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Research Paper

An Assessment of Willingness To Pay by Maize and Groundnut Farmers for Aflatoxin Biocontrol Product in Northern Nigeria

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ABSTRACT

In Nigeria, Aflasafe is a registered biological product for reducing aflatoxin infestation of crops from the field to storage, making the crops safer for consumption. The important questions are whether farmers will purchase and apply this product to reduce aflatoxin contamination of crops, and if so under what conditions. A study was carried out to address these questions and assess determinants of willingness to pay (WTP) for the product among maize and groundnut farmers in Kano and Kaduna states in Nigeria. A multistage sampling technique was used to collect primary data from 492 farmers. The majority of farmers who had direct experience with Aflasafe (experienced farmers) in Kano (80.7%) and Kaduna (84.3%) had a WTP bid value equal to or greater than the threshold price ($10) at which Aflasafe was to be sold. The mean WTP estimates for Aflasafe for experienced farmers in Kano and Kaduna were statistically the same. However, values of $3.56 and $7.46 were offered in Kano and Kaduna states, respectively, by farmers who had never applied Aflasafe (inexperienced farmers), and the difference here was significant ($P < 0.01$). Regression results indicate that contact with extension agents ($P < 0.01$) and access to credit ($P < 0.05$) positively and significantly influenced the probability that a farmer would be willing to pay more for Aflasafe than the threshold price. Lack of awareness of the importance of Aflasafe was the major reason cited by inexperienced farmers (64% in Kano state and 21% in Kaduna state) for not using the product. A market strategy promoting a premium price for aflatoxin-safe produce and creating awareness and explaining the availability of Aflasafe to potential users should increase Aflasafe usage.

Key words: Aflasafe; Aflatoxin; Biocontrol; Logit model; Willingness to pay

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Aflatoxins are highly toxic chemical poisons produced mainly by the fungus *Aspergillus flavus* in many crops, including maize (*Zea mays*) and groundnut (*Arachis hypogaea*). These fungal toxins suppress the immune system, impede growth and development, cause liver disease, and may cause death depending on the level and duration of exposure *(18)*. Between 2004 and 2006, nearly 200 Kenyans died after consuming aflatoxin-contaminated maize, and in 2010 over 2 million bags of maize were found to be highly contaminated *(18)*. To improve the health and incomes of farming families in Africa, scientists at the International Institute of Tropical Agriculture (IITA) in partnership with the U.S. Department of Agriculture–Agricultural Research Service, University of Ibadan, and University of Bonn developed Aflasafe, a natural, safe, and cost-effective biocontrol product that drastically reduces aflatoxin contamination in food crops. This product has been registered under the name Aflasafe in Nigeria for application to maize and groundnut crops *(9)*. This product reduces the aflatoxin-producing fungus, making the crop safer for consumption. The biocontrol is effective for reducing aflatoxin by up to 50 to 90% *(29)*. Field testing of Aflasafe in Nigeria has produced extremely positive results; aflatoxin contamination of maize and groundnut was consistently reduced by 80 to 90% *(9, 16)*.

For small-scale farmers, the question of affordability and added value is central and will determine whether these farmers use the product, no matter how effective it is. Although commercial farmers can afford to pay the cost of Aflasafe, individual small-scale farmers may not be willing to pay even the relatively low cost of Aflasafe if they do not understand the risks associated with aflatoxin *(29)*. Small-scale farmers might require subsidies to get started using Aflasafe because use of this product does not have a direct effect on crop yields. However, use of Aflasafe will allow a farmer to produce grain that is safer for consumption for his or her personal consumption and to receive a premium market price from buyers who value grain that is aflatoxin safe. This increase in price also provides an additional incentive to increase the quality of grain a farmer can sell.

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The question is whether farmers will be willing to invest in technology given the current conditions in Nigeria where awareness of aflatoxin risks is still low. This study was carried out to answer the following research questions: (i) Are farmers willing to pay for Aflasafe, and if yes, under what conditions? (ii) What are the factors that influence farmers' willingness to pay (WTP) for Aflasafe? (iii) What are the key constraints to adoption of Aflasafe use in the study areas?

MATERIALS AND METHODS

Study region and data collection. The population for the study was composed of maize and groundnut farmers selected in Kano and Kaduna states, Nigeria. The farmers interviewed were separated into two groups. Group 1, experienced farmers (EFs), included those farmers who had applied Aflasafe and/or might have sold Aflasafe-treated maize and/or groundnut for a premium price; all the farmers in this group had had direct contact with the manufacturer of Aflasafe at some time in the past. Group 2, inexperienced farmers (IFs), included those farmers who did not have any experience with the product; all farmers in this group did not have any direct contact with the Aflasafe manufacturer or its representatives.

Primary data were collected through structured questionnaires administered using well-trained enumerators (see the supplemental material). A multistage sampling technique was adopted obtain a sample of 580 respondents for the study. The first stage involved directed selection of seven local government areas where there were high numbers of maize and groundnut farmers and where at least some farmers used Aflasafe in their crop production. The second stage involved directed selection of farming communities where aflatoxin and Aflasafe were already known. Ten farming communities from each local government area were then randomly selected.

The third stage involved random selection of 6% of the farmers from the EFs in each community to obtain a total of 120 farmers in 10 communities from Kano state and 170 farmers in 10 communities from Kaduna state who had experience with Aflasafe. This three-stage process was then repeated in communities where aflatoxin and Aflasafe were not known using the list of farmers with the head of each community. A total of 580 questionnaires were prepared for interviewing respondents, but only 492 questionnaires were successfully completed and retrieved for analysis. The observations from the 492 respondents were used in all the results of this study. Information on WTP was collected from farmers through the use of the contingent valuation method. This method is used to estimate the value that a person places on a particular item. Participants are asked to directly report their WTP to obtain a specified item rather than drawing inferences from observed behaviors in regular marketplaces *(14)*. This approach has been criticized as potentially leading to biased results when the questionnaires are not properly administered. In this study, data were collected through detailed interviews of farmers in their local language.

Method of analysis. The contingent valuation method was used to capture farmers' WTP, and descriptive statistics were employed to compute statistics such as mean, standard deviation (SD), and frequency distributions. Results were then used to compare WTP between EFs and IFs in the two states. Econometric modeling was used to determine factors influencing farmers' WTP for Aflasafe if it were made available. The base cost for 10 kg of Aflasafe was estimated for this study at $10, which was the minimum price it could be sold for at the time of the survey. Farmers were also asked whether they would pay $20 for Aflasafe. If the response was negative, the farmer was then asked the amount he or she was willing to pay. In the econometric analysis, a dependent variable corresponding to respondent's WTP for Aflasafe was represented by a dichotomous choice: 1 was recorded for any farmer willing to pay between $10 and $20, and 0 was recorded otherwise.

The logit model is specified below in its estimable form following a previous description *(15)*. The model is expressed implicitly as

$$\mathrm{Ln}\left(\frac{P_i}{1-P_i}\right) = Z_i = \beta_i + \beta\sum kX_{ik} + \varepsilon \qquad (1)$$

where $\mathrm{Ln}(P_i/1 - P_i)$ is the log-transformed odds ratio; P_i is the probability that a farmer will be willing or not willing to pay for Aflasafe, which ranges from 0 to 1 and is nonlinearly related to Z_i; β_i is a constant term or intercept; β_k is the coefficient of the explanatory variables X_{ik}; k ranges from 1, 2, . . . , n as an independent variable (with the ith observation); and ε is the error term with a mean of 0 as Z_i ranges from $-\infty$ to ∞ and P_i ranges from 0 to 1.

Empirically, data collected included the decision of farmers to buy and not to buy Aflasafe; thus, the dependent variable P is 1 when a farmer is willing to pay or has paid for Aflasafe at the price of $10 or above and is 0 otherwise. Based on the maximum likelihood estimation method, explanatory variables and the empirical model are as given below:

$$\begin{aligned}\mathrm{WTP}_i = {} & \beta_0 + \beta_1\mathrm{MALE}_i + \beta_2\mathrm{MARRIED}_i + \beta_3\mathrm{FEXPERIENCE}_i \\ & + \beta_4\mathrm{EDUCATED}_i + \beta_5\mathrm{HOUSEHOLD\_SIZE}_i \\ & + \beta_6\mathrm{USED\_AFLASAFE}_i + \beta_7\mathrm{ASSOCIATION}_i \\ & + \beta_8\mathrm{EXTENSION}_i + \beta_9\mathrm{CREDIT}_i \\ & + \beta_{10}\mathrm{EXPENDITURE}_i + \beta_{11}\mathrm{MAIZEONLY}_i \\ & + \beta_{12}\mathrm{KADUNA}_i + \varepsilon_i \qquad (2)\end{aligned}$$

The independent variables shown in equation 2 are explained in Table 1 and include farmer, farm technology–related, and institutional factors postulated to influence WTP. The rationale for inclusion of these factors was based on an a priori expectation from the agricultural technology adoption literature *(3, 28)*. In regard to gender (MALE) measured as a dummy variable (1, male; 0, female), the sign of this variable could not be determined a priori. A male farmer might be more proactive than a female farmer in WTP for a new technology because men often have easier access to new technologies than do women *(10, 13, 26, 27)*. Marital status (MARRIED) of the farmer also was hypothesized to be either positively or negatively related to WTP. Farm experience (FEXPERIENCE) might imply greater resources or authority that may give a farmer more possibilities for trying a new technology; this variable was hypothesized to be positively related to WTP. Education (EDUCATED) was hypothesized to influence WTP positively because as farmers acquire more education, their ability to obtain, process, and use new information improves and they are more likely to use it. In several studies, positive relationships have been found between education and technological adoption *(4, 5, 23, 27)*. Household size, defined here as all the number of people living under the same roof and eating from the same pot, has been identified to have either a positive or a negative influence on WTP *(8, 10, 19, 22, 27, 31)*. Larger family size is generally associated with a larger labor force available for the timely operation of farm activities. However, the negative relationship of this variable with the use of new technology has been linked to the increased

TABLE 1. *Variables used in regressions analysis*

Variable	Variable descriptions	A priori sign	Mean (SD)	% yes[a]
Dependent				
WTP	Willingness to pay for Aflasafe: 1, farmer is willing to pay at least the threshold; 0, farmer is not willing to pay the threshold		0.55 (0.50)	
WTPRICE	Actual price a farmer is willing to pay ($)		9.35 (6.32)	
Independent				
MALE	Gender of farmer: 1, male; 0, female	±		0.96
MARRIED	Marital status: 1, married; 0, otherwise	±		0.90
FEXPERIENCE	No. of years of farming experience	+	18.52 (10.57)	
EDUCATED	Farmer education: 1, educated; 0, otherwise	+		0.63
HOUSEHOLD_SIZE	No. of people living in a household	±	10.00 (7.00)	
USED_AFLASAFE	Farmers had used Aflasafe before: 1, EFs; 0, IFs[b]			0.5
ASSOCIATION	Membership in association: 1, association; 0, other	+		0.75
EXTENSION	Contact with extension agent: 1, contact; 0, no contact	+		0.85
CREDIT	Access to credit: 1, access; 0, no access	+		0.42
EXPENDITURE	Total household expenditure ($)	+	1391.4 (1,315.20)	
MAIZEONLY	Type of crop(s) grown: 1, only maize; 0, maize and groundnut	+		0.63
KADUNA	State: 1, Kaduna; 0, Kano	+		0.52

[a] Yes answers were given a value of 1.
[b] EFs, experienced farmers; IFs, inexperienced farmers.

consumption pressure associable with a large family. Therefore, it was difficult to predict the impact of this variable a priori in this study. USED_AFLASAFE is a variable that classified farmers into users or nonusers of Aflasafe: 1, EFs; 0, IFs. Farmers' involvement in social activities was measured by membership in social organizations (ASSOCIATION); membership was expected to positively influence WTP because belonging to a social organization provides a platform for spread of information about innovations and willingness to adopt such innovations *(7, 24)*. Access to extension agents (EXTENSION) by the farmers can be a positive influence on WTP for Aflasafe due in part to access to information about aflatoxin and its pervasive threats to humans and animals and the mitigating effects of Aflasafe *(25)*. Access to credit (CREDIT) relates to financing the expenses associated with the use of innovations. Access to credit boosts farmers' WTP, and this variable was hypothesized to have a positive influence on the probability of adoption and use of Aflasafe *(7, 10, 21, 27, 31)*: 1, access; 0, no access.

Total expenditure (EXPENDITURE) is a proxy for the wealth status of the farmers because higher expenditure is synonymous with greater wealth. Thus, farmers with higher total expenditure were more likely to pay for Aflasafe because more cash would be available to allow them to try new things. The type of crop grown was also captured as a dummy variable; 1, maize only; 0, maize and groundnut. Growing maize only was hypothesized to be positively related to WTP for Aflasafe possibly because of increased tendency to avoid loss and mitigate risks associated with growing only one crop. The geographical location of the study state (KADUNA) can also influence the WTP. The population and state of development of supporting institutions of a particular state could favor WTP *(20)*: 1, farmer from Kaduna; 0, farmer from Kano.

RESULTS

Socioeconomic factors. There are significant differences in socioeconomic factors (Table 2) between farmers who have used Aflasafe (EFs) and those who have not used it (IFs). Evaluation of the socioeconomic characteristics across states revealed significant differences with some inconsistencies in few cases. However, socioeconomic factors were expected to influence farmers' WTP for Aflasafe at the threshold price of $10 *(1, 2)*.

TABLE 2. *Socioeconomic characteristics of responding farmers*[a]

	Kano state			Kaduna state		
Variable	EFs	IFs	Mean difference[b]	EFs	IFs	Mean difference
Age (yr)	49 (10.97)	40 (12.87)	9**	39 (12.02)	36 (8.69)	3
Farm experience (yr)	25 (10.98)	17 (11.43)	8***	18 (10.28)	9 (6.61)	9**
Farm size (ha)	9 (9.32)	4 (2.84)	5***	7 (10.35)	4 (1.76)	3**
Household size (no.)	14 (7.52)	9 (6.61)	5**	10 (7.51)	9 (6.89)	1
Organization membership (yr)	9 (5.98)	7 (4.11)	2***	4 (3.15)	6 (3.93)	2***
Formal education (% of respondents)	62.20	45.30		56.70	50.40	
No. of respondents	119	119		127	127	

[a] Values are mean (SD). EFs, experienced farmers; IFs, inexperienced farmers.
[b] *** $P < 0.01$; ** $P < 0.05$; * $P < 0.10$.

TABLE 3. *Aflatoxin and Aflasafe awareness in the study area disaggregated by type of farmer*[a]

	% of farmers					
	Pooled		Kano		Kaduna	
Variable[b]	EFs	IFs	EFs	IFs	EFs	IFs
Aflatoxin aware	100.0	56.7	100.0	39.3	100.0	72.4
Aflasafe aware	100.0	56.1	100.0	38.7	100.0	72.4
Aflasafe use	100.0	0.0	100.0	0.0	100.0	0.0
WTP (if available)	100.0	48.4	100.0	22.7	100.0	72.4
WTP (1, ≥$10; 0, <$10)	82.5	31.7	80.7	17.7	84.3	44.9
WTP (1, >$0; 0, $0)	100.0	53.7	100.0	33.6	100.0	72.4
No. of respondents	246	246	119	119	127	127

[a] EFs, experienced farmers; IFs, inexperienced farmers.

[b] All variables are dummies. For WTP, >$0 indicates that farmers were willing to pay above $0 but not necessarily the minimum price for Aflasafe; $0 indicates that farmers were not ready to pay anything for Aflasafe.

Awareness on aflatoxin and Aflasafe among maize and groundnut farmers. The rate of awareness disaggregated by type of farmer indicates that all EFs in both states were fully aware of aflatoxin. However, awareness of aflatoxin was higher among IFs from Kaduna state than among IFs of Kano state; awareness of Aflasafe followed the same trend. Aflasafe was used only among the EFs (Table 3). All EFs in both states were ready to pay for the Aflasafe when available. Similar to the awareness and adoption results, WTP for Aflasafe was found among a higher percentage of IFs in Kaduna state than among IFs in Kano state.

Information source for aflatoxin and Aflasafe. Respondents identified more than one source of information about aflatoxin and Aflasafe (Table 4). The main sources of information for the EFs were IITA and the Commercial Agriculture Development Program. These two sources played a major role in promoting aflatoxin and Aflasafe awareness in Kaduna state first and were then later active in Kano state. Farmer-to-farmer contact was the most important source of awareness among IFs in Kano state (Table 4). As for most agricultural technologies in Africa, farmer-to-farmer contact is often the first source of information for many smallholders. The result for IFs in both states was limited to a subsample of IFs who were aware of aflatoxin and Aflasafe, as indicated by number of respondents (n) in Table 4.

Perceived benefits and constraints of using Aflasafe. Reasons stated by EFs for using Aflasafe are presented in Table 5. The first reason was health implication (33%), and the second reason was a desire to control aflatoxin (31%).

EFs in the study areas also identified more than one limiting factor to their stated WTP and constraints to the further expansion of Aflasafe use (Table 6). The high price of Aflasafe ranked first by 67.9% of farmers in Kano state and 51.5% of farmers in Kaduna state. This factor was followed by inadequate capital to acquire the product. Some of the EFs still lacked detailed information about Aflasafe, and some lacked a market for their aflatoxin-safe maize and groundnut crops. Some IFs did not use and were not willing to pay for Aflasafe at the threshold price in Kano state (64%) and Kaduna state (21%) because of lack of awareness and information on the use and effectiveness of the product (Table 6). The IFs in Kaduna state (67%) were also more informed about Aflasafe than were those in Kano state (25%). Nonusage might be owing to nonavailability of the product. Therefore, promotion of Aflasafe should be based on creating awareness of the product and increasing its availability to potential users.

TABLE 4. *Respondents' sources of information on aflatoxin and Aflasafe*[a]

	% of farmers					
	Pooled		Kano		Kaduna	
Source[b]	EFs	IFs	EFs	IFs	EFs	IFs
Extension agent	4.4	10.7	8.2	29.9	0	0
ADPs	0.2	0.5	0.4	0	0	0.8
IITA task force	53.6	40.1	47.6	10.4	60.4	56.7
CADP	41.6	29.4	43.3	6	39.6	42.5
Friends, neighbors	0.2	19.3	0.4	53.7	0	0
No. of respondents	246	138	119	46	127	92

[a] EFs, experienced farmers; IFs, inexperienced farmers.

[b] ADPs, agriculture development programs; CADP, commercial ADP.

TABLE 5. *Reasons given by EFs for adopting Aflasafe*

Reason	% of farmers		
	Pooled	Kano	Kaduna
Health	33	34	32
IITA or collaborator intervention	15	12	18
Aflatoxin control	31	33	29
Clean or quality grain of high market value	9	13	5
Make more money from sale	13	9	16
No. of respondents	246	119	127

TABLE 6. *Constraints to WTP for Aflasafe*

Constraint	% of farmers		
	Pooled	Kano	Kaduna
Experienced farmers			
Inadequate capital	24.0	25.4	23.0
Inadequate information about Aflasafe	6.6	0.7	10.5
High price of Aflasafe	58.1	67.9	51.5
Lack of market for aflatoxin-safe products	11.4	6.0	15.0
Inexperienced farmers			
Lack of awareness	41	64	21
Not interested	11	11	12
Nonavailability of product	47	25	67
No. of respondents	246	119	127

Estimated WTP for Aflasafe: estimates based on price quoted by farmers. A large majority of the EFs in Kano (80.7%) and Kaduna (84.3%) states had a WTP bid value equal to or greater than the $10 threshold (Table 3). This finding is important for Aflasafe use because this WTP estimate exceeds the minimum price limit and suggests that a potential demand (acceptability and affordability) for Aflasafe exists in the study areas. A smaller percentage of IFs in Kano (17.7%) and Kaduna (44.9%) states had WTP estimates that exceeded the threshold price. However, 66.4 and 27.6% of the IFs in Kano and Kaduna states, respectively, did not bid for the product. Among the IFs in Kano state, 33.6% gave a bid value greater than zero, and 52.7% had WTP values exceeding the minimum price limit ($10) at which Aflasafe can be sold. That result also suggests a demand scenario, which is important for this innovative technology. Figures 1 and 2 show the prices of Aflasafe versus the percentage of farmers that wanted to pay for it. In general, EFs in both states were willing to pay more than were IFs for 10 kg of Aflasafe.

Estimated WTP for Aflasafe: mean prices offered by different groups of farmers. Farmers were not actually aware of the lower price limit when the study was conducted but were asked to start bidding at $20. This strategy was used to reduce part of the bias inherent in contingent valuation with price for an innovation. The mean (SD) WTP was $9.40 ($6.33). Disaggregation by state revealed mean WTP values of $8.29 for Kano and $10.44 for Kaduna states, which were significantly different ($P < 0.01$). When disaggregated by farmer type, the EFs were willing to pay a higher mean price of $13.22 than were IFs, who were willing to pay only $5.57; this difference was significant ($P < 0.01$) (Table 7). Comparing EFs and IFs in Kano revealed that EFs were willing to pay a higher mean price ($13.01) for Aflasafe than were IFs ($3.56). The same trend was observed in Kaduna state. This difference indicates the importance of information and experience because farmers who had information and experience with Aflasafe were willing to pay higher prices for it in both states.

Estimated WTP for Aflasafe: comparison of farmer types. Comparison among EFs in the two states revealed that an EF in Kaduna state was willing to pay more (mean = $13.42) than an EF in Kano state ($13.01). However the difference was not significant (Table 8). Comparison among IFs in the two states revealed that farmers in Kaduna state were ready to pay more ($7.46) than were those in Kano state ($3.55). This difference was significant ($P < 0.01$).

Determinants of WTP for Aflasafe. WTP was regressed in two forms against the set of independent variables in Table 1. First, a logit form was estimated using the dummy variable of WTP, where farmers willing to pay at least the threshold price ($10) were scored 1 and those who were not were scored 0. Second, a linear regression using ordinary least square was estimated using actual price (WTPRICE) that farmers stated as their WTP. This analysis was also an additional test of the robustness of the logit results (Table 9). The logit model results revealed that the

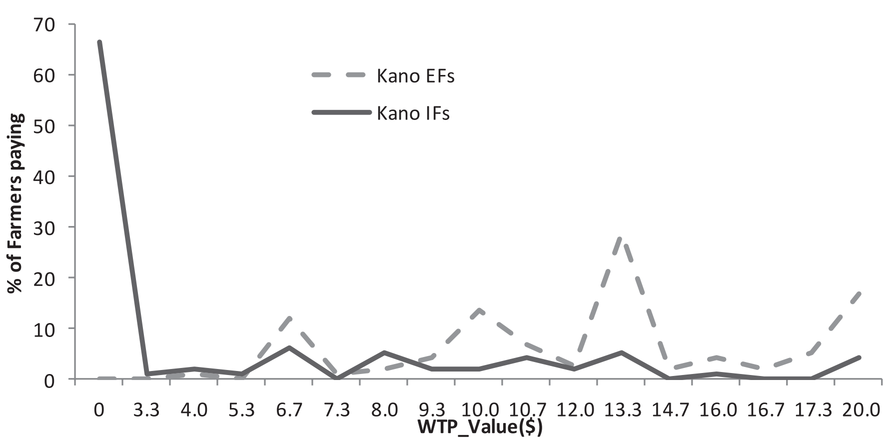

FIGURE 1. *Values of willingness to pay (WTP) for Aflasafe by experienced farmers (EFs) and inexperienced farmers (IFs) in Kano state, Nigeria.*

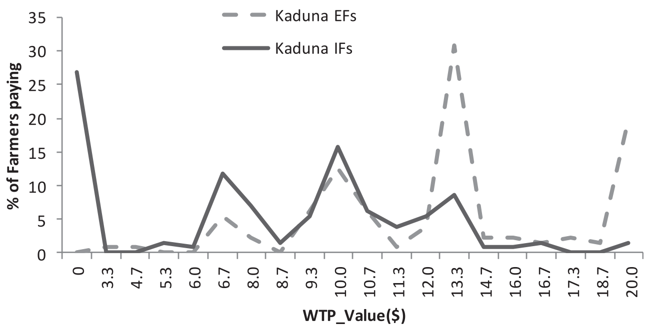

FIGURE 2. *Values of willingness to pay (WTP) for Aflasafe by experienced farmers (EFs) and inexperienced farmers (IFs) in Kaduna state, Nigeria.*

log-likelihood value (–232.19), the pseudo R^2 (0.314), and the chi-square value (212.17) were significant ($P < 0.01$), which indicates that the overall models were well fitted and the explanatory variables used in the model were collectively able to explain the farmers' decisions regarding the WTP for Aflasafe in the study area. Many of the included variables were significant for determining the farmers' WTP for Aflasafe.

Regression results indicate that socioeconomic characteristics of the farmers had significant effects on their WTP for aflatoxin biocontrol on maize and groundnut in Kano and Kaduna states. Being educated (EDUCATED) was positively and significantly associated with WTP for Aflasafe ($P < 0.001$). The marginal effect indicates that on average being educated will increase a farmer's WTP by 19.8%. Household size was negatively and significantly correlated with WTP for Aflasafe ($P < 0.01$); as household size increased the probability of WTP decreased by 1.6%. Being a farmer that was informed and had used Aflasafe (i.e., an EF) (USED_AFLASAFE) positively and significantly influenced WTP ($P < 0.001$) and increased it by 58.5%.

TABLE 7. *WTP values by different groups of maize and groundnut farmers*

Variable[a]	Mean ± SD WTP ($)	Difference ($)[b]
General (n = 492)	9.40 ± 6.33	
State		
Kano (n = 238)	8.29 ± 6.90	2.16 (3.8)***
Kaduna (n = 254)	10.44 ± 5.56	
Farmer type		
Experienced (n = 246)	13.22 ± 4.23	7.65 (16.80)***
Inexperienced (n = 246)	5.57 ± 5.75	
Farmer type within states		
Kano		
Experienced (n = 119)	13.01 ± 4.27	9.46 (14.5)***
Inexperienced (n = 119)	3.56 ± 5.69	
Kaduna		
Experienced (n = 127)	13.42 ± 4.19	5.96 (10.10)***
Inexperienced (n = 127)	7.46 ± 5.17	

[a] n, number of respondents.
[b] *** $P < 0.01$.

TABLE 8. *WTP values by state and farmer type*

Variable[a]	Mean ± SD WTP ($)	Difference ($)[b]
Experienced farmers		
Kano (n = 119)	13.01 ± 4.27	0.41 (0.757)
Kaduna (n = 127)	13.42 ± 4.19	
Inexperienced farmers		
Kano (n = 119)	3.56 ± 5.69	3.91 (5.629)***
Kaduna (n = 127)	7.46 ± 5.17	

[a] n, number of respondents.
[b] *** $P < 0.01$.

Contact with an extension agency also positively and significantly influenced the WTP for Aflasafe decisions of the farmers ($P < 0.10$). Farmers that have contact with an extension agent had a 17.5% probability of increasing their WTP for Aflasafe.

Total expenditure (both on and off the farm) is also used here as a proxy for wealth status because it is a commonly used indicator of farmers' economic resources *(7)*. Total expenditure positively and significantly influenced WTP for Aflasafe ($P < 0.001$). The marginal effect for expenditure is 1.0E–04, which means that when other factors remain constant, with an expenditure increase of $1 the probability of paying for Aflasafe will increase by 1.0E–04%. The state-specific variable (KADUNA) significantly influenced WTP for Aflasafe ($P < 0.001$). Being from Kaduna state increased the probability of a farmer's WTP being above the threshold price by 23.7%, based on the estimated marginal effect. This finding suggests that farmers in Kaduna state were more willing to pay for Aflasafe than were their counterparts in Kano state.

Results of the linear regression were similar to those of the logit model, indicating the robustness of the estimations. All variables in both models had the same signs and significance levels except the HOUSEHOLD_SIZE variable, which was significant only for the logit model (Table 9). The elasticity estimation from the linear regression analysis revealed that, all other things being constant, an educated farmer was likely to have a WTP that was 0.095% higher than that of a noneducated farmer. Experience using Aflasafe (USED_AFLASAFE) resulted in a 0.26% increase in the amount a farmer was willing to pay. Access to extension services via contact with an extension agent resulted in a 0.178% increase in the amount a farmer was willing to pay for Aflasafe. For expenditure, when other factors remained constant, a 1% increase in expenditure increased the value a farmer was willing to pay by 0.094%. The location variable (KADUNA) also was a significant determinant of WTP; those farmers from Kaduna state where aflatoxin and Aflasafe awareness is higher, will on average offer a 0.13% higher price for Aflasafe than their counterparts from Kano.

Sensitivity analysis of effects of change in exchange rate on WTP. Given the changes in economic conditions, a sensitivity analysis was carried out to evaluate how farmers' WTP would be affected by changes in some key parameters.

TABLE 9. *Determinants of willingness to pay (WTP) for Aflasafe in the study area*

Explanatory variable	Logit model				Linear regression (with actual price stated by farmers)			
	Coefficient[a]	z	$P > \|z\|$	Marginal effect	Coefficient	t	$P > \|t\|$	Elasticity
MALE	−0.018	−0.030	0.977	−0.004	1.890	1.6	0.111	0.269
MARRIED	0.097	0.220	0.826	0.024	0.903	1.07	0.284	0.108
FEXPERIENCE	0.002	0.160	0.875	0.001	0.001	0.04	0.968	0.003
EDUCATED	0.814***	2.950	0.003	0.198	1.246**	2.55	0.011	0.095
HOUSEHOLD_SIZE	−0.066***	−2.820	0.005	−0.016	−0.059	−1.42	0.155	−0.079
USED_AFLASAFE	2.740***	8.750	0.000	0.585	6.811***	12.29	0.000	0.261
ASSOCIATION	−0.225	−0.740	0.461	−0.054	0.045	0.07	0.94	0.004
EXTENSION	0.709*	1.910	0.056	0.175	1.771**	2.56	0.011	0.178
CREDIT	−0.117	−0.440	0.660	−0.029	−0.041	−0.08	0.936	−0.002
MAIZEONLY	−0.001	0.000	0.998	0.238	−0.282	−0.52	0.605	−0.028
EXPENDITURE	2.48E−06***	2.980	0.003	0.0001	0.001***	2.95	0.003	0.094
KADUNA	0.988***	3.360	0.001	0.237	2.237***	4.24	0.000	0.130
CONSTANT	−2.399	−2.790	0.005		−0.224	−0.14	0.885	
NO OF OBSERVATIONS	492				492			
LOG LIKELIHOOD	−232.193							
CHI SQUARE	212.170							
PROB>CHI2	0.000							
PSEUDO R2	0.314							
$F(12, 497)$						32.17		
$P > F$						0.0000		
R^2						0.4463		
Adjusted R^2						0.4324		

[a] *** $P < 0.01$; ** $P < 0.05$; * $P < 0.10$.

Because Aflasafe is sold in nairas (N, the local currency) at a nominal price, this sensitivity analysis is presented in nairas. The exchange rate of the naira to the U.S. dollar rose from 150:1 to 315:1 between 2014 and 2016. However, Aflasafe is made of raw materials produced locally. Both maize and groundnut are also sold in the local markets. The loss of value (compared with the U.S. dollar) of nairas experienced in the recent past could affect the farmers' WTP. The results reported here must be interpreted in the context of the year of the study (2014). The main results were based on the exchange rate adopted by the IITA (the agency that produces Aflasafe) and other prevailing economic conditions during the study year, including base cost of Aflasafe per hectare (N1500), mean price of maize (N55/kg), and mean price of groundnut (N193/kg). The recent changes in the exchange rate and other economic conditions led to an increase in the cost of Aflasafe to N3600 because the cost of the major ingredient (sorghum, which is used as carrier) increased from N55/kg in 2014 to N140/kg in 2016. The exchange rate increased by 110%, the price of maize increased by 100%, the price of groundnut increased by 55%, and the price of Aflasafe increased by 140%. The input (Aflasafe) and the output (maize and groundnut) increased approximately at the same rate as did the exchange rate. The expectation was that the cost of Aflasafe, maize, and groundnut would increase at a lower rate than that would the exchange rate because Aflasafe is made with mainly local material (sorghum) and because the outputs (maize and groundnut) are traded locally, but that was not the case. Therefore, additional analyses were conducted to show the sensitivity of the WTP results to the changes in the input and output prices. Results are summarized in Tables 10 and 11 and Figure 3. Table 10

TABLE 10. *Comparing farmers' willingness to pay (WTP) based on change in exchange rates*[a]

Variable[b]	Both states (%)			Kano (%)		Kaduna (%)	
	Pooled	EFs	IFs	EFs	IFs	EFs	IFs
Base_WTP (1, ≥N15,000; 0, <N1,500)	55.3	82.5	31.7	80.7	17.7	84.3	44.9
New_WTP (1, ≥N3,600; 0, <N3,600)	38.0	62.6	13.4	60.5	7.6	64.6	18.9
Base WTP (1, WTP > N0; 0, other)	77.0	100	53.7	100	33.6	100	72.4
New _WTP_ (1, WTP > N0; 0, other)	77.0	100	54.1	100	33.6	100	73.2
No. of observations	492	246	246	119	119	127	127

[a] EFs, experienced farmers; IFs, inexperienced farmers.

[b] All variables are dummies. N, Nigerian naira. WTP > N0, farmers willing to pay a positive amount (not necessarily the minimum price) for Aflasafe; WTP = 0, farmers not willing to pay anything for Aflasafe; Base_WTP, WTP at the old exchange rate of $US1 = N150; New_WTP, WTP at the new exchange rate of $US1 = N315.

TABLE 11. *Comparisons of revenues of products and willingness to pay (WTP) with changes in exchange rates*[a]

Variable	Pooled	EFs	IFs
Revenue from 1 ha of maize			
Base WTP	N48245.1 (N57344.7)	N63755.4 (N50333.6)	N33144.7 (N59779.4)
New_WTP	N96490.1 (N114689.3)	N127510.8 (N100667.2)	N66289.4 (N119558.8)
Revenue from 1 ha of groundnut			
Base WTP	N38077.4 (N79822.1)	N40915.5 (N95101.6)	N32052.6 (N26527)
New_WTP	N59187.7 (N124075.8)	N63599.3 (N147826.3)	N49822.7 (N41233.6)
Base_WTP	N1402.8 (N948.3)	N1983.7 (N634.1)	N822 (N850.1)
New_WTP	N2946.0 (N1991.5)	N4165.9 (N1331.5)	N1726.1 (N1785.2)

[a] Values are means (SDs); N, Nigerian naira. Base_WTP, WTP at the old exchange rate of \$US1 = N150; New_WTP, WTP at the new exchange rate of \$US1 = N315.

shows changes in the percentage of farmers willing to pay under the different prevailing economic conditions before (Base_WTP) and after (New_WTP) the change in exchange rate. Table 11 provides a comparison of revenues for maize and groundnut farmers from growing 1 ha of each crop under the base (150:1) and new (315:1) exchange rates of nairas to U.S. dollars.

The change in the exchange rate led to an almost parallel upward shift in the WTP curve, indicating higher values at each level (Fig. 3). Table 10 results mirror those in Table 3 for the new exchange rate; for the general pooled data, WTP dropped from 55.3% with the old rate to 38.0% with the new rate. This decrease is also reflected in the percentages for farmer type (EF and IF) and state. The mean revenues from 1 ha of maize increased by almost 100% and those from groundnut increased by 55% with the increased exchange rate (Table 11). These increases are expected to compensate for the increase in the cost of Aflasafe for most farmers. The average New_WTP now is about N2900 compared with the Base_WTP of N1400 (Table 11); this new WTP is also higher for EFs than for IFs. With the change in the minimum quoted price of Aflasafe to N3600, the mean WTP for EFs is above N4000 (Table 11), indicating consistency in our results that information and education are key factors for farmers' WTP. The simulated results based on the new exchange rate indicate that EFs are ready to pay more than the minimum price for Aflasafe, which is similar to the result shown in Table 7 for the base analysis. Although the exchange rate has influenced prices, farmers will still make a profit after sales, as seen from revenues obtain from groundnut and maize sales.

Based on this simulation, the percentage of farmers who are willing to pay the minimum quoted price for Aflasafe will be reduced (from 55.3 to 38.0%) because the minimum nominal price has risen from N1500 to N3600. However, the changes in exchange rate will also increase revenues from maize and groundnut sales, which will allow farmers to afford to pay for Aflasafe and still make profit. The findings for EFs versus IFs remain the same, with the mean WTP higher for EFs than for IFs despite an increase in the exchange rate.

DISCUSSION

This study was conducted to examine the WTP for aflatoxin biocontrol among maize and groundnut farmers who did and did not have experience using the product in Kaduna and Kano states, Nigeria. The contingent valuation method was employed to analyze farmers' WTP. Descriptive statistics were used to describe and compute statistics such as mean, SD, and frequency distributions. The results were used to compare the WTP of EFs and IFs in the two states. Econometric modeling also was used to determine factors influencing farmers' WTP for Aflasafe if it were available. A linear regression was also estimated to test the robustness of the results.

Information about and experience with using Aflasafe were the key factors that determine farmers' WTP. Most of the EFs were willing to pay more than the minimum cost of the product, but some EFs suggested that the high cost of

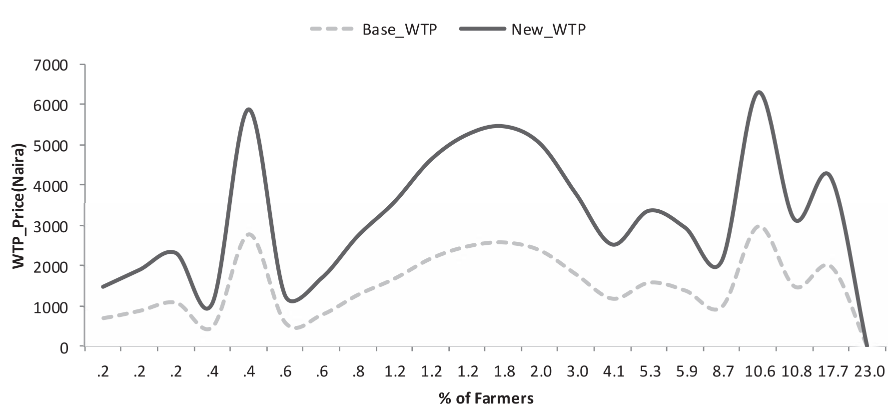

FIGURE 3. *Effect of increase in the exchange rate (nairas to U.S. dollars) on WTP values of farmers in the study areas. Base_WTP, old exchange rate; New_WTP, new exchange rate.*

Aflasafe was their major constraint. In contrast, most IFs were not willing to pay the threshold price of the product. The majority of the EFs in Kano (80.7%) and Kaduna (84.3%) states willing to pay ≥$10 (threshold price). For IFs, only 17.7% in Kano state and 44.9% in Kaduna state were willing to pay ≥$10. The mean WTP estimates for Aflasafe among the EFs in Kano and Kaduna states were $13.01 and $13.42, respectively. These values were not significantly different ($P < 0.01$). Mean bids for Aflasafe of $3.56 and $7.46 were offered by IFs in Kano and Kaduna states, respectively. Thus, IFs were ready to pay for Aflasafe but on average were willing to pay less that the minimum price of $10.

Education positively and significantly influenced WTP for the biocontrol product. The positive value of the coefficient is in line with the a priori expectation that educated farmers would better understand the challenges associated with aflatoxin in their crops and have a higher WTP for Aflasafe. This result is in line with findings of previous studies in which the respondent's education status influenced his or her WTP because he or she was better informed about agricultural technologies *(4, 6, 11, 25)*. In other studies, education was not significant in influencing WTP decisions *(30)*. Household size, which includes all people living under the same roof and eating from the same pot, has been identified as having either a positive or a negative influence on WTP *(8, 10, 19, 22, 27, 31)*. However, the negative relationship of this variable with WTP for Aflasafe may be linked to the increased consumption pressure associable with a large family, thus limiting their WTP the threshold price. USED_AFLASAFE was positively and significantly related to WTP, which was expected because the EFs that had used this product and understood its benefits were more willing to pay the threshold price than were farmers who were new to Aflasafe. This response by EFs also confirms that the product is improving the livelihood of the users by increasing their income from sales of aflatoxin-safe maize.

Extension agency contact positively and significantly influenced the farmers' WTP for Aflasafe ($P < 0.10$). Access to extension agents increased the probability of these farmers being willing to pay above the threshold price compared with farmers who did not have contact with extension agents *(12, 25)*. This difference was due in part to access through the extension agents to information about aflatoxin and its pervasive threats to humans and animals and about the availability of the Aflasafe mitigating strategy. Extension agencies have always been one of the major ways to access and understand technologies for smallholder farmers in Africa. Even when a farmer initially refuses to adopt a particular new strategy, continual contact with extension agents can help such a farmer to change *(12, 25)*.

Regression results also indicated that farmers with higher total expenditures (a proxy for higher income or wealth status) were more likely to pay for Aflasafe because they had lower liquidity constraints. This finding is supported by other studies on the effect of wealth status on use of agricultural technologies *(6, 17)*. The state-specific dummy variable (KADUNA) also was an important determinant of WTP, which in this situation implies that maize and groundnut farmers in Kaduna state were more willing to pay for the biocontrol than were their counterparts in Kano state. This difference could be as a result of better information due to longer exposure to the aflatoxin extension messages and the use of Aflasafe by EFs in Kaduna state compared with Kano state. The descriptive results that awareness and usage of Aflasafe was higher in Kaduna than in Kano is in line with the logit results.

Aflasafe is made of local materials, and maize and groundnut products are priced locally. The devaluation of the local currency increased the Aflasafe price, which could result in a reduction in the number of users. However, the changes in exchange rate also increased revenues from maize and groundnut, which should allow farmers to afford to pay for Aflasafe and still make profit.

This study was conducted to estimate WTP for Aflasafe among maize and groundnut farmers in Kano and Kaduna states of Nigeria. The results could also be useful for guiding other African countries with similar or more severe aflatoxin problems in designing approaches to disseminating and sustaining use of biological controls by smallholder farmers. Proper dissemination of information on aflatoxin and the relevance of Aflasafe to farmers both in training and on fields is important. Although a reduction in the unit cost for Aflasafe might lead to more farmers buying the product, a market for aflatoxin-safe grain at a premium price must be developed to reduce the relative coast of Aflasafe application. Provision of credit, strengthening of social groups, and facilitating activities that increase farmers' income would also increase farmers' WTP for Aflasafe. Increasing farmer and consumer awareness of the health risks associated with consuming aflatoxin-infected grain could also boost WTP for Aflasafe.

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SUPPLEMENTAL MATERIAL

Supplemental material associated with this article can be found online at: https://doi.org/10.4315/0362-028X.JFP-16-281.s1.

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