



Research Article

Bio-Control Technology (Aflasafe) Usage among Smallholder Maize Farmers in Oyo State, Nigeria

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ARTICLE INFO:

Keywords:

Aflatoxin,
Aflasafe,
Bio-control Technology,
Smallholder farmers
Maize

ABSTRACT

Bio-Control Technology was apt as one of the most promising and cost-effective methods to reduce aflatoxin in maize and groundnut. This study therefore analyzed smallholder maize farmers' aflatoxin bio control technology (Aflasafe) decision and extent of usage determinants among smallholder maize farmers in Oyo state, Nigeria. Multistage sampling techniques was used to select 297 smallholder maize farmers for the study. Primary data for the study was collected using well-structured questionnaire; the data was then analyzed using descriptive statistics and double hurdle model (DHM). Descriptive findings of the study shows that maize production is predominantly by male (86.87%) farmers, that had an average age of 49 years, with a household size average of seven (7) persons and a farm size average of 2.68 hectares; Findings further show majority of the farmers as formally educated (77.1%) with average of 19years in to maize production. Moreover findings revealed farmers in the study area to be reasonable (60%) aware of aflatoxin prevalence in their farms, however only 48.33% of them reported taking measures to control it. Meanwhile only 25% of the farmers are aware of Aflasafe to control aflatoxins, however only 49.35% of farmers that control aflatoxin reported using it to control aflatoxin. The study further revealed decision to using Aflasafe as been significantly influenced by education level, extension visit and membership of association. On the other hand extent of Aflasafe usage was found to be significantly influenced by age of the farmers, highest level of education, farm size and farming experience. Inadequate markets for aflatoxin free maize, low awareness, additional input cost, unavailability and price of Aflasafe were identified as constraints to using of Aflasafe in the study area. The study recommended the need for more awareness campaigns, as well as ensuring availability and affordability of Aflasafe among maize farmers.

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INTRODUCTION

Maize (*Zea mays*) is an Africa's most important food crop grown on nearly 30 million hectares of land; supporting livelihood of over 300 million people on the continent. It provides over half of the calories and protein consumed in Eastern and Southern Africa as well as one-fifth of the calories and protein consumed in West Africa (Fisher *et al.*, 2015; Badu-Apraku & Fakorede, 2017). Nigeria is the largest maize producer in West Africa (FAOSTAT, 2017). However, Maize production in Nigeria is bedeviled with low productivity with an average yield of about 1.89 tons/ha, which is 16% of the total maize production in Sub-Saharan Africa (FAOSTAT, 2022). Low maize yield is often ascribed to various factors such as low yield variety, lack of incentives, high cost of inputs, price fluctuation, lack of storage facilities, and pest and diseases incidences (Assa *et al.*, 2020). Among the pest and diseases that currently threaten maize productivity growth is aflatoxin, known to be one of the most potent and dangerous groups of mycotoxins worldwide (IITA, 2012). Aflatoxin are toxic to crops and animals, as it pose serious risk to human health resulting into food insecurity, hunger, famine and huge economic losses (Cardwell, Desjardins, Henry, Munkvold & Robens, 2001; Stronider *et al.*, 2006; Legreve & Duveiller, 2010; Waliyar & Sudini, 2012; IITA, 2012).

Consumption of aflatoxin-contaminated crops by humans causes aflatoxicosis and increases liver cancer risk. Maize has become the preferred cereal for food, feed and industrial use, displacing traditional cereals such as sorghum and millets; but it was significantly more heavily colonized by aflatoxin-producing *Aspergillus* spp. than either sorghum or millet (Bandyopadhyay, Kumar, & Leslie, 2007). "According to IITA's estimates, 40–60 percent of Nigeria's maize crop would be deemed unfit for sale (if limits were enforced), jeopardizing perceived food security and the livelihoods of thousands of smallholders"

(Dahlberg, 2012). Both domestically and globally, aflatoxin imposes large burdens on maize trade. On the domestic level, estimates have been made in various studies on the cost aflatoxin has on food producers. Some studies like Ladoye, *et al.* (2017) and Johnson, *et al.* (2018) segregate the costs of aflatoxin by crop (e.g. maize, peanuts), while others such as James, *et al.*, (2018) produce cost estimates across all crops, and include costs associated with livestock illness due to aflatoxin exposure.

Technologies to combat aflatoxin contamination have been sought for decades (Hell, Cardwell, Setamou & Poehling, 2000). Several pre-and post-harvest methods have been recommended for aflatoxin mitigation (Udomkun *et al.*, 2017; Wagacha & Muthomi, 2008). Biological control was thought as one of the most promising and cost-effective methods to reduce aflatoxin in maize and groundnut (Bandyopadhyay *et al.*, 2016; Dorner, 2004; Wu & Khlangwiset, 2010). In Nigeria, The International Institute of Tropical Agriculture (IITA), in partnership with the United States Department of Agriculture–Agriculture Research Service (USDA–ARS), and national partners in Africa have developed a biological control technology that is environmentally safe to reduce aflatoxin contamination of crops using beneficial fungi that displace toxigenic fungi called Aflasafe. Aflasafe is a safe product composed of natural strains of *Aspergillus flavus* that do not produce toxins (Bandyopadhyay *et al.*, 2016). When Aflasafe is introduced in a farm field, the non-toxic strains out-compete the strains that produce the toxins, through a process known as competitive exclusion (Atehnkeng *et al.*, 2008). Aflasafe is currently the most effective technology for aflatoxin mitigation in maize and groundnut at the pre-harvest stages (Bandyopadhyay *et al.*, 2016). The protection continues at post-harvest stage even when the grains are in storage (Bandyopadhyay *et al.*, 2016).

Reductions in aflatoxin contamination of >80% have been documented in fields treated with Aflasafe compared to untreated fields (Bandyopadhyay *et al.*, 2016). The benefits of Aflasafe continue during crop storage because the non-toxic *A. flavus* remains on maize, still competing with the toxic *A. flavus* strains that would otherwise increase aflatoxin levels during storage (Atehnkeng, Ojiambo, Cotty & Bandyopadhyay, 2014). Unique Aflasafe products are registered for commercial use in several African nations including Nigeria. The regular continued use of Aflasafe by smallholder farmers is important for its commercialization and contribution to the production of a safe food supply, economic development and poverty alleviation. Aflasafe is cost-effective for farmers, industries and governments. It gives farmers and farm businesses a low-cost solution to the increasingly expensive problem of aflatoxin, and opens up premium markets. It does not only excel at cutting aflatoxin, it does it consistently – minimizing risks for both farmers and buyers (Bandyopadhyay *et al.*, 2016).

Meanwhile, various barriers to market, including consumer awareness, affordability and lack of contamination limits among other reasons, have prevented widespread adoption of Aflasafe and other available technologies. Although several studies have shown that there are high level of awareness and adoption of Aflasafe in some sub-Saharan Africa countries (Ayedun *et al.*; 2015, Johnson *et al.*; 2018, Ladoye, Bamire & Afolayan, 2017, Georges, Fang, Beckline, & Wu, 2016). However in Nigeria specifically there is a dearth of information about the awareness, cost, acceptability and adoptability of Aflasafe by maize farmers in Nigeria. Even though, Ayedun *et al.* (2017) have recently reported Aflatoxin awareness and Aflasafe adoption potential of Nigerian smallholder maize farmers. In the wake of this background, this study aimed at achieving the following specific objectives in order to expedite decision and adoption of aflatoxin bio-

control technology (Aflasafe) among smallholder maize farmers.

- i. Describe socioeconomic characteristics of maize farmers in the study area
- ii. Examine farmers awareness on bio-technology control of maize aflatoxin in the study area
- iii. Determine factors influencing decision and extent of using bio-technology (Aflasafe) for maize aflatoxin in the study area
- iv. Describe constraints to using bio-technology(Aflasafe) for maize aflatoxin in the study area

METHODOLOGY

Description of study area

The study area, Oyo State, located in southwestern Nigeria, it is characterized by a diverse and dynamic environment. With a projected population of 7,976,100 in 2023, the state occupies a land area of about 27,249 sq km, situated between latitudes 7 °3' and 9 °12' north of the equator and longitudes 2° 47' and 4° 23' east of the Meridian. Oyo State experiences an equatorial climate, featuring distinct dry and wet seasons. The dry season spans from November to March, while the wet season extends from April to October. The climate fosters relatively high humidity levels. The average daily temperature ranges from 25 °C (77.0 °F) to 35 °C (95.0 °F) throughout the year, creating favorable conditions for various agricultural activities

The primary occupation of the people in Oyo State is Agriculture. The climate condition in the area supports the cultivation of a several crops, including maize, yam, cassava, millet, rice, plantains, cocoa, palm produce, and cashew. Noteworthy government farm settlements are established in Iseyin/Ipapo, Ilora, Eruwa, Ogbomosho, Iresaadu, Ijaiye, Akufo, and Lalupon. The region is rich in natural resources, with abundant clay, aquamarine, and kaolin available. The state Agricultural Development Programme, headquartered in Saki, plays a

pivotal role in promoting agricultural initiatives. Additionally, the state hosts several international and federal agricultural establishments,

contributing to the overall development and sustainability of the agricultural sector in the State.

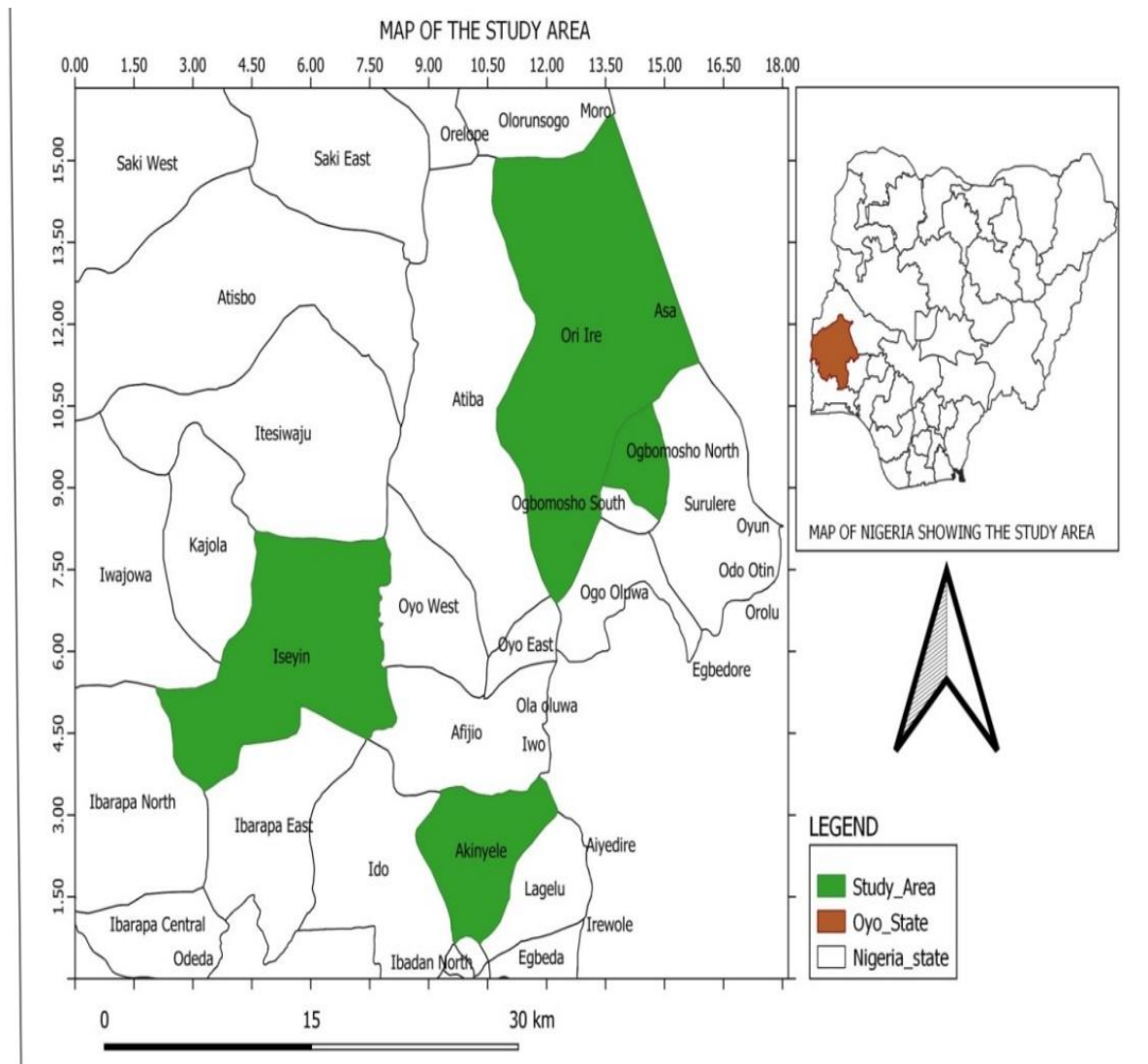


Figure 1: Map of Oyo State showing the study area

Sampling Procedure

A multi-stage sampling technique was used for this study. The first stage involves purposive selection of four Local Government Areas (LGAs) in Oyo State where maize is predominantly produced and there are incidence of aflatoxin and awareness about Aflasafe. In the second stage, 3 villages were randomly selected from each selected local government area. In order to ensure unbiased representation the

sample frame was subjected to Raosoft sample size calculator at 95% confidence level which subsequently provided 297 respondents to scientifically represent the population. The 297 respondents were then proportionately distributed across the selected community based on the population of smallholder maize farmers in each selected community. Finally in the third stage systematic random sampling procedure was used in selection and interviewing of the respondent

from each selected community in the study area. table 1.
The summary of the procedure can be shown in

Table 1: Sampling Procedure

LGA	Selected Communities	Sample Frame	Sample Size
Akinyele	Ijaye	105	24
	Elekuru	57	13
	Ijaye town	80	18
Iseyin	Abatitun	85	19
	Alagbede	117	27
	Aba sule	129	29
Orire	Tewure	122	28
	Oniyo	225	52
	Elewure	109	25
Ogbomosho north	Masifa	85	19
	Aguodo	128	29
	Abogunde	63	14
4	12	1305	297

Source: Oyo State Agricultural Development Programme (OYSADEP), 2019

Method of Data Collection

Primary data were used for this study. The primary data was obtained using pre-designed pilot tested, structured questionnaire. The data was collected by the researcher and well-trained enumerators that was carefully selected by the researcher and they have better understanding of local language of the respondents. The information collected include socio economic characteristics of the smallholder maize farmers in the study area; factors that influence the decision to adopt and extent of application of the bio-control technology; and constrains to application of the bio-control technology usage in the study area.

Analytical Tools

The following analytical tools were employed to achieve objectives of the study

Descriptive Statistics

Descriptive statistics such as mean, minimum, maximum, standard deviation and standard error, frequency, percentage and graphs was used to achieve the specific objectives of describing socio

economic characteristics; farmers awareness on bio-technology control of maize aflatoxin and constrains to using bio-control technology (Aflasafe) in the study area.

Double Hurdle Model

The double hurdle model (DHM) was used to determine the decision and extent of aflasafe adoption in the study area. The double hurdle model (Cragg, 1971), which assumes that households must pass two hurdles; i) decide whether to adopt or not (probability of adoption); and ii) amount of the Aflasafe package (intensity/extent of use) which is conditional on the first decision. The model was justified over Heckman two stage least square model and Tobit model because the later is limited in the sense that adoption is observe only if it is above or below some cut off level hence, it underestimates the intercept and overestimate the slope; while Heckman model assumes that the same set of parameter and variables determine both the probability of using the technology and the level of usage. However It is possible to include

different explanatory variables in the two hurdles or even the same explanatory variables in both hurdles may have different effects (Tambo & Abdoulaye, 2012). Recently, this model is frequently used in technology adoption literatures (see for example; Dimara & Skuras, 2003;

Amare, Asfaw & Shiferaw,2012; Gebremedhin & Swinton, 2003). The double hurdle model (DHM) is expressed as:

The first hurdle, decision to adopt Aflasafe package (A) is expressed as:

$$A_i^* = \alpha x_i + \mu_i; \mu_i \sim N(0, 1) \dots\dots\dots(1)$$

$$\text{With } A_i = 1 \text{ if } A_i^* > 0 \text{ and } A_i = 0 \text{ if } A_i^* \leq 0. \dots\dots\dots (2)$$

The second hurdle, intensity to adoption (I) is expressed as,

$$I_i = \beta z_i + V_i; V_i \sim N(0, \sigma^2) \dots\dots\dots(3)$$

$$\text{With } I_i = I_i^* \text{ if } I_i^* > 0 \text{ and } A_i = I; I_i = 0 \text{ otherwise} \dots\dots\dots (4)$$

Where, A_i is a discrete (observed) variable measuring whether or not Aflasafe is adopted, and A_i^* is a latent (unobserved) variable for A_i .

A and β are vectors of the parameters to be estimated. μ_i and V_i are the error terms and they are assumed to be independent.

I_i denotes the observed area under Aflasafe (intensity of adoption), and I_i^* is a latent variable for I_i . X_i and Z_i are vectors of variables illustrating the decision to adopt Aflasafe and the intensity of Aflasafe adoption respectively, which can overlap or can be same.

Based on this assumption, the double hurdle model is equivalent to a combination of a probit model and a truncated regression in the two hurdles respectively. Thus, we use maximum likelihood method of probit and truncated regressions to estimate the first and second hurdles respectively (Gebremedhin & Swinton, 2003).

The empirical model employed to determine the decision to adopt Aflasafe package (A) is specified as follows:

$$A_i = \alpha_0 + \alpha_1 X_1 + \alpha_2 X_2 + \alpha_3 X_3 + \alpha_4 X_4 + \alpha_5 X_5 + \alpha_6 X_6 + \alpha_7 X_7 + \alpha_8 X_8 + \alpha_9 X_9 + \alpha_{10} X_{10} + \mu_i \dots (5)$$

Where;

A_i = individual's adoption decision of bio-control technology

α_0 = the constant term

$\alpha_1, \alpha_2, \alpha_3 \dots \alpha_{10}$ = the parameters of the respective explanatory variables in the model

X_1 = Age (years)

X_2 = Gender (years)

X_3 = Marital status (0 = unmarried, 1 = married)

X_4 = Household size (numbers)

X_5 = Educational level (years)

X_6 = Farming experience (years)

X_7 = Extension visit (number of visit/year)

X_8 = Membership of cooperative association (years)

X_9 = Farm size (hectares)

X_{10} = Amount of credit received (₦)

μ_i = Error term.

The empirical model that will be employed to determine the intensity of adoption (I) is specified as follows;

$$I_i = \beta_0 + \beta_1 Z_1 + \beta_2 Z_2 + \beta_3 Z_3 + \beta_4 Z_4 + \beta_5 Z_5 + \beta_6 Z_6 + \beta_7 Z_7 + \beta_8 Z_8 + \beta_9 Z_9 + \beta_{10} Z_{10} + V_i \dots (6)$$

Where;

I_i = the intensity/ extent of use

β_0 = the constant term

$\beta_1, \beta_2, \beta_3 \dots \beta_{10}$ = the parameters of the respective explanatory variables in the model.

Z_1 = Age (years)

Z_2 = Gender (years)

Z_3 = Marital status (0=unmarried, 1= married)

Z_4 = Household size (numbers)

Z_5 = Educational level (years)

Z_6 = Farming experience (years)

Z_7 = Extension visit (number of visit/year)

Z_8 = Membership of cooperative association (years)

Z_9 = Farm size (hectares)

Z_{10} = Amount of credit received (N)

V_i = Error term.

RESULT AND DISCUSSIONS

Socioeconomic characteristics of maize farmers in the study area

The result for socioeconomic characteristics of maize farmers in the study area was shown in Table 2. A finding shows that the respondents have an average age of 49 years with a minimum age of 25 years and maximum of 78 years. This indicates that majority of the farmers were within the economically active age category (FAO, 2004). In line with these research findings, Fakoya & Daramola (2015) noted that respondents within this age bracket (45years) are innovative and motivated individuals who can cope with challenges that may emanate from farming activities. Gender results show males (86.87%) as majority of the total respondents. Females, on the other hand, have a frequency of 39, accounting for 13.13% of the total respondents. This indicates that the respondents are predominantly male. This is in consonance with the finding of Olaoye et al., (2013) who also reported that fish farming was male dominated as indicated by 84.2% of the fish farmers in a similar study in Oyo State, Nigeria. In terms of education the result shows that majority had access to education. However, the level of education revolves around secondary and primary education and with question quality of education,

and production decision may be of low quality with attended consequences on productivity and profitability of farm enterprise. Joshua, Obille, John and Shuaibu (2016) argued that access to quality education influence the application of new technology which translates to better income and well-being. In the analysis of household size, it was found that with a minimum size of 1 and maximum size of 15, smallholder maize farmers have a mean household size of 7. The study does corroborate with the finding of Ekunwe & Emokaro (2012) who reported that the mean household size was 7 persons, in a study in Kogi State, Nigeria. The farmers were found to have 19 years of farming experience. This is in line with the findings of Mbanasor & Kalu (2008) as well as Obare, Nyagaka, Nguvo & Mwakubo (2010) that reported 1-20 years of experience for majority of smallholder maize farmers. The average farm size of 2.68ha as revealed in table 2 implied that most of the maize farmers are operating on marginal land which could not create room for commercial agriculture based on the current land holdings which require the use of very heavy equipment. Apata (2016) opined that high degree of farmland fragmentation is associated with small farms. When analyzing membership of association, 85 individuals are members, representing 28.62% of the

respondents. The majority of the respondents, 212 individuals, are non-members, accounting for 71.38% of the respondents. The result implies that majority of the smallholder maize farmers were not members of cooperative society which means that majority of them will not benefit from the gestures of being member of cooperative such as capacity building, training, access to production and market information, linkage to source of farming technologies. Kolade & Herphamis (2014) revealed that cooperative membership is the main contributor to the

adoption of new technologies. About 247 individuals have had contact with extension services, representing 83.16% of the respondents. Conversely, 50 individuals, accounting for 16.84% of the respondents, report having no contact with extension services. The result means that majority of the smallholder maize farmers in the study area had contacted extension agent for their production activities. This result is consistent with the study findings of Asres, Makoto, Kumi and Akira (2013) and Tiwari, Jana, Das and Roubaud (2018).

Table 2: Socioeconomic characteristics of maize farmers in the study area

Variable	Frequency	Percentage	Min	Max	Mean	SD
Age (years)			25	78	49	11.04
Sex						
Male	258	86.87				
Female	39	13.13				
Education level						
Informal/Religious	68	22.90				
Primary	138	46.46				
Secondary	53	17.85				
NCE/Diploma	19	6.40				
Degree	9	3.03				
PG	10	3.37				
Household Size (persons)			1	15	7	2.42
Farming Experience (years)			1	50	19	11.32
Membership of Association						
Member	85	28.62				
Non-member	212	71.38				
Farm Size (ha)			0.40	5	2.68	1.54
Extension Agent Contact						
Contact	247	83.16				
No Contact	50	16.84				
Total	297	100				

Farmers Awareness and Control of Aflatoxin

The result in table 3 reveals that reasonable number of respondents (60%) of the respondents reported being aware of aflatoxin existence in their various farms; this indicates a relatively high level of awareness, the fact that 40% of the respondents are still unaware of aflatoxin suggests a need for increased education and awareness campaigns on the dangers of aflatoxin contamination in crops and food products. Regarding the duration of awareness among the

respondents that are aware of it, 55.83% of them observed it in 11-15 years duration, indicating that a significant portion of the respondents have been aware of aflatoxin for a substantial period. However, it is essential to continue and reinforce these efforts to maintain and expand the awareness levels, especially among those with a shorter duration of awareness (0-5 years and 6-10 years categories). Result in table 3 further reveals that 48.33% of the respondents reported taking measures to control aflatoxin. This is a positive

indication that a considerable portion of the respondents recognizes the importance of mitigating aflatoxin contamination. However, it is concerning that 51.67% of individuals indicated not taking any control measures. This highlights the need for targeted interventions to promote the adoption of control measures and reinforce their

significance in reducing aflatoxin-related health risks. Among those who took control measures, the most commonly reported measures were proper storage (31.03%), proper drying (39.66%), and the use of biocontrol (5.17%). However, it is worth noting that the adoption rates for these measures are relatively low.

Table 3: Awareness and Control of Aflatoxin

Variable	Frequency	Percentage	Min.	Max	Mean	SD
Awareness						
Aware	178	60.00				
Not aware	119	40.00				
Duration of Awareness						
1-5	49	27.50	1	15	8.33	3.75
6-10	30	16.67				
11-15	99	55.83				
Control measures						
Control	86	48.33				
Not control	92	51.67				
Control measures taken						
Proper storage	27	31.03				
Proper drying	34	39.66				
Use of biocontrol	4	5.17				
Others Measures	21	24.14				

Source: Field survey, 2020

Awareness and use of Bio-control technology (Aflasafe) to control Aflatoxin

The result in Table 4 shows that only (26%) of the respondents reported being aware of Aflasafe, while majority (74%) indicated not being aware of it. This indicates a relatively low level of awareness regarding the availability and use of Aflasafe as a control measure for aflatoxin. Among those aware of Aflasafe, about 49.35% reported using it to control aflatoxin, while 50.65% indicated not using it. This suggests that despite being aware of Aflasafe, a significant number of the respondents have not adopted its use. Encouraging farmers to utilize Aflasafe as part of their agricultural practices is essential to effectively control aflatoxin contamination. The result further shows variations in the quantity

used per hectare. The most common quantity reported was 2 units per hectare, accounting for 57.89% of users. This indicates a consistent trend among farmers who have adopted the use of Aflasafe. It is also in line with the usage guidance provided by Aflasafe producers. Moreover result indicates variations in the purchase price of Aflasafe among the respondents that use Aflasafe. About half of respondents (52.63%) reported a purchase price range of 3,601-4,400 NGN. Another 7 respondents purchase their own at 2000-2,800 naira while others purchase at 4,401-5,200 naira or 5,201-6,000 naira with 10.52% each. Hence, increasing awareness about the existence and benefits of Aflasafe is crucial to promote its adoption and mitigate aflatoxin contamination in crops and food products

Table 4: Awareness and use of Aflasafe to control Aflatoxin

Variable	Frequency	Percentage	Min	Max	Mean	SD
Aware of Aflasafe						
Yes	77	26.00				
No	220	74.00				
Use of Aflasafe to control Aflatoxin						
Yes	38	49.35				
No	39	50.65				
Quantity of Aflasafe Used/ha						
1	4	10.52	1	4	2.33	4.5
2	22	57.89				
3	8	21.05				
4	4	10.52				
Aflasafe Purchase Price						
2000-2,800	7	18.42	2000	6000	4100	1000
2,801-3,600	3	7.89				
3,601-4,400	20	52.63				
4,401-5,200	4	10.52				
5,201-,6000	4	10.52				

Source: Field Survey, 2020

Sources of obtaining Aflasafe used by farmers

The result for sources of obtaining Aflasafe as used by farmers was reported in table 5 findings reveals that 50% of the respondents reported obtaining Aflasafe from local markets. This suggests that local markets play a significant role in providing access to Aflasafe for farmers. Additionally, 21.05% of the respondents reported obtaining Aflasafe through extension agents and cooperatives. Interestingly, private traders were reported as a source of obtaining Aflasafe by 4%

of the respondents. The result also indicates that 10.52% of the respondents reported obtaining Aflasafe from other sources not specified in the table. This highlights the importance of agricultural extension services and cooperatives in facilitating the access and distribution of Aflasafe to farmers. Also by exploring partnerships with private traders and encouraging their involvement in the distribution and marketing of Aflasafe can potentially expand the reach and accessibility of the product to farmers.

Table 5: Sources of obtaining Aflasafe

Sources	Frequency	Percentage (%)
Local markets	19	50.00
Extension agents	8	21.05
Cooperatives	7	18.42
Private traders	4	10.52

Source: Field survey, 2020

Maize farmer's reasons and perceived effectiveness for using Aflasafe

Table 6 reveals that 60% of the respondents indicated that the primary influencing factor to use Aflasafe is to improve food production. This suggests that farmers recognize the potential of Aflasafe to enhance crop yields and overall food

production. This corroborate with the statements that Aflasafe is known to reduce aflatoxin contamination, which can lead to improved crop quality, reduced post-harvest losses, and enhanced marketability of agricultural products. About 30% of the respondents identified the reduction of aflatoxin contamination as a

significant factor influencing their decision to use Aflasafe. This demonstrates an understanding of the health risks associated with aflatoxin and the importance of mitigating its contamination in crops and food products. While the remaining 10% of the respondents mentioned fungi resistance as an influencing factor for using Aflasafe. This suggests that farmers are aware of the role Aflasafe plays in controlling aflatoxin-producing fungi, thereby reducing fungal

infections and subsequent aflatoxin contamination. Aflatoxin effectiveness in controlling aflatoxin for farmers using Aflasafe result in table 6 further shows that majority of the respondents (78.94%) found Aflasafe very effective in controlling Aflatoxin. This is in line with the reports of Frisvad (2019) that establishes the significance and effectiveness of biocontrol to Aflatoxins

Table 6: Maize Farmers Reasons and perceived Effectiveness for using Aflasafe

Farmers Reasons	Frequency	Percentage
Improve food production	23	60.00
Reduction of aflatoxin contamination	11	30.00
Fungi resistance	4	10.00
Perceived Effectiveness		
Very Effective	30	78.94
Effective	8	21.05

Source: Field survey, 2020

Determinants of Decision Aflasafe Usage among Maize Farmers in the Study Area

The double hurdle model was used to estimate the factors that influence the decision to adopt and extent of application of aflatoxin of bio-control technology this was revealed in table 7. In the first step, the probit model was used to determine the factors of adoption and in the second step; the truncated model was used to estimate intensity of adoption.

The estimated LR chi-square is 31.84 and the log likelihood is 109.456 explain the goodness of fit of the double hurdle model indicating a joint significant of both drivers and intensity of adoption. The results further reveal variation in the estimated probit and truncated model indicating that the factors influencing bio-control technology use decisions to adopt are not exactly the same with factors that influence intensity of application justifying the use of Double hurdle model.

The estimated coefficient of education was positive (coefficient, 0.209) and significant (p-value, 0.005) in the study area, implying that one unit increase in the educational level of the

farmers has the tendency of improving their likelihood of adoption of bio-control technology in their farming operation by 20%. This finding compares favorably with that of Khonje, Manda, Alene and Kassie (2015), who obtained similar result on adoption of improved maize varieties in Eastern Zambia. This is because education improves the managerial skills and human capital of farmers. It also enhances their ability to assess and understand information on improved maize varieties, and this will invariably influence their probability of adoption of bio-control technology. The family size with (-0.045) was negatively related to adoption of bio-control technology and was significant at 5% indicating that adoption tends to decrease with an increase in household size. This is because a large household size implies more mouths to be fed. This could place a high demand on the ability of the household to purchase inputs such as fertilizer, bio-control chemicals especially for smallholder farmers. This is in conformity with the findings of Ouma, Bett and Mbataru (2014), who found that household size had negative effect on adoption of improved maize varieties in Kenya.

The estimated coefficient of membership of association (1.423) was positively related to the farmers' likelihood of adoption of bio-control technology. This implies that probability of adoption tends to increase by 142% with one unit increase in active involvement of farmers in associations. Farmer associations afford members the opportunity of having access to improved seed varieties and other farming inputs at favorable cost, access to marketing services and knowledge sharing among members of the associations.

The truncated model in Table 7 revealed that age, highest level of education, farm size and farming experience influence the intensity of using the technology. The estimated coefficient of age (-0.008) is negatively related to intensity of application of bio-control technology which is significant at 10%. It implies that increase in the age of farmer will reduce the likelihood of intensity of technology. This is because younger farmers are assumed to have more access and acquainted to modern technology time and is better able to evaluate technology information than older farmers, which can influence their decision and extent of application.

The estimated coefficient of farm size (0.11) is positive and significant at 1%. This implies that farmers with large farms are more likely to adopt new technology because they have land to try out new technology and also scale up technology

after trial compared to farmers will small farms. This is because land is a vital factor of production in agriculture, and farmers having large farm size are better endowed and can take risk in trying new things than poor farmers with small landholdings, who avoid taking risk in replacing their existing varieties with new ones. Accordingly, Mignouna, Manyong, Mutabazi and Senkondo (2011) found that farm size was a significant determinant of adoption of improved maize varieties in southern Zambia.

Moreover, the coefficient of highest level of education is positive and significant at 1% level of confidence. This means that highly educated farmers are more likely to use Aflasafe than less educated farmers. Implying that creation of more awareness of the bio-technology among educated farmers will significantly improve is adoption in the study area. The finding corroborate with that of Ouma, Bett, and Mbataru (2014) that improve production technology for maize is highly among educated farmers in Kenya.

Farming experience coefficient is highly significant and positively related to adoption intensity of bio-control technology at 5% level of significance. Implying that experienced farmers are more likely to adopt the technology than less years of maize production experience. This supported the finding of Ayedun *et al.*, (2017) that farming experience is positively related to maize production technology adoption.

Table 5: Determinants of Decision Aflasafe Usage among Maize Farmers in the Study Area

Variables	Probit Model		Truncated Model	
	Coefficient	P-Values	Coefficient	P-Values
Intercept	-1.974	0.001***	1.505(0.792)	0.000***
Sex	-0.136	0.655	0.876(0.015)	0.184
Age (Years)	0.010	0.509	-0.008(0.015)	0.003**
Highest level of education (Years)	0.209	0.005**	0.312(0.013)	0.017**
Marital status	-0.218	0.549	-0.093 (0.114)	0.417
Farming experience (Years)	-0.005	0.791	-0.087(0.158)	0.087*
Family size (Number of person)	-0.045	0.010**	-0.037 (0.036)	0.637
Farm size (Ha)	-0.002	0.961	0.11 (0.009)	0.000***
Extension visits (Frequency)	1.300	0.000***	0.059(0.093)	0.637

Membership of cooperative	1.423	0.005**	-0.247 (0.29)	0.393
LR Chi-square	31.84			
Prob> chi-square	0.000			
Sigma	0.5052			
Pseudo R-square	0.1270			
Log-likelihood	109.45584			

Source: Field Survey, 2020. ***, **, * implies Significance at 1%, 5% and 10% respectively.

Constraints to Aflatoxin Bio-Control Technology (Aflasafe) Usage in the Study Area

Several maize growing states in Nigeria, including Oyo state, have been identified with the incidence of aflatoxin occurring beyond the acceptable threshold of 247 and 276.1 ppb (Meridian Institute, 2013), and the level and frequency of occurrence are particularly high in 30% of maize in stores (IITA, 2013). Some of the constraints as reported by farmers in Table 8 revealed that inadequate markets for aflatoxin free maize (96.5%) was indicated by the farmers as the most serious constraint to maize production and marketing enterprise. The second serious problem in decreasing order of magnitude was the problem of lack of awareness (90.5%). Farmers especially did not know what caused aflatoxin, the health effects in humans and livestock and how to mitigate them. This clearly points to the need for greater awareness in the maize growing areas in Oyo state in order to ensure the production, storage and marketing of aflatoxin clean maize. Product awareness is

gradual, with some individuals within a group becoming aware sooner than others. Therefore, it is not surprising that some farmers are still not aware of aflatoxin. The survey farmers had a low awareness of different aflatoxin control technologies used in maize. The low awareness of aflatoxin control technologies was reflected in the low utilization modern, pre and postharvest control methods in the study area. This finding reflects in particular the failure of public extension system support. The third most frequently reported constraint, with 86.50% of respondents, is the price of Aflasafe. This indicates that the cost of Aflasafe is a significant barrier for some farmers. Addressing the affordability of Aflasafe is important to encourage its use. This could involve exploring cost-effective production methods, subsidies, or incentive programs to reduce the price of Aflasafe, making it more accessible to small-scale farmers. Unavailability of Aflasafe and high price of Aflasafe were ranked 4th and 5th with 78.0% and 62.5% respectively.

Table 8: Constraints of adoption Aflatoxin bio-control technology (Aflasafe)

Constraints	Frequency	Percentage	Rank
Inadequate Markets for Aflatoxin free maize	287	96.5	1 st
Low Awareness	268	90.4	2 nd
Additional Input Cost	257	86.5	3 rd
Unavailability of Aflasafe	232	78.0	4 th
Price of Aflasafe	186	62.5	5 th

Source: Field Survey, 2020.

CONCLUSION AND RECOMMENDATION

Maize production in the study areas is dominantly by male farmers. The farmers are found to be reasonable aware about aflatoxin and its negative consequences in their respective farms, however,

despite the effectiveness of Aflasafe biocontrol technology control only few of the farmers reported using it to control aflatoxin in maize crop they are producing. Although findings revealed education level, extension visit,

membership of association, age of the farmers, farm size and farming experience as determinants of Aflasafe Usage among farmers. The farmers were also constraint to adopting it majorly due to inadequate markets for aflatoxin free maize, low level of its awareness, high costs of inputs and unavailability of Aflasafe. The following can therefore be recommended to ensure adoption and usage of Aflasafe in the study area

- i. Awareness campaigns by Agricultural extension service officers shall be intensified among the maize farmers in the study area,
- ii. Given the cost constrain of the technology (Aflasafe) government shall subsidized the product to ensure its availability and affordability among maize farmers.
- iii. Government and non-governmental agricultural programmes on maize shall incorporate aspect of Aflasafe given the important of maize as food security staple crop.

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