Chapter 17

Aflatoxin and Peanut Production Risk and Net Incomes

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Additional information is available at the end of the chapter

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1. Introduction

Aflatoxins (AFs) are naturally occurring mycotoxins and they are produced by species of *Aspergillus fungi*, namely *A. flavus* and *A. parasiicus*. AF contamination of peanut affects the quantity and quality produced and marketed. AF contaminated peanut is tainted and cannot be marketed and must be thrown away. Awuah et al. (2009) stated that about 5 to 15 percent of peanut in Ghana was discarded during sorting. This reduces the supply of peanut marketed at the farm level. Lower quality peanut is less attractive to buyers who offer a lower price for AF contaminated peanut. Hence it is expected that AF will lower farmer revenue and increase production and marketing risks.

The toxic effects of AF on human and animal health constitute one of the major factors for establishing regulations regarding acceptable levels of AFs in food. These regulations require pre-harvest and post-harvest control, such as appropriate drying, sorting and storage structures. Therefore, implementing food safety standards can be costly. According to Mitchell (2003), government regulations increase production costs which generally cause the supply curve of a firm to shift to the left: from S_0 to S_1 (Figure 1). Hence, if consumers are aware of the AF problem and its consequences, they will be willing to pay a higher price for a safer food supply.

Although, consumers throughout the world desire a safe food supply, not all consumers are willing to pay a higher price for safer foods. Furthermore, if they perceive the product as unsafe they may be willing to buy less of the product. This will lead to the following conclusion: Risk of AF negatively affects demand. Both (cost for sorting peanut and perception of lower quality) result in a decrease of the firm's revenue (Figure 1).

Since AF contamination of peanut is both a pre-harvest and a post-harvest problem, factors that affect production of the mycotoxin will also be discussed along these lines. AF production may occur during pre-harvest. In tropical countries, humidity, high temperature and rainfall are some of the factors encouraging fungal growth and AF production. Moisture content exceeding a safe range of 8 to 12% may contribute to fungal growth (Schatzki and Haddon, 2002; Diener and Davis, 1967). At harvest, moisture content in peanut is generally high and can lead to development of aflatoxigenic fungi. ICRISAT (2008) recommended drying of peanut immediately after harvest down to 8% moisture in order to avoid the production of AF when the crop is stored. In Benin, the most commonly used drying method for peanut is sun drying. Farmers spread the nuts on a wooden or concrete floor usually for one to three days. Paz et al. (1989) reported that delayed drying could lead to a rapid increase in AF from 14.0 ppb at harvest to 93.8 ppb, if maize is not dried for 5 days after harvest. This was confirmed by Hell et al. (2003) who found that post-harvest contamination with AF in Benin increased when harvesting took more than 5 days and drying was delayed.

Another important post-harvest factor affecting AF contamination is storage condition. Grain crops may be attacked by fungi in the field which can then develop rapidly during storage when conditions are suitable for producing mycotoxins (Turner et al., 2005). During the survey, it was reported that the most common storage system for unshelled peanuts used by farmers across all regions was polyester bags in storage houses or rooms. In addition, farmers were questioned about the time of storage of their products. Most of them reported that they can store peanut for up to six months depending on market conditions. However, this time can be expanded to 8 to 12 months for other market participants. The relationship between the length of storage and the level of AF was, therefore, examined to assess the risk associated with storage time. Sorting of peanuts includes the elimination of broken, shriveled, discolored nuts or nuts burrowed by insect. The removal of contaminated nuts from a pile of nuts can reduce contamination level to less than 4ppb. In larger households the young children usually are assigned the tasks for sorting the nuts (Awuah et al., 2009). The risk of contamination by AF is an important food safety hazard for field crops (Dolman, 2003). In order to protect consumers from health risks, regulatory limits have been imposed on field crops intended for use as food and feed, and have significant impacts on world export market. The World Health Organization (WHO) has set a maximum level for AF at 20 ppb in human foods and 100 ppb in animal feed (WHO, 1998). Likewise, the Food and Drug Administration (F.D.A) set a tolerance limit for peanut at 15 ppb for human (FDA, 1978). The European Union (E.U) has set stricter standards: any food products for human consumption with a concentration of AF greater than 4 ppb cannot be marketed. These standards are bound to affect the production and marketing of peanut as efforts to reduce contamination result in lower grain supply at a higher cost. This means that decisions lo reduce levels of AF in peanut may affect producers net income.

The main objective of this paper was to examine the effects of AF on peanut production in Benin. The first hypothesis states that AF contamination of peanut affects quality and quantity marketed. Based on survey answers and visual observations peanut were sorted. We examined the peanut that were discolored, broken, punctured and discarded them. The removal of bad peanut from the lot leaves us with lower quality of marketable peanut. The second hypothesis is that AF contamination of peanut influences selling price; we examined buyers' responses to test the influence of AF on selling price. Our third hypothesis is that AF contamination influences labor costs and reduces net returns from peanut. We examined sorting, labor requirement, labor costs from survey data, and enterprise budgets. We also examined how sorting affects financial and marketing risks with capital budgets and risk analysis.

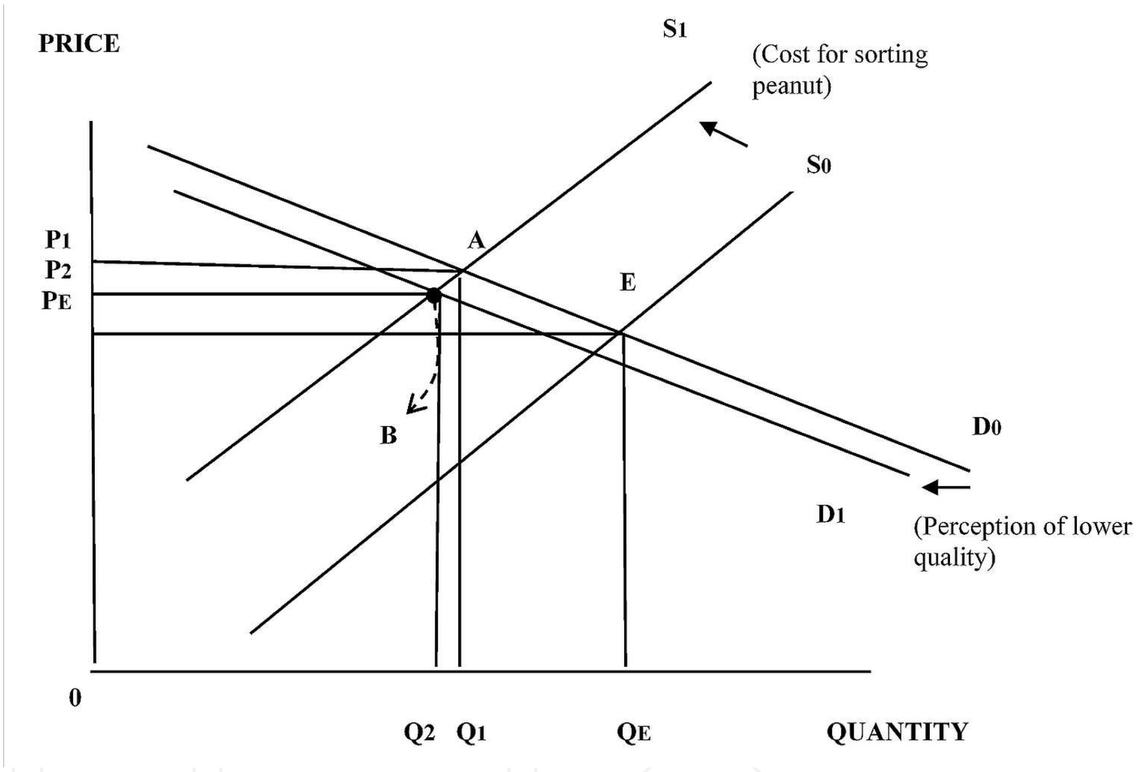

Figure 1. Market impact of food safety regulation

We can further represent the market equilibrium by these equations:

$$S_1 = \alpha + \beta_1 P - \theta_1 \quad (1)$$

$$D_1 = \alpha - \beta_1 P - \theta_2 \quad (2)$$

S_1 and D_1 are supply and demand respectively,

P represents the market price,

θ_1 and θ_2 represent both risk factors of AF.

2. Material and methods

2.1. Market participant identification, data and sample collection

We conducted surveys on AF contamination in peanut in three agro-ecological zones of Benin. Kandi (North), Savalou (South-east) and Abomey-Bohicon (South) were selected on the basis of their climatic conditions and levels of peanut production (Figure 2). A total of 30 farmers were selected in each of the three peanut producing regions of Benin during the period of May to July 2007. Peanut farmers were identified through the assistance of agricultural officers in the Ministry of Food and Agriculture (MoFA) and through the help of personnel from the University of Abomey-Calavi, Republic of Benin.

During the visits to each farm household, farming practices related to grain storage and handling were observed and documented using information on the survey instrument. Questionnaires were administrated to farmers by trained interviewers. Primary data collected included information on demographic and socioeconomic status, farming, post-harvest handling, storing and sorting practices, scheduled production activities, production level, household revenues and consumption frequency of peanut.

Peanut samples were collected at different post-harvest points and under different storage conditions. The levels of infestation of AF contaminated peanut under farmers' storage and marketing conditions were determined. It has been noted that AF levels vary along the marketing chain and the level of AF is more pronounced during storage and processing (Awuah et al., 2009).

Samples of 0.800 Kg (= 1.764 pounds) of peanut were taken in the fields and markets from each farmer. These samples were divided into two groups: sorted clean and rejected (bad) nuts. Bad nuts were the ones with discoloration and holes.

2.2. Determination of aflatoxin (AF) level

Assessment of AF levels was undertaken using the VICAM technique. VICAM is an AF test that produces numerical results using monoclonal antibody-based affinity chromatography. The test can isolate AF β1, β2, ğ1, and ğ2 from feeds, foods, grains, and nuts, and from dairy products.

This test involved observation of post-harvest and handling of peanut, collection of data on management issues related to grain storage and handling, collection of peanut samples, and testing them to detect AF levels. Each farmer's farm or business selected for the study was visited. The frequency of levels of AF found in peanut was used to estimate the probabilities of occurrence of AF.

2.3. Statistical analysis

Data collected during the survey were entered into an EXCEL spreadsheet and analyzed using SAS software package version 9.1. These data were used to develop enterprise budgets for producing peanut. The costs of each business activity were estimated based on the data

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collected in the survey. Furthermore, a simulation of the risk of AF contamination on farmers' income from the production, storage and trading of peanut was done using the @RISK software.

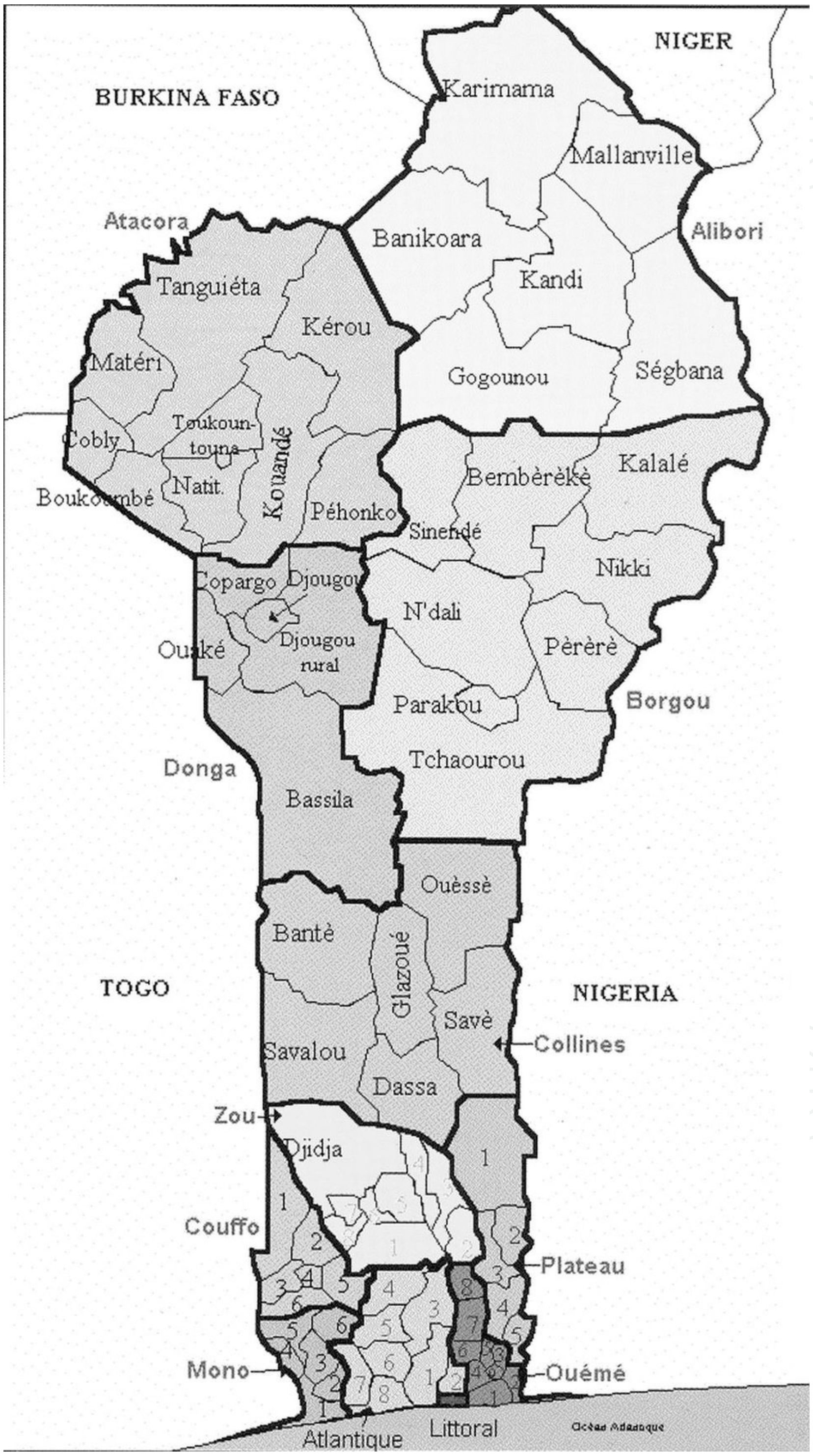

Figure 2. Map of Benin showing research sites

3. General assumptions

Regional effects: The survey was carried out in three different agro-ecological zones: Kandi, the northern region has one growing season starting at the end of May to September, with a temperature ranging from 28 to 45°C and a low rainfall averaging 800 to 900 mm. However, Savalou and Abomey-Bohicon both have two growing seasons (April to July and September to November) with higher rainfall between 1,300 and 1,500 mm, and temperature from 25 to 35°C (Setamou et al., 1997). Because of its dry climate, Kandi is the most productive region and is also the least prone to AF production.

In the southern regions, AF production is due to the high rainfall and high temperature. Under these tropical conditions, development of fungi and AF proliferation are facilitated. A higher concentration of AF in Abomey-Bohicon than in Savalou and Kandi.

Decision on drying, sorting and storing peanut: Based on previous studies, drying, sorting and storing methods are reported as the most important factors that encourage AF production. Farmers are recommended to dry peanut immediately after harvest, importantly to bring the moisture level of less than 8% (ICRISAT, 2008).

Sorting is considered as one of the ultimate solutions for the AF problem. This method has been reported as a post-harvest intervention strategy successful in reducing AF levels in peanut. An essential question was how much farmers or market participants will lose if they decide to sort peanut. In case the decision was "no sorting", not only quantity is affected but also labor cost. Hence, based on the answers obtained during the survey, the probability to throw away some nuts was estimated at one to five percent of quantity produced if farmers decided to sort them. However, if not, the risk of fungal growth and from nuts (molded or contaminated with AF) will increase.

Long-term storage in warm environment results in *Aspergillus* growth and increased in AF contamination. Previous research has yet to suggest a safe period in which peanut can be stored. We assumed, therefore, that after two months, with a risk of having bad nuts (mold, insect damage, and AF contamination), the percentage of rejection will be one percent and will increase by one percent more after each of two months. This percentage is applied on the quantity harvested as the percentage representing the loss in quantity if the storage length exceeds two months. This period (two months) was chosen based on survey reports.

Enterprise budgets: Budget analyses are used to evaluate the profitability of peanut enterprises in the short run. Costs and returns were estimated for each region. Most information used to develop each enterprise budget was obtained during the survey. Data such as seed quantity, seed price, quantity of peanut harvested, peanut selling price, material and equipment, labor hours and costs were obtained from the survey. They are the averages for the various size farms. All lands included in the budgets are treated as owned by farmers. Material and equipment are the same in each region and are depreciated according to the useful life, using the straight-line method. Costs for repairs and maintenance are assumed to be $1.00 for a one-hectare farm. Labor costs include land preparation, planting, harvest, drying, sorting, bagging, and transport costs. Labor costs and hour of use vary depending on the farm size.

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Risk analysis: Parameters such as price of output, inputs and quantity are manipulated to examine how changes in parameters affect peanut production and revenues. A total of 5,000 iterations of the model are executed to generate all probability distributions that are used to establish stochastic dominance. All parameters used to develop the risks models are presented in Appendix 1.

Here we assume that net returns from peanut sales are affected by the costs of production and post-harvest handling. Hence, we use the formula:

$p_i*N.R = [p_i*(P_p*Q_p) - (p_i*Cost)]$

where,

p_i is the probability of the occurrence,

N.R is net return,

P_p is the price for peanut,

Q_p is the quantity for peanut, and

Cost is the cost of production; cost includes seed quantity and price, equipment, cost of pre-harvest, harvest, sorting, storage, bagging, winnowing…

Cost = $p_1*\beta_1$ drying cost + $p_2*\beta_2$ storing cost + $p_3*\beta_3$ sorting cost +…+ $p_n*\beta_n$ costs of n

Stepwise least squares regression is conducted between the collected input distribution values and the selected output values. The assumption is that there is a relationship between each input and output. The output of the stepwise regression is expressed in the form of a tornado chart.

Tornado chart is used to show the influence an input distribution has on the change in value of the output. Its main use is to enable the researcher to determine which variable contributes more to the output. It is also used for model diagnostic.

Therefore, the coefficient for any of the variables is standardized and will vary from -1.0 to +1.0. Variables contributing zero to the cost will be eliminated. Variation in cost, each year will be kept and their importance to cost will be explained.

4. Results

4.1. Demographics and socio-economic results

Socio-demographic information, knowledge of AF on peanut and farming practices were collected during the survey. Age of the respondents ranged from 35 to 55 years old, and over 55 years old (Table 1). Peanut production is done mostly by men in Kandi (63.3%), Savalou (100%), and in Abomey-Bohicon (54.4%). A large number of peanut producers in Benin have not received any formal education, and have never heard of AF contamination of peanut.

Most respondents have no formal education. A large number is found in Kandi with 43.3% (13) literates. Over 9 respondents who received a formal education in Savalou, only 3.3% (1) continued to secondary school in Abomey-Bohicon, 36.7% (11) had primary education and only 6.7% (2) attended secondary school (Table 1).

	Kandi		Savalou		Abomey-Bohicon	
	Number	%	Number	%	Number	%
Age groups						
Under 35	8	26.7	14	46.7	8	26.7
36-55	20	66.7	9	30.0	38	43.3
over 55	2	6.7	7	23.3	8	26.7
Gender						
Female	11	36.7	0	0	5	45.6
Male	19	63.3	30	100	25	54.4
Education						
No formal education	17	56.7	23	76.7	19	63.3
Primary school	13	43.3	7	23.3	11	36.7
Secondary school	5	16.7	1	3.3	2	6.7
Years of experience						
0-15	9	30.0	16	53.3	7	23.3
16-30	14	46.7	6	20.0	7	23.3
Over 30	7	23.3	8	26.7	16	53.3
Land tenure						
Owner	26	86.7	18	60.0	5	16.7
Renter	4	13.3	5	16.7	25	83.3
Income levels (month)						
$0-$350.14	10	33.3	13	43.3	18	60.0
$350.14 - $700.28	3	10.0	15	50.0	9	30.0
$700.28 - $1,400.56	10	33.3	2	6.7	2	6.7
Over $1,400.56	7	23.3	0	0.0	1	3.3

Table 1. Socio-demographics characteristics of peanut producers in Kandi, Savalou and Abomey-Bohicon.

Years of experience were divided into 3 groups: less than 15 years (group one), between 15 and 30 years (group two) and over 30 years (group three). In Kandi, most farmers belong to

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the second group (46.7%); In Savalou, the majority (53.3%) is in group 1. More than half of the respondents in Abomey (53.3%) have been farming for at least 30 years.

The majority of the respondents own their land in Kandi (86.7%) and Savalou (60%), while in Abomey a large percent (83.3%) rent land to produce peanut.

Income levels for most farmers in Kandi (33.3%) are less than $350.14, and between $700.28 and $1,400.56. Half of the producers in Savalou an income level between to generate an income level to$350.14 and $700.28, while in Abomey, approximately 60.0% earn less than $350.14.

Aflatoxin Knowledge and Identification: Very few respondents know about AF contamination of food. As Kaaya and Warren (2005) reported, a large number of producers, traders and even consumers are not aware of food contamination with AF. When respondents were asked about the criteria used to identify AF contaminated peanut, some of them reported that they could identify spoiled or contaminated crops by the color or the shape; common colors are black, brown, white dust and greenish. Respondents suspect also any nut that are broken or attacked by insects to be contaminated by AF.

When asked if they had ever been sick from ingestion of AF contaminated peanut, most of the respondents' answers were negative. There is no report of diseases related to AF; however, it was reported that important consumption of peanut could affect consumers' health (Table 2). About 27.78% (Kandi), 43.33% (Savalou) and 47.78% (Abomey) of respondents reported that they were affected by diseases such as malaria, diarrhea and coughing, due to a large and frequent consumption of peanut. This may show limited knowledge of the health effects of consumption of AF contaminated peanut.

Of 90 farmers interviewed in Benin, about 95.6% dry peanut immediately after harvesting, and only 10% sort peanut before selling. However, the remaining farmers explained that not only it is time consuming to sort peanut but also, it reduces peanut quantity by 5 percent on average. Nevertheless, when peanut samples were tested for AF, results indicated that 91.5% of the samples tested were below the European standard (4 ppb), and only 8.5% were above that limit.

During the survey, a number of respondents (78%) stated that they store their products for approximately 2 to 6 months or longer if market price is not favorable. In the northern region (Kandi), this period can exceed 6 months (up to 12 months) because there is only one growing season each year.

Aflatoxin level: Distribution of AF levels for farmers samples are shown in Table 3. Based on European standards, we observe that a large number of the samples tested (91.5%) have a concentration level of less than 4 parts per billion (ppb). About 93.2% of the samples have a level less than the tolerance limit (15 ppb) set by the Food and Drug Administration (FDA). Based on WHO standards, the majority of the samples (96.6%) were safe for consumption, while 3.4% exceeded 20 ppb. In addition, most of the samples (98.3%) were less than the permissible level in animal feed (100 ppb).

Region (N = 90 per region)	Yes		No	
	Number	%	Number	%
Producers report sickness related to aflatoxin in three regions of Benin, 2007				
Kandi	25	27.8	65	72.2
Savalou	39	43.3	51	56.7
Abomey	43	47.8	47	52.2
Characteristics				
Dry peanut after harvesting	86	95.6	4	4.4
Sort peanut	9	10.0	81	90.0
Consume bad* grains	0	0.0	90	100.0
Give bad* grains to your animal	10	10.0	80	90.0

* Bad: discolored or contaminated

- Source: survey data

Table 2. Producers report sickness related to aflatoxin in three regions of Benin, and their characteristics

Aflatoxin limit	European standards 4 ppb	USA standards 15 ppb	WHO standards 20 ppb	Animal standards 100 ppb
Less than	91.5	93.2	96.6	98.3
Greater than	8.5	6.8	3.4	1.7

- Source: analysis of marketed peanut

Table 3. Distribution of aflatoxin level for farmers based on standards (%).

4.2. Enterprise budget

Enterprise budgets for each region studied are shown in table 4. AF contamination reduces farmers' net returns. Peanut production is more profitable in Kandi than in the other regions. Table 4 shows that net returns above total expenses are $1,626.54, $1,294.26, and $802.62 in Kandi, Savalou and Abomey-Bohicon, repectively. Estimated costs and returns budgets for sorting are also reported in table 4. Results show that there is a decrease in revenue and returns when farmers decide to sort peanut to improve quality. In addition, there is a decrease in yield (5%) and an increase in labor cost due to sorting, which in turn reduce farmers revenue and net returns. Previous studies conducted on the relationship between AF contamination and environmental conditions showed that high levels of AF are found in regions with warm and humid climates (Dohlman, 2003; Farombi, 2006). The present study demonstrates that farmers in the most humid area (Abomey-Bohicon) generate lower net returns ($783.09).

-Sell unshelled and per bag of 100 kg	-Sell in local markets (price: $0.42/kg).
-Straight line method for depreciation	-Kandi (Plant in May and harvest in September)
-Savalou (Plant in April and Harvest in August)	-Abomey (Plant in March and Harvest in July)

	Kandi		Savalou		Abomey	
	Not sorted	Sorted	Not sorted	Sorted	Not sorted	Sorted
Yield (Kg)	4,500	4,455	3,600	3,564	2,400	2,376
Revenue ($)	1,890.75	1,871.85	1,512.60	1,497.48	1,008.39	998.31
Labor costs ($)	174.69	184.14	174.69	184.14	174.69	184.14
Total variable costs ($)	259.29	268.74	213.93	223.38	200.85	210.30
Total fixed costs ($)	4.92	4.92	4.41	4.41	4.92	4.92
Income above variable costs ($)	1,631.46	1,603.11	1,298.70	1,274.10	807.57	788.04
Net returns ($)	1,626.54	1,598.16	1,294.26	1,269.69	802.62	783.09
Break-even price ($/kg)	0.06	0.06	0.06	0.06	0.08	0.09
NPV (6%)	5,714	5,614	4,536	4,450	2,811	2,743
PI (6%)	1,060.00	1,042.42	1,134.02	1,112.44	522.46	509.75
IRR	95.13	93.47	10.08	98.79	46.88	45.74

- Material and Equipment are physical resources used in the farm operation. They are renewed every year.

Table 4. Estimated annual costs and returns budget for a large size farm (3ha) in each region, assuming that there is no change in price when farmers sort peanut and using the following peanut production practices

Table 5 summarizes the costs and returns generated by farmers after 6 months of storage. Following Hell et al. (2000) and Kaaya and Kyamuhangire (2006) reports, who indicated that duration of storage positively influences fungal growth and AF production in food crops, this paper hypothesized that peanut stored for more than 6 months have a negative effect on farmers net returns. Since consumers may perceive that peanut quality will deteriorate during storage, due to AF contamination, they might lower price. Results show that AF growth increases with the length of storage and lowers revenue from peanut production, due to lower peanut quality.

The assumption in this table is that there is a decrease in price by five percent, due to peanut quality. After 6 months of storage, significant differences are observed in product quality and on farmers' income. Hence, net returns per hectare above all expenses are reduced.

	Kandi	Savalou	Abomey
Revenue ($)	1,796.22	1,440.60	957.98
Income above variable costs ($)	1,536.90	1,226.27	757.14
Net returns ($)	1,531.90	1,222.27	752.34

- Assuming that after 6 months, peanut quality worsens resulting in a lower price.

- Peanut price decrease from $0.42 to $0.40 per kg.

- Results in this table are compared to the results in Table 4.

Table 5. Storage impact in each agro-ecological region (large farms 3 ha).

4.3. Risk analysis

Table 6 displays the results for the risk analysis. As farmers sort their stored product, we assume that an increase in peanut price of 15, 10 and 5 percent is offered over the storage period. Assumptions are shown in table 6.1, table 6.2 and table 6.3. These tables report the simulated effects of change in price and storage duration on farmers' costs and returns. We observe a significant relationship between net returns and price, and also a negative relationship between net returns and sorting when farmers sort their peanut. The longer peanut is stored, the smaller is the final quantity due to fungal and AF production; however, for each region, as price increases by 5%, 10%, and 15%, revenue and net returns also increase. Overall, to improve quality of stored peanut, farmers sort peanut which results in an increase in labor cost, a decrease in yield and higher net returns. This finding confirms that sorting causes economic losses to peanut producers who want to improve peanut quality. Drying has also a positive impact on farmers' revenue and net returns, which shows that farmers have to dry peanut efficiently before selling their products. Further, as storage period exceeds 6 months, the enterprise becomes less profitable. It is, therefore, more profitable and less risky, to increase selling price to cover cost of sorting; however, it is more risky for farmers to sort peanut 6 months after harvesting than to sort at harvest.

Storage time	Change in price	Price	Quantity	Revenue	Net returns
(months)	%	($/kg)	(kg)	($)	($)
0-2	15	0.48319	4,455.00	2,152.62	1888.38
2-4	10	0.46219	4,410.45	2,038.45	1774.21
4-6	5	0.44118	4,366.35	1926.33	1662.09
6-8	-5	0.39916	4,322.68	1725.43	1461.19
8-10	-10	0.37815	4,279.46	1618.28	1354.04
10-12	-15	0.35714	4,236.66	1513.09	1248.85

Table 6.1. Sensitivity analysis for peanut budget by changing price and the effect on revenue, and net returns (Kandi)

Storage time	Change in price	Price	Quantity	Revenue	Net returns
(months)	%	($/kg)	(kg)	($)	($)
0-2	15	0.48	3564.00	1722.10	1503.77
2-4	10	0.46	3528.36	1630.76	1412.43
4-6	5	0.44	3493.08	1541.07	1322.74
6-8	-5	0.40	3458.15	1380.35	1162.02
8-10	-10	0.38	3423.56	1294.63	1076.30
10-12	-15	0.36	3389.33	1210.47	992.14

Table 6.2. Sensitivity analysis for peanut budget by changing price and the effect on revenue and net returns (Savalou)

Storage time	Change in price	Price	Quantity	Revenue	Net returns
(months)	%	($/kg)	(kg)	($)	($)
0-2	15	0.48	2376.00	1148.06	942.42
2-4	10	0.46	2352.24	1087.17	881.53
4-6	5	0.44	2328.72	1027.38	821.73
6-8	-5	0.40	2305.43	920.23	714.59
8-10	-10	0.38	2282.38	863.08	657.44
10-12	-15	0.36	2259.55	806.98	601.34

Table 6.3. Sensitivity analysis for peanut budget by changing price and the effect on revenue and net returns (Abomey)

Table 6. Sensitivity analysis for large farms (3 ha) gross margins, assuming that price varies through sorting and storage.

Results are also confirmed further. Figure 3 presents the tornado graphs for net returns for farmers who sort peanut before marketing. Price is the most important variable in the regression analysis. Drying has also a positive impact on farmers' revenue and net returns, which shows that farmers have to dry peanut efficiently before selling their products. However, there is a negative relationship between sorting and net returns. It is evident that when farmers sort peanut, it negatively affects net returns. Similarly, coefficients for storage (-0.03) and other labor variables like harvesting (-0.001) have a negative influence on net returns for each region.

In addition, based on the assumptions used to develop the sensitivity analysis of the NPVs in Table 6, risk is incorporated in NPV at different price levels and at different storage times. Figure 4 shows that NPV for farmers who sort peanut and sell at the normal price is smaller than those who sell sorted peanut at a higher price (5%). It is, therefore, more profitable and less risky, to increase selling price to cover cost of sorting. Tornado graphs above show that there is a significant relationship between price and NPV. As price goes up due to sorting, the NPV also increases; for instance, with a probability of 80%, NPV is 15.24% smaller when farmers sort immediately at harvest (Figure 5). Sorting peanut stored for 6 months is more risky than when farmers sort at harvest;

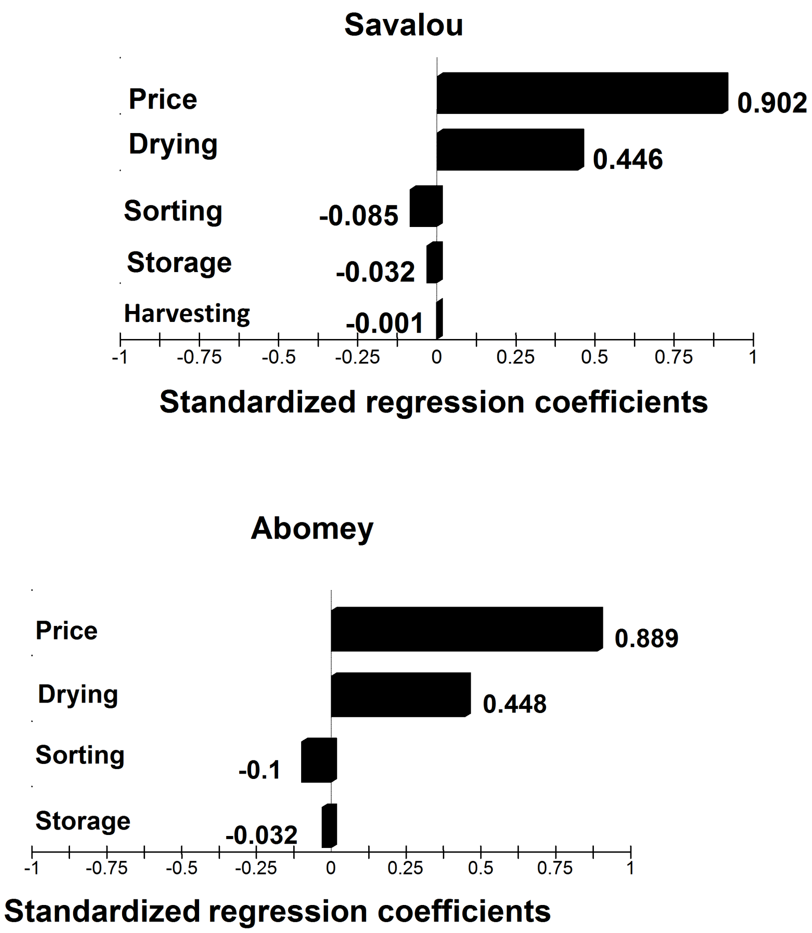

Figure 3. Tornado graphs of the net returns of peanut production in each region, assuming that peanut is sorted before marketing.

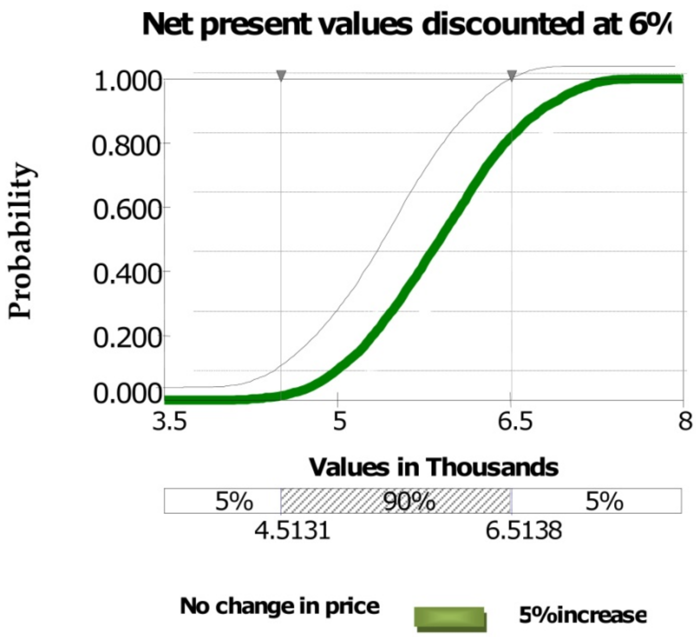

Figure 4. Cumulative probability distribution of the net present value for sorted and non-sorted peanut at varying prices according storage time (no change, 5% increase).

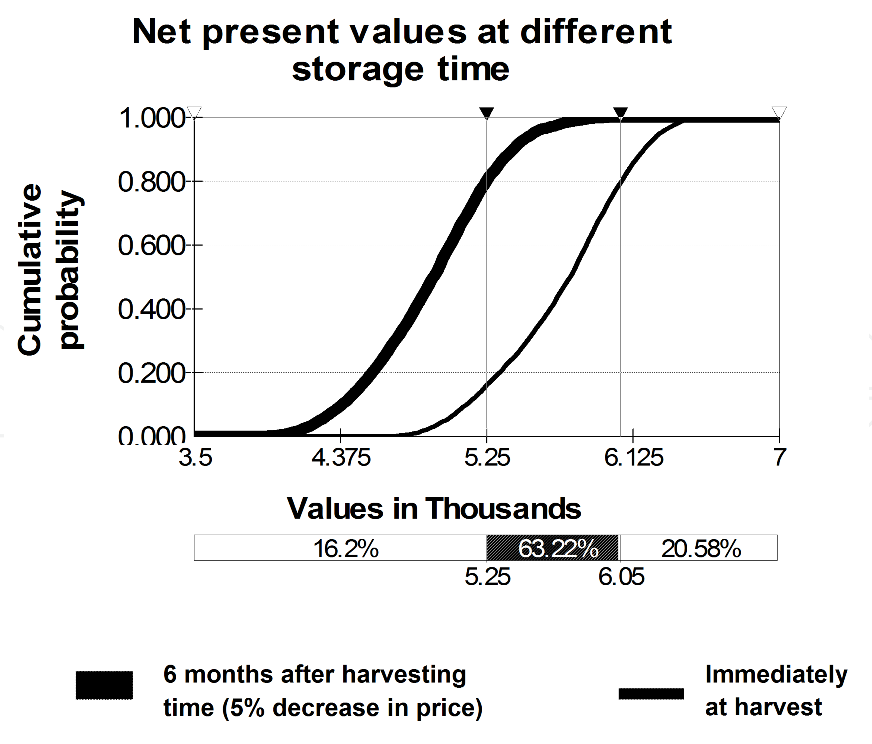

Figure 5. Cumulative probability distribution of the net present value for stored peanut at harvest and six months later.

5. Conclusion

This study compares the costs and returns of peanut production in three agro-ecological zones of Benin. Findings demonstrate that AF is affected by pre-harvest and post-harvest factors. During the survey, most farmers stated that drying of peanut was done immediately after harvest. However, sorting was practiced only by few respondents. In many studies, sorting has been suggested as an efficient method to control AF development in peanut. In addition, another factor that needs to be highlighted is storage condition. Growth of storage fungi followed by AF production is also determined by storage structure and storage length. Plastic bags or other synthetic bags used mostly by farmers during storage promote increases in humidity, and hence, increase in AF levels. Since AF contamination in storage is dependent on the storage system, the solution would be to sort peanut during storage.

Results from enterprise budgets show that AF reduces farmers' net returns. Sorting of peanut results in higher labor costs and smaller net returns than the costs and returns generated when farmers do not sort peanut. Net returns per hectare after sorting peanut were reduced to $532.7 in Kandi, $423.2 in Savalou, and $261.03 in Abomey-Bohicon. Net returns were higher for Kandi which is the most productive region.

Results also demonstrate that AF increases with length of storage and lowers revenue from peanut production. After 6 months of storage, farmers' net revenues decrease due to lower peanut quality. It is evident that storage conditions have a significant impact on AF development. Moreover, in the risk analysis results, we note a significant relationship between net returns and price, and also a negative relationship between net returns and sorting when farmers sort peanut. This finding confirms that sorting causes economic losses to peanut producers who want to improve quality. Hence to compensate for their losses due to costs of sorting, producers have to increase price to cover at least their variable costs.

Although investigations in this study indicate that it is more profitable for farmers to sell peanut immediately after harvest than to store it, the solution would be to improve farming practices and management, storage conditions, increase price in order to improve peanut quality and minimize risk of losses from AF. Improvements of quality and higher prices are obtainable with government legislations, and consumer and producer education.

Appendix 1. Definition of parameters (inputs) used for risk models

Parameters	Unit	Risk function
Price (selling)	$	RiskTriang (0.32,0.42, 0.51)
Drying: No (0), Yes (1)	-	RiskDiscrete ({0,1},{0.044,0.956})
Sorting : No (0), Yes (1)	-	RiskDiscrete ({0,1},{0.04,0.96})

Parameters	Unit	Risk function
Storage	Month	RiskTriang (0, 2, 4)
Pre-harvest cost	$	RiskTriang (50, 52.5, 55)
Harvest cost	$	RiskTriang (1, 2, 3.5)
Drying costs	$	RiskTriang (0, 1.58, 3)
Sorting cost	$	RiskTriang (0, 3.15, 6.5)
Bagging cost	$	RiskTriang (0.5, 1.4, 2.5)
Transportation cost	$	RiskTriang (0.1, 0.5, 1.5)

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