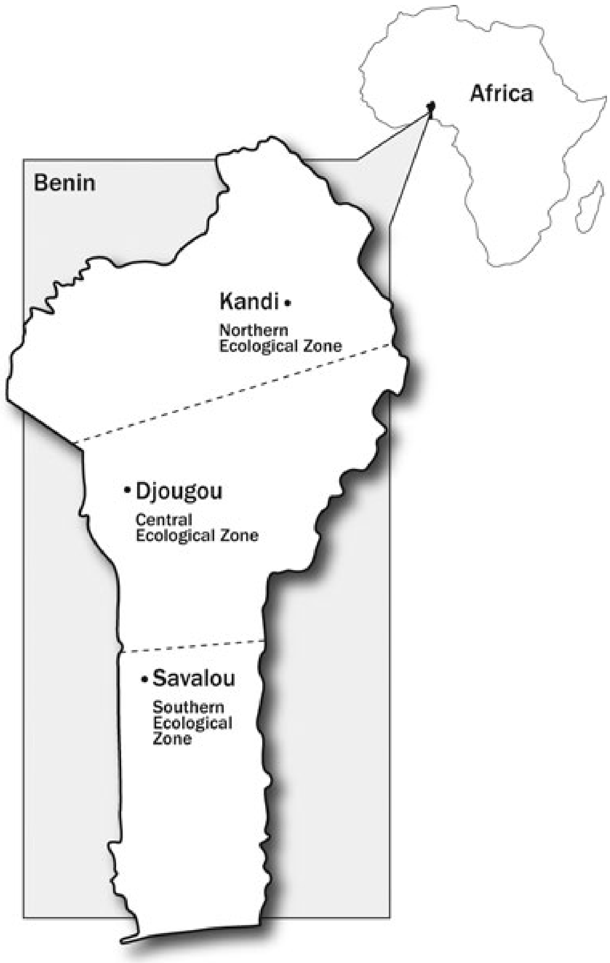

Fig. 1. Map of Benin showing research sites.

Burkina Faso and Niger on the north with the Atlantic Ocean on the south. We carried out the survey in three zones representative of groundnut producing areas in Benin. The southern area is represented by the Southern Guinea Savanna and villages around Savalou, the central region; Djougou represents the Northern Guinea Savanna, and Kandi represents the Sudan Savanna. The country is hot and humid with an annual rainfall of 36 cm or 14 inches. The country has two rainy seasons and two dry seasons. The principal rainy season is from April to late July and a shorter season from late September to November. Farmers cultivate their lands during both seasons but more groundnuts are produced during the first rainy season (April–July).

The country is mainly agricultural with 55% of its labor force dependent on agriculture. Palm products, cotton, yams, manioc, rice, corn, sorghum, and groundnuts are some of the main crops grown in Benin. In the year 2003, 142,500 metric tons of groundnuts were produced on 165,000 ha. About 90% of the agricultural output is produced on small holdings ranging from 0.1 ha to 5 ha in size. The country is self-sufficient in food and has a surplus for exports. Groundnuts are grown throughout the country, but the bulk of the nuts are produced in the northern Guinea and Sudan savannas. Groundnuts are produced in association or as a single crop. Farmers use traditional tools without much chemical inputs.

3.2. Sample and Survey Instrument

The sample of 181 farmers selected for the study included individuals directly involved in agriculture in general, and groundnut production and marketing in particular. The main objective of the survey was to gather information on farmers' perceptions and awareness of AF in groundnuts. The survey questionnaire was used to collect information on personal characteristics of the respondents, on their household, and on the structure of the farm. The questionnaire included seven sets of items that examined farmers' awareness, knowledge, and perceptions of AF problems. The included questions also represented perceptual constructs of perceived susceptibility to AF problems, perceived seriousness of the problem, perceived benefit of reducing AF risks in groundnuts, and perceived barriers to control.

3.3. Measure and Analysis

Items defining perceptions, awareness, and knowledge of AF in groundnuts were measured on a 5-point Likert scale. The questions were designed in a way that each element of the question represented a statement the respondents would have made if asked a question.[21] This was done to minimize respondent bias. For the perception and awareness variables, respondents indicated how sure they were about each statement, whereas the knowledge variables were labeled in terms of how important an issue was. An exploratory factor analysis of the awareness, knowledge, and perception variables was performed to assess farmers' beliefs about AF problems in groundnuts. A SCREE test with varimax rotation was used to identify the factors.[31] Results of this preliminary analysis are shown in the appendices.

The scale dimensional structure of each construct was assessed using a confirmatory factor analysis. Lisrel 8.54[32] provides a chi-square statistic to evaluate the fit of the factor model. The Bentler and Bonnet's Normed Fit Index (NFl) and the goodness-of-fit (GFI) were considered in model fit assessment. Since the chi-square test is sensitive to sample size, the comparative fit index[33,34] was also used in the fit assessment. The CFI is particularly appropriate for small samples.[31] A value of 0.90 or above for NFl, GFI, and CFI is considered a good fit.

3.4. Structural Relationships Between Perceptions and Sociodemographic Variables

For each perceptual construct developed, a multiple indicator and multiple cause (MIMIC) model,[32] we used the sample covariance matrix to examine the influence of farmers' sociodemographic characteristics on their beliefs. In this analysis, the effects of gender, age, size of household, education, size of farm, years of experience in farming, and the level of farmers' dependency on the market for groundnuts on perceptions, awareness, and knowledge were examined. "Market dependency" can be defined as the share of groundnuts sold out of the total production value.

4. RESULTS

4.1. Farmers' Responses

Male respondents accounted for about 71% of the sample, whereas women represented 29% (Table I). Respondents were on average 40.5 years old, with a range of 20–70 years. Sixty-nine percent of the respondents had no formal education. Respondents in the sample have been in the farming business for an average of l8 years. The average size farm was about 5.76 ha with 1.35 ha in peanuts produced in association with other crops, and with an average of 1.10 ha in pure peanut stand. Agricultural revenues per year were fairly evenly distributed, 35.6% earned less than 27,500 FCFA (US $1.00 = 4,500 FCFA), 31.1% earned between 275,000 and 575,000 FCFA, and 33.3% earned above 575,000 FCFA. About 29.3% of farmers had less than 10 years' experience in farming, 37.0% had between 11 and 20 years, and 33.7% had over 20 years.

Farmers were somewhat certain or definitely certain that they were aware of the dangers of AF shown in the Appendix, Table AI. Males revealed less uncertainty (43.4%) than females (10.16%) ($\chi^2 = 38.7629$, $p = 0.0001$). There was no difference in the levels of awareness among the three age groups, those less than 35 years old (10.72% uncertain), those between 35 years and 50 years (21.98%), and those older than 50 years old (29.41%) ($\chi^2 = 11.22$, $p = 0.19$). Farmers with lower levels of agricultural revenue were less uncertain (7.82%) than middle revenue earners (23.22%) and high agricultural revenue earners (30.0 percent) who were aware of the dangers of AF in groundnuts ($\chi^2 = 18.94$, $p = 0.015$). There were, however, differences in awareness among farmers with varying years of farming experience ($\chi^2 = 28.22$, $p = 0.0004$). Farmers with less than 10 years of farming experience showed less uncertainty (11.32%) of awareness than those with experience between 11 and 20 years (11.95%), and those with more than 20 years of farming experience (36.07%).

Table I. Sociodemographic Profile of Farmers in Benin

	Number of Farmers	Percentage (%)
Sex		
Female	53	29.3
Male	128	70.7
Age		
Less than 35 years old	56	30.9
35–50 years old	91	50.3
Over 50 years	34	18.8
Education		
No formal education	122	69.3
Primary school	46	26.1
Other	8	4.6
Agricultural revenue/year		
Less than 275,000 FCFA	64	35.6
275,000–575,000 FCFA	56	31.1
More than 575,000 FCFA	60	33.3
Years in farming		
Up to 10 years	53	29.3
11–20 years	67	37.0
More than 20 years	61	33.7

The "susceptibility" construct was divided into two subconstructs "Health Belief' and "Self-Confidence." In terms of the degree of susceptibility there was a marked difference between males (31.26% uncertain) and females (7.17 uncertain) in terms of their certainty of their susceptibility to the ill effects of AF ($\chi^2 = 12.02$, $p = 0.017$; Appendix, Table AII). Females were also less confident (75.47% uncertain) about their ability to withstand the effects of AF than males (87.5%) ($\chi^2 = 28.31$, $p = 0.0001$). There was no difference in age of farmers in terms of susceptibility to health effects of AF ($\chi^2 = 8.26$,

$p = 0.36$). However, farmers between the ages of 35 and 50 years old showed less uncertainty about their confidence to ward off the ill effects of AF than older or younger farmers ($\chi^2 = 14.34$, $p = 0.026$). Farmers with low levels of revenue were less certain about their susceptibility to the ill effects of AF than the farmers with higher levels of revenue ($\chi^2 = 18.09$, $p = 0.02$). However, there was no difference ($\chi^2 = 6.22$, $p = 0.398$) among the different income groups in their confidence to withstand the likely harmful effects of AF.

The seriousness construct was divided into two subconstructs "Self-Belief" and "Cynicism." Female farmers were more uncertain in the seriousness of self-beliefs than males farmers about the seriousness of the dangers of AF ($\chi^2 = 34.79$, $p = 0.0001$) (Appendix, Table AII). However, there were no differences in Cynicism among the sexes ($\chi^2 = 1.13$, $p = 0.0.769$). In terms of the subconstruct "Self-Belief" there was no difference among age groups ($\chi^2 = 5.2913$, $p = 0.726$), and similar results were obtained for "Cynicism" ($\chi^2 = 10.01$, $p = 0.132$). There was a significant difference among income groups for the seriousness subconstruct "Self-Belief" ($\chi^2 = 29.85$, $p = 0.0002$), but there was no difference for the "Cynicism" subconstruct ($\chi^2 = 8.06$, $p = 0.0233$).

The barrier construct was divided into two subconstructs "Cost" and "Lack of Control." There were significant differences by gender in the "Cost" subconstruct ($\chi^2 = 38.94$, $p = 0.0001$) (Appendix, Table AIII). There were also age differences ($\chi^2 = 21.73$, $p = 0054$) in certainty of meeting the cost of reducing the incidence of AF, with younger farmers showing the most uncertainty (Appendix, Table AIII). There were no differences ($\chi^2 = 2.69$, $p = 0.122$) among income groups about the certainty of handling the costs of reducing the incidence of AF contamination of groundnuts. For the "Lack of Control" subconstruct, there were no significant differences in age, gender, income, and years of experience in farming.

The benefit construct was divided into two subconstructs, "Hygiene," which connotes the benefit derived from the cleaning of the groundnut, and the "Health Improvement," which emanates from consuming a cleaner product. Males revealed more certainty ($\chi^2 = 45.51$, $p = 0.0001$) about the hygienic benefits of having a cleaner product than females. The younger farmers, those younger than 35 years, were more assertive of the hygienic benefits of a cleaner product. Surprisingly, the lower income group indicated that they were more certain about the hygienic benefits of AF-reduced groundnuts ($\chi^2 = 13.236$, $p = 0.039$). Farmers who had been farming between 11 and 20 years were more certain of the hygienic benefits of a cleaner groundnut.

Male farmers were less certain than females of the health improvement benefits of a cleaner groundnut ($\chi^2 = 28.38$, $p = 0.0001$). There was no significant difference ($\chi^2 = 12.56$, $p = 0.117$) among age groups about the health improvement benefits of a cleaner groundnut. However, the various income groups differed in their opinion about the benefits of a cleaner groundnut ($\chi^2 = 28.56$, $p = 0.0004$). The highest income group was less certain about the health improvement effects of an AF-reduced groundnut. Farmers with less than 10 years of experience were also less certain of the health improvement benefits of a cleaner groundnut ($\chi^2 = 23.50$, $p = 0.0001$).

Simple Spearman's correlation of the constructs and sociodemographic variables show that action, awareness, seriousness, and barrier were significantly correlated with gender. Susceptibility and seriousness were correlated with age (Table II). Action was positively related to awareness, but negatively associated with susceptibility. Action was also positively related to barrier. Seriousness was positively related to both barrier and benefits, and net per capita revenue was negatively related to susceptibility.

The results of the confirmatory factor analysis are presented in Tables III and IV. Confirmatory factor analysis supports the unifactorial structure of the awareness of AF in groundnuts. The analysis showed that awareness was fairly and adequately described by a one-factor model. The chi-square was 22.28 for 11 degrees of freedom. Although a p-value of 0.022 was obtained, values for NFl, GFI, and CFI were 0.98, 0.97, and 0.99, respectively. Those indicators suggest that the model fit is acceptable. All items submitted to the analysis were strongly related to the awareness construct. Items indicated that farmers were aware of AF in groundnuts and maize, and economic and associated human risks of consuming AF-contaminated groundnuts were isolated.

The two knowledge factors suggested by the factor analysis were supported by the confirmatory factor analysis. The first factor "AF production familiarity" can be interpreted as knowledge of importance of nut preparation. This factor has a chi-square of 2.81 ($df = 1$, $p < 0.093$), a NFl of 0.97, a GFI of 0.99, and a CFI of 0.98. The second factor "AF market familiarity" can be viewed as knowledge of importance of cultural practices to reduce AF in groundnuts. The model for the second factor was saturated with a perfect fit ($p = 1$) (Table III).

Table II. Correlation Coefficient Matrix of Socioeconomic, Farm Variables, and Perceptual Constructs

	Gender	Age	Dependent	Active in Ag.	Temp. Paid	Action	Awareness	Susceptibility	Seriousness	Barrier	Benefit	*N* per Capita[c]
Gender	1											
Age	−0.230**	1										
Dependents	−0.182*	0.068	1									
Active in Agr.[a]	0.085	−0.106	0.324**	1								
Temp. paid[b]	0.127	−0.049	0.117	0.041	1							
Action	0.458**	−0.065	−0.01	0.129	0.076	1						
Awareness	0.458**	−0.089	−0.03	0.006	−0.035	0.713**	1					
Susceptibility	−0.029	0.172*	−0.031	−0.061	0.101	−0.194**	−0.221**	1				
Seriousness	0.185*	0.176*	−0.041	0.108	0.234**	0.13	−0.067	0.521**	1			
Barrier	0.440**	0.002	0.044	0.071	0.105	0.374**	0.422**	−0.057	0.290**	1		
Benefit	−0.039	0.086	0.019	−0.225**	0.069	0.037	0.107	0.284**	0.219**	0.073	1	
N per capita[c]	−0.027	−0.322**	0.051	−0.079	0.038	−0.072	−0.093	−0.170*	−0.146	−0.101	−0.214**	1

[a]Number of active persons in household engaged in agriculture.
[b]Number of temporary workers employed.
[c]Net per capita revenue.
**Correlation is significant at the 0.01 level (two-tailed).
*Correlation is significant at the 0.05 level (two-tailed).

Table III. Confirmatory Factor Analysis for the Awareness of Aflatoxin

Indicator	Standardized Estimate		*t*-Value
Awareness			
Are you aware of aflatoxin contamination in crops	0.83[a]		–
Are you aware of aflatoxin contamination in groundnuts	0.86		14.16*
Are you aware of the effects of aflatoxins on animals	0.51		7.16*
Are you aware of the harmful effects of aflatoxins on humans	0.72		10.9*
Discolored nuts are not harmful when eaten	0.69		10.37*
Damaged and broken nuts do not spoil the others in storage	0.60		8.57*
Are you aware of socioeconomic impacts of aflatoxin	0.93		15.9*
X^2		22.28	
df		11	
p-value		0.022	
NFI		0.98	
GFI		0.97	
CFI		0.99	
Knowledge 1			
Sorting of groundnuts	0.38		–
Proper storage	0.47		3.98
Use of pesticides to reduce moldiness	0.55		3.20
Sorting of groundnut pods at harvest time	0.66		3.04
X^2		2.81	
df		1.0	
p-value		0.093	
NFI		0.97	
GFI		0.99	
CFI		0.98	
Knowledge 2			
Timing of the planting of groundnuts	0.59		–
Cultural practices to control moldiness	0.83		5.27
Timely harvesting to control moldiness	0.60		5.82
The model has a perfect fit; *p*-value = 1			

[a]Parameter was fixed to 1; no *t*-value is given. $^*p < 0.05$.

A single factor was retained to indicate farmers' susceptibility to the problem. The results of the analysis revealed that seriousness of AF in groundnuts, benefits of controlling the problem, and barriers to actions were adequately described by a one-factor model. The seriousness factor can be termed "self-belief." Items related to this factor dealt with farmers' beliefs about the effects of eating contaminated nuts on animal and human health. The seriousness factor had a chi-square of 2.27 ($df = 1$, <0. 1 3), a NFl of 1 .0, a GFI of 0.99, and a CFI of 1 .0, suggesting an adequate fit (Table IV).

The unique barrier factor was adequately defined by five items stressing the costs of controlling AF contamination in groundnuts. This factor had a relatively good fit with a chi-square of 1 1.57 ($df = 5$, $p < 0.04$l), a NFl of 0.97, a GFI of 0.97, and a CFI of 0.98. The benefit factor was described by three variables that stressed the hygienic and market importance of controlling AF in groundnuts. Farmers realized that good quality groundnuts sold faster, and for a better price. The one-factor model showed a perfect fit. The factor was correlated with cost of sorting, space, time, and difficulty of irrigation and harvesting in a timely manner.

To assess factors influencing farmers' perceptions of AF in groundnuts, a MIMIC model was estimated for each perceptual concept. The estimated results are displayed in Table V. In all models, values for NFI, GFI, and CFI exceeded 0.90, indicating an acceptable fit. The results showed that male respondents are most likely to be aware of AF in groundnuts, to have some knowledge about the problem, to perceive its seriousness, and to have greater perception of barriers to behavioral control. Age was significantly related to perceived seriousness of AF in groundnuts. Older farmers are more likely to perceive the seriousness of AF contamination in groundnuts than younger ones.

Household size was significantly related to perceived net economic benefits and perceived barriers of AF control. The results showed a positive

Table IV. Confirmatory Factor Analysis for Farmers Beliefs About Aflatoxins

Indicator	Standardized Estimate		t-Value
Seriousness			
My animals have never been sick from eating contaminated nuts	0.93		–
We have been eating groundnuts for years, but have never gotten sick	0.89		15.02
Sickness from discolored nuts is for a short time	0.89		14.19
Eating discolored groundnuts may make me sick, but they cannot kill me	0.68		10.44
X^2		2.27	
df		1	
p-value		0.13	
NFI		1.0	
GFI		0.99	
CFI		1.0	
Barrier			
Sorting groundnuts is too costly	0.84		–
Sorting groundnuts is time consuming	0.73		9.25
Irrigation is not possible here	0.53		6.72
Proper storage requires too much space	0.67		8.51
Harvesting during the first rainy season is possible only during the humid period	0.50		6.29
X^2		11.57	
df		5	
p-value		0.041	
NFI		0.97	
GFI		0.97	
CFI		0.98	
Benefit			
Sorting of nuts is hygienic	0.44		–
Clean nuts give a better product price	0.87		3.79
Clean nuts always sell faster	0.60		4.79
This model has a perfect fit; p-value = 1			

relationship between household size, benefits, and barriers. The results indicated that education has a positive influence on perceived seriousness, benefits, and barriers. Better educated farmers had a greater perception of the seriousness of AF in groundnuts and perceived greater benefits of reducing risks associated with the consumption of AF in groundnuts. Though this outcome may seem perverse, the more educated farmers also perceived greater barriers to control AF groundnut contamination.

The results suggest that awareness of AF in groundnuts decreases with the number of years of experience in farming, whereas perception of the seriousness of the problem is negatively related to the size of the farm. The level of farmers' dependence on the market for groundnut production distribution was negatively related to their perception of seriousness of AF problem, perceived benefits, and barriers. Knowledge of AF problems in groundnuts was also negatively related to market dependence.

5. DISCUSSION AND CONCLUSION

The study showed that there were significant differences among sociodemographic groups in their awareness of the AF problems. Generally, males who worked and produced groundnuts revealed greater awareness of the AF risks. There were no significant differences among age groups about the perception of the AF contamination problem. However, there were differences among income classes and years of experience. There were also differences in terms of health belief and the risks of perceptions of AF contamination of groundnuts, and these varied by socioeconomic characteristics. In general, farmers were serious about the AF problem; they felt susceptible to the dangers though there was some expressed Cynicism and they felt that the problem was burdensome and they were doubtful of the benefits.

This study developed scale measures of farmers' perceptions, awareness, and knowledge of AF

Table V. Regression Analysis of Constructs on Socioeconomic Variables and Farm Variables

	Seriousness		Benefits		Barriers		Awareness		Knowledge	
	Estimate[a]	*t*-Value	Estimate	*t*-Value	Estimate	*t*-Value	Estimate	*t*-Value	Estimate	*t*-Value
Gender (male)	0.19*	2.81	0.20	1.93	0.45*	4.93	0.32*	3.99	0.35*	2.55
Age	0.21*	2.62	−0.05	−0.45	–	–	–	–	0.17	1.65
Size of household	0.09	1.37	0.24*	2.45	0.16*	2.03	0.05	0.86	0.03	0.42
Education	0.12*	1.99	0.33*	3.31	0.22*	2.84	–	–	−0.02	−0.30
Years of experience in farming	−0.05	−0.59	−0.03	−0.24	−0.07	−0.94	−0.16*	−2.34	−0.10	−1.13
Size of farm	−0.21*	−3.36	0.11	1.27	–	–	–	–	−0.01	−0.12
Market dependence of groundnuts	−0.56*	−7.14	−0.26*	−2.42	−0.30*	−3.24	−0.09	−1.18	−0.28*	−2.30
X^2 (*df*)	32.94 (21)		23.67 (14)		28.43 (15)		83.16 (39)		31.07 (21)	
p-value	0.047		0.05		0.019		0.002		0.073	
NFI	0.97		0.93		0.94		0.95		0.94	
CFI	0.99		0.97		0.97		0.97		0.98	
GFI	0.97		0.97		0.97		0.93		0.97	
R^2	0.45		0.23		0.33		0.19		0.30	

[a]Standardized estimate; *Significant at 0.05 level.

contamination in groundnuts in Benin. The process involved using confirmatory factor analysis to examine the dimensional structure of the perceptual variables. The results revealed one factor with multiple indicators for awareness, seriousness, benefit, and barriers. The analyses provided support for two types of knowledge, the importance of adequate operations on the nuts, and that of the cultural practices in AF control. Results of the confirmatory factor analysis globally provided an adequate fit for all of the models. The analysis shed light on the issues that are central to the analysis of farmers' perceptions of AF-contaminated groundnuts in Benin.

Household size was positively related not only to benefits, but also to barriers. This means as the household size increased, the greater the market participants were likely to be influenced by the hygienic and economic benefits emanating from adopting measures to reduce the risks of contaminated groundnuts. On the other hand, the household size was positively related to the placement of barriers to reduce risks of AF-contaminated groundnuts. While the two preceding statements may seem to contradict each other, one may think about the attempts made by the household to maximize net benefits. Two of the processes in maximizing net benefits require expanding income and reducing costs. Since the barriers are measured in terms of costs, large households would be positively opposed to increasing costs though they are in favor of increasing total benefits from improving groundnut quality.

An important result of this study is the significant relationships between farmers' level of education and their perceptions of the seriousness of AF contamination, their perceived benefits, and barriers. This could mean that these farmers, though willing to reduce AF levels, are more conscious of the accounting burden of the activities to reduce AF in groundnuts. Dosman *et al.*[27] stated that education can affect respondents' perceptions of health risks in two ways. Individuals with higher levels of education may have a better understanding of food risks, and education may help with the understanding of risks and how to proceed to mediation. This result suggests that education, formal or informal, may play a significant role in a campaign to control AF dissemination in Benin.

Age was positively related to the seriousness, benefits, and barriers. A study by Krewski *et al.*[29] reported that respondents in the higher age categories (55 and older) were more likely to rate risks than those younger than 30 years old. Van Liere and Dunlap[35] found that concern for health risks from toxic waste was more serious among younger respondents.

The influence of gender on awareness, knowledge, and perceptions is worth mentioning. Previous studies have shown that a gender role in food preparation influences food safety risk perception.[28] In Benin, agricultural production is mainly dominated by men, who are the prime target of any program in agriculture. The study showed that men are more likely to be aware of AF contamination in groundnuts. These results suggest that special attention should be given to women who are primarily involved in food preparation and/or groundnut seeds.

The more farmers produce groundnuts for the market, the less they consume their own production and the more they appear to be indifferent to AF problems. Farmers may be less preoccupied by this issue if they consume only an insignificant portion of their own production. They may also perceive the high costs of producing good quality nuts of less importance than the financial benefits derivable from a sustainable product price.

This study has some important and worthwhile implications for putting in perspective the knowledge of the indicators underlying farmers' perceptions, awareness, and knowledge of AF in groundnuts in Benin. It also provides indications of factors that are likely to influence individuals' beliefs. Policies directed at reducing AF contamination of groundnuts should consider gender and the role played in the household, the age of farmer, market dependence on groundnuts, the education of farmers, and the size of households. These policies should be supported by strong awareness programs to educate the populace about the seriousness of the problems and the costs and benefits of reducing the associated risks.

Although the results are insightful, it is necessary to consider a larger sample size in order to improve the knowledge of the dimension of farmers' perceptions of issues related to AF reduction in groundnuts. Also, structural relationships between perceptual variables need to be explored, along with the sociodemographic factors, in order to develop a broader understanding of the factors that may influence farmers' beliefs.

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APPENDIX

Table AI. Perceived Awareness of Groundnut Aflatoxin Contamination by Categories of Benin Farmers (Values in Percentage)

Perceptions	Categories	Uncertain	Somewhat Certain	Definitely Certain	(p-value)
	Gender				
	Female	43.40	54.71	1.89	38.76 (0.0001)
	Male	10.16	66.41	23.44	
	Age groups				
	<35 years old	10.72	67.85	21.43	
	35–50 years old				
	>50 years old	29.41	52.94	17.65	11.218 (0.189)
Awareness	Agricultural revenue				
	Income less than 275,000 FCFA	7.82	76.56	15.63	
	275,000–575,000 FCFA	23.22	62.50	14.29	18.94 (0.015)
	>575,000 FCFA	30.00	48.33	21.67	
	Years in farming				
	≤10 years in farming	11.32	66.04	22.64	
	11–20 years in farming	11.95	71.64	16.42	28.22 (0.0004)
	>20 years in farming	36.07	50.82	13.11	

Table AII. Susceptibility to AF Contamination and Seriousness by Categories of Benin Farmers (Values in Percentage)

Categories	Uncertain	Somewhat Certain	Definitely Certain	x^2 (p-value)	Categories	Uncertain	Somewhat Certain	Definitely Certain	x^2 (p-value)
Perceptions of susceptibility health belief					Perceptions of seriousness self-belief				
Gender					Gender				
Female	7.17	52.83	0	12.02 (0.017)	Female	77.36	22.64	0	24.79 (0.0001)
Male	31.26	57.03	11.72		Male	57.82	29.69	12.5	
Age groups					Age groups				
<35 years old	48.22	44.65	7.14		<35 years old	71.43	21.43	7/14	
35–50 years old	30.77	61.54	7.69		35–50 years old	62.64	28.57	8.79	
50 years old	29.41	58.82	11.76	8.8263 (0.35.72)	>50 years old	52.94	35.29	11.76	5.2913 (0.726)
Agricultural revenue					Agricultural revenue				
Income less than 275,000 /FCFA	18.75	68.75	12.5		Income less than 275,000 FCFA	45.32	40.63	14.06	
275,000–575,000 FCFA	41.07	68.21	10.71		275,000–575,000 FCFA	75	14.28	10.71	
>575,000 FCFA	48.34	50	1.67	18.09 (0.020)	>575,000 FCFA	71.67	26.67	1.67	29.85 (0/0002)
Years in farming					Years in farming				
≤10 years in farming	43.4	47.17	9.43		≤10 years in farming	64.15	26.42	9.43	
11–20 years in farming	38.8	55.23	5.97		11–20 years in farming	76.12	17.91	5.97	
>20 years in farming	26.23	63.94	9.84	9.783 (0.280)	>20 years in farming	49.18	39.34	11.4	19.96 (0.010)
Perceptions of susceptibility self-confident					Perceptions of seriousness Cynicism				
Gender					Gender				
Female	75.47	24.53	–	28.31 (0.0001)	Female	26.41	73.39	–	1.13 (0.769)
Male	87.5	12.5	–		Male	29.69	70.32	–	
Age groups					Age groups				
<35 years old	92.86	7.14	–		<35 years old	42.86	57.14	–	
35–50 years old	74.72	25.27	–		35–50 years old	24.17	75.82	–	
>50 years old	94.11	5.88	–	14.34 (0.026)	>50 years old	17.65	82.35	–	11.15 (0.083)
Agricultural revenue					Agricultural revenue				
Income less than 275,000 FCFA	81.25	18.75	—-		Income less than 275,000 FCFA	20.32	79.69	—	
275,000–575,000 FCFA	89.29	10.71	—		275,000–575,000 FCFA	32.15	67.86	—	
>575,000 FCFA	81.66	18.34	—	6.22 (0.398)	>575,000 FCFA	35	65	—	8.06 (0.233)
Years in farming					Years in farming				
≤10 years in farming	94.34	5.66	—		≤10 years in farming	37.74	62.26	—	
11–20 years in farming	80.6	19.41	—		11–20 years in farming	32.84	67.16	—	
>20 years in farming	78.69	21.31	—	11.58 (0.0710)	>20 years in farming	16.39	83.61	—	10.01 (0.123)

Table AIII. Perceived Barriers and Benefits to Groundnut AF Control by Categories of Benin Farmers (Values in Percentage)

Categories	Uncertain	Somewhat Certain	Definitely Certain	x^2 (*p*-value)	Categories	Uncertain	Somewhat Certain	Definitely Certain	x^2 (*p*-value)
Perceptions of barrier (cost)					Perceptions of benefit (hygiene)				
Gender					Gender				
Female	9.43	83.02	7.55	38.94 (0.0001)	Female	0	75.47	24.53	47.5115 (0.0001)
Male	8.6	52.34	39.06		Male	0.78	28.134	71.09	
Age groups					Age groups				
<35 years old	17.86	57.14	25		<35 years old	1.79	37.5	60.71	
35–50 years old	3.3	67.03	29.67		35–50 years old	0	6.76	58.24	
50 years old	8.82	52.94	38.24	21.73 (0.0054)	>50 years old	0	50	50	14.925 (0.0208)
Agricultural revenue					Agricultural revenue				
Income less than 275,000 /FCFA	4.69	59.37	35.94		Income less than 275,000 FCFA	1.56	26.57	71.88	
275,000–575,000 FCFA	10.72	66.08	23.21		275,000–575,000 FCFA	0	50	50	
>575,000 FCFA	11.67	60	28.33	12.691 (0.122)	>575,000 FCFA	0	51.66	48.33	13.236 (0.039)
Years in farming					Years in farming				
≤10 years in farming	16.98	50.95	32.08		≤10 years in farming	1.89	37.73	60.38	
11–20 years in farming	1.49	67.16	31.34	12.6	11–20 years in farming	0	35.82	64.18	
>20 years in farming	9.84	63.93	26.23	−0.126	>20 years in farming	0	52.46	47.54	13.989 (0.0298)
Perceptions of barrier (lack of control)					Perceptions of benefit (health improvement)				
Gender					Gender				
Female	57.49	41.51	0	21.20 (0.0003)	Female	28.3	67.93	3.77	28.38 (0.0001)
Male	67.19	21.88	10.94		Male	71.09	27.35	1.56	
Age groups					Age groups				
<35 years old	58.93	33.93	7.14		<35 years old	62.5	35.71	1.79	
35–50 years old	71.43	21.98	6.59		35–50 years old	53.85	42.86	3.3	
>50 years old	55.88	32.35	11.26	11.80	>50 years old	64.7	35.3	0	12.85 (0.117)
Agricultural revenue					Agricultural revenue				
Income less than 275,000 FCFA	73.44	20.32	6.25		Income less than 275,000 FCFA	56.25	42.19	1.56	
275,000–575,000 FCFA	57.15	33.92	8.93		275,000–575,000 FCFA	59.54	41.07	0	
>575,000 FCFA	61.67	30	8.33	5.6568 (0.6856)	>575,000 FCFA	61.67	35	3.33	28.558 (0.0004)
Years in farming					Years in farming				
≤10 years in farming	62.27	32.07	5.66		≤10 years in farming	71.7	24.53	3.77	
11–20 years in farming	68.66	17.92	13.43		11–20 years in farming	58.21	41.3	1.49	
>20 years in farming	62.29	34.43	3.28	12.986 (0.1155)	>20 years in farming	47.54	50.82	1.64	23.50 (0.0028)

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