

1. Final Summary

a. Brief statement of overall goal

The goal of the project was to assess the financial and health risks of aflatoxin contamination with the aim of improving the quality of groundnut consumed and traded in Ghana (the effects of improved post-harvest handling of groundnut in reducing aflatoxin contamination in nuts was examined in non-human studies). We estimated the health and financial costs of aflatoxin to the agricultural sector. The objectives are:

- 1) Evaluate the effects of aflatoxin on the profitability of market participants producing and trading groundnut and groundnut products.
- 2) Determine the factors influencing the adoption of techniques to reduce the levels of contamination of stored groundnuts.
- 3) Estimate the perceived health risks and the costs to human health of consuming AF contaminated groundnut in Ghana.
- 4) Compare improved storage techniques with traditional methods of stored groundnuts.
- 5) Evaluate the effects of aflatoxin contamination reduction on the groundnut industry and the agricultural sector.

b. Significant Technical Achievements-Host Country, US?

Objective #	Technical Achievement – Host Country	Technical Achievement – US	Significant Issues and Challenges
<p>1. Evaluate the effects of aflatoxin (AF) on the profitability of market participants producing and trading peanuts</p>	<p>The methods used for reducing AF in Ghana were mainly post-harvest treatments which require drying, sorting and storage. The studies showed that drying to less than 12 percent moisture could almost reduce AF contamination to acceptable standards of less than 4pp and prevent financial losses. Sorting of the nuts were costly and did not increase profitability. Proper storage was essential for increasing profitability</p>	<p>Proper drying and storage were costly and there was risk associated with profitability when sorting and storing were done to reduce AF levels.</p>	<p>Manual sorting was more costly than mechanical but there was greater risk of using mechanical sorters. This remains a challenge for developing countries since they may find mechanical sorters unaffordable.</p>

<p>2. Determine the factors influencing the adoption of techniques to reduce the levels of contamination of stored groundnuts.</p>	<p>Farmers who belonged to a cooperative were 2.1 times more likely to adopt new storage technologies, and farmers who had from 1 to 6 years of farming experience were 1.9 times more likely to recognize the difference between traditional and improved storage technologies. Farmers who were aware of the ill-effects of contaminated nuts on human health were more likely to store their groundnuts in well-aerated and well-covered groundnut storage bins than those who were unaware. Farmers who belonged to a cooperative were 2.2 times more likely to store their groundnuts in well-ventilated storage bins. Those who belonged to a cooperative and those who had 1 to 6 years farming experience were 2.2 times more likely to adopt storage techniques to reduce AF levels.</p>	<p>The factors influencing technology adoption to reduce AF levels were outlined. Formal education as a whole does not influence the adoption of technologies to reduce AF levels but training in groups and cooperatives has greater effect on technology adoption.</p>	<p>The greatest challenge was to differentiate between traditional and modern technology since most farmers kept some form of the traditional technology but modified it. It was difficult to determine recommended storage practices from non-recommended since farmers received information from various sources, government, NGO's, PVO's and other charitable organizations and international donors.</p>
<p>3. Estimate the perceived health risks and the costs to human health of consuming AF contaminated groundnut Ghana.</p>	<p>We examined the relationship between AF levels in contaminated groundnuts and found that there is a link between AF levels of contamination and the levels of poverty as indicated by levels of per capita household income.</p>	<p>Poor consumers are, therefore, less educated and are less likely to adopt food safety measures and have greater exposure of consuming AF contaminated groundnuts.</p>	<p>There is a problem of establishing a poverty line since a large number of farmers produce for own consumption with and additional amount being sold on the market place. In many cases there is no clear cut distinction between producer and consumer.</p>

	Poorer households are more likely to believe that they are in good health than wealthier households. They are less likely to sort their peanuts before consumption; they are less likely to feed the AF suspected contaminated peanuts to animals and they are less likely to inspect the peanuts before consumption.		
4. Compare improved storage techniques with traditional methods of stored groundnuts.	Improved storage requires a large investment costs. The study results indicate an increase in price of peanuts is needed to encourage farmers to adopt new storage technologies.	Farmers in the US can adopt similar technologies to reduce AF in the future,	The problem rests with the definition of traditional and non-traditional technologies.
5. Evaluate the effects of AF contamination reduction on the groundnut industry and the agricultural sector.	<p>This research determines price and quantity effects owing to introduction of AF regulations in the Ghanaian peanut sector. Stricter standards raises costs and amount of groundnuts discarded of over 50% of edible peanuts in order to adopt EU, WHO, and US. A high correlation between AF contaminated groundnuts and maize AF contamination at the household level.</p> <p>A rise in consumer price implies consumer welfare losses while a drop in producer price suggests a decrease in producer welfare. Generally, AF</p>	This study, though related to Ghanaian producers and consumers, have implications for U.S. producers and consumers since stricter compliance and regulations as that of the EU are likely to affect U.S. producers and consumers. There is no need to repeat the study in the U.S. since the information obtained is rather universal.	In the U.S. regulations are in force but in Ghana there is no regulation in force. It is therefore, harder to institutionalize regulations to deal with the problem.

	<p>standards introduce additional (compliance) costs into the peanut industry. The compliance cost effects are borne by both producers and consumers depending on demand and supply elasticities as well as the importance of international trade in the peanut sector. Consumers and producers share consequences of strict AF standards enforcement (i.e. increased compliance costs) with distribution critically determined by relative magnitude of supply and demand elasticities.</p>		
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a. Significant Issues/Challenges

The biggest challenge for the program is the lack of human capital in the host country to develop a true measure of collaboration and the required capacity. One economist might be engaged in research, teaching, policy making and other government tasks and he/she is unable to devote continuous time for the research. Secondly, researchers a base pay do not reflect research output; therefore, researchers are likely to put less than the desired amount of research effort to accomplish research results. I wish we could fund more domestic students at local universities to conduct the research.

b. Capacity development, i.e. laboratory, field, equipment-Host Country, US

We purchased a second VICAM equipment for testing aflatoxin in grains and attachments costing over \$10,000. 00. We shipped about \$21,000 worth of VICAM test kits to Ghana. We sent a graduate student to Ghana to train two technicians on how to use the VICAM machine. We had Dr. Fialor visit the U.S. for training for a period of three weeks in data analysis. We conducted training for interviewers and graduate students. We purchased software in data analyses and had 15 graduate students from the Kwame Nkrumah University of Science and Technology trained in the use of the software. We have recruited two graduate students who are being trained at the Ph.D. and masters level in Applied Economics and Rural Sociology.

c. Human Capacity/Training Table

Name	Sex	Country	Degree	Completion date	Country trained	Employment
Michael Agyekum	Male	Ghana	Ph.D.	2013	USA	-
Akua Gyamfi	Female	Ghana	M.S.	2013	Ghana	-
Festus K. Attah	Male	Ghana	MPhil	2012	Ghana	KNUST
Magdelene Aidoo	Female	Ghana	MPhil	2013	Ghana	KNUST
Bretford Griffin	Female	U.S.	Ph.D.	2014	U.S.	Graduate Assistant Auburn

d. Key workshops/short-term trainings listed in a table that includes:

Location of Training	Training Type	Number of M/F
Ghana	Training in Risk Analysis and Financial Management	5 Females and 8 Males
Ghana	Analytical Hierarchical	5 Females 8 Males
U.S.	Data analysis	1 Male

Ghana

Non-degree

Farmers-500 farmer were trained three days per week during a week’s workshop-we trained farmers on the dangers of aflatoxin and methods of handling aflatoxin contaminated groundnuts. Farmers’ knowledge and perception of aflatoxin were discussed during the workshops..

Processors/traders-250 received three-day training at workshops during the period 2003 to 2007.

Wholesalers/retailers-250 received three-day during the period 2003 to 2009.

Administrators, Doctors, Nurses, Agricultural Officers-300 received three-day training on aflatoxin awareness

Consumers-500 consumers received three-day training during the period 2003 to 2007.

Enumerators-200 interviewers received one week training during the period 2001 to 2011 on survey techniques.

Laboratory technicians-We trained two laboratory technicians in aflatoxin analysis for one week.

P.I-s and collaborators [3]-Dr. One received one week training at the FDA on aflatoxin detection and management; one received training in the US on laboratory procedures; and another on data analysis for two weeks.

e. Publications since 2007 to 2012

1. Ligeon C. **C. M. Jolly**; Bencheva, N., Delikostadinov, S., and C., Puppala; Production Efficiency and Risks in Limited Resource Farming: The case of Bulgarian Peanut Industry; *Journal of Development and Agricultural Economics*.
2. Jolly, P.E., Jiang, Y., Ellis, W.O., Appawu, J., Awuah, R.T., Nnedu, O., Adjei, O., Stiles, J., Person, S., and **Jolly, C.M.** Association between aflatoxin levels, health characteristics, liver function, hepatitis and malaria infections in Ghanaians. *Journal of Nutritional and Environmental Medicine*, 16:1-16, 2007.
3. Bley N'Dede, **C. Jolly**, C. M., Vodouhe, D. S., and Jolly, P.E.. Economic Risks of Aflatoxin contamination in Marketing of Peanut in Benin. *Economics Research International*, 2012, Article ID 230638, 12 pages. doi:10.1155/2012/230638.
4. Bley N'Dede, **C. Jolly, C. M.**, Vodouhe, D. S., and Jolly, P.E..2012. Economic Risks of Aflatoxin contamination in Marketing of Peanut in Benin. *Economics Research International*, Volume , Article ID 230638, 12 pages. doi:10.1155/2012/230638.
5. **Jolly, C. M.** R.T. Awuah, S. C. Fialor, Bayard, B. 2012, Ghanaian health and agricultural administrators' perceptions of the health and economic effects of aflatoxin contamination of groundnuts; *International Journal of AgriScience*, Vol. 2 (11):1000-1015.
6. **Jolly, C. M.**, B. Bayard and S. Vodouhe; Risks of ingestion of aflatoxin-contaminated groundnuts in Benin: scale measurements, beliefs, and socioeconomic factors, *Risk Analysis: An International Journal* (2009), 30:1395-1409.
7. Awuah, R.T. S. C. Fialor, A.D. Binns, J. Kagochi, and **C. M. Jolly**, 2009, Factors influencing market participants decision to sort groundnuts along the marketing chain in Ghana, *Peanut Science*, (2009) 36 (1).68-76.
8. Ligeon, C.Bencheva, N., Delikostadinov,S., C., Puppala, N. and **C. Jolly**. 2008. "Production Risks in Bulgarian Peanut Production, *Agricultural Economics Review*, Vol. 9. ISS 1.
9. **Jolly, C. M.**, B. Bayard, R. T. Awuah, S. C. Fialor, and J. T. Williams, 2009, Examining the Structure of Awareness and Perceptions of Groundnut Aflatoxin among Ghanaian Health and Agricultural Professionals and its Influence on Their Actions, *Journal of Socio-Economics*, 38: 280-287.
10. **Jolly, C. M.**, R. T. Awuah, S. C. Fialor, K. O. Agyemang, J. M. Kagochi and A. D. Binns, 2008, Groundnut Consumption Frequency in Ghana, *International Journal of Consumer studies*, 32:675-686.
11. Bencheva, N., Delikostadinov,S., Ligeon, C., Puppala, N. and **C. Jolly**. 2008. "The Economic and Financial Analysis of Peanut Production in Bulgaria" *Journal of Central European Agriculture*. Volume 9, No 2 (273-282).
12. Bencheva, N., Delikostadinov,S., Ligeon, C., Puppala, N. and **C. Jolly**. 2007. "The Economics of Peanut Production in Bulgaria During the Transition Period." *Journal of Central European Agriculture*. Volume 8, No 3 (285-294).
13. Amoako-Attah, R.T. Awuah, K.A. Kpodo, S.C. Fialor and **C.M. Jolly**. 2007. "Cost effectiveness of Selected Post Harvest Pod Handling Techniques Against Damage, Moldiness and Aflatoxin contamination of Shelled Groundnut in Ghana." *Journal of Science and Technology*, Volume 27 no. (1):1-17.
14. D Jolly, P. Y. Jiang, W. Ellis, R. Awuah, O. Nnedu, T. Phillips, and J-S. Wang, E. Afriyie-Gyawu, L. Tang, S. Pearson, J. Williams, **C. Jolly**, Determinants of

Aflatoxin Levels in Ghanaians: Socio-demographic factors, knowledge of Aflatoxin and Food Handling and Consumption Practices, *International Journal of Environmental Hygiene*, 209 (2006)345-358.

a. Importance of Technical Achievements-

b. The technical information generated by the project by the host country is extremely important and serves as a basis for further research. The information on the effects of post-harvest handling on AF reduction is important. The drying of the peanuts can reduce the spread of AF to an acceptable level and reduce cost. AF reduction increases cost and risk, and therefore, farmers will be unwilling to participate in a program to reduce AF unless buyers are willing to pay a higher price for AF reduced peanut. Price and income increases are important incentives to guarantee an AF reduced product. The US has benefitted from the reverse transfer of information back on the importance of post-harvest handling on peanuts. The risk associated to peanut contamination is high in Ghana and there is shifting of risk in the market place. Most farmers still hold on to traditional means of storing groundnuts but try to incorporate new adaptations to their storage houses. Hence farmers are aware of the importance of improved storage on AF. The regulation of improved peanut quality and the adoption of standards will result in quantity reduction and increase prices. The storage information is important to the US producers who should investigate some of the materials used in Ghana for the preservation of storage houses in the U.S.

c. Importance of physical and human capacity development-

i. The development of human capital for the Host Country is significant since training was conducted in the U.S. and Ghana and a wide range of training from farmers to the Ph.D. took place in survey methods, data base management, data analysis and software management. The U.S. benefitted from the research conducted in the U.S. by the Ph.D. students. U.S. exporters also benefited from the greater U.S. and sale of software.

d. Heritage left from workshops and short-term training-

i. In the host country several training sessions were
ii. conducted at the farm and village level. Host Country nationals participated in several workshops on AF awareness and before surveys were conducted the participants were informed on the benefits of conducting surveys. U.S. researchers learned and improved their techniques in the design of studies when participants spoke a different language and were hardly literate.

e. Heritage left in publications

13. The research generated information on post-harvest handling, the cost of AF reduction, the adoption of storage technologies and the importance of awareness on knowledge and action in reducing AF. The research and workshops generated information on the types of produce used to reduce AF in peanuts. *The article: **Jolly, C. M.**, R.T. Awuah, S. C. Fialor, Bayard, B. 2012, Ghanaian health and agricultural administrators' perceptions of the health and economic effects of aflatoxin contamination of groundnuts; International Journal of AgriScience, Vol. 2 (11):1000-1015.* The paper on awareness and perception increased administrators and policy and decision makers knowledge of Aflatoxin; ***Jolly, C. M.**, B. Bayard, R. T. Awuah, S. C. Fialor, and J. T. Williams, 2009, Examining the Structure of Awareness and Perceptions of Groundnut Aflatoxin among Ghanaian Health and Agricultural Professionals and its Influence on Their Actions, Journal of Socio-Economics, 38: 280-287.*

3. Final Summary of Accomplishments by Objective

Objective 1: Evaluate the effects of AF on the profitability of market participants producing and trading groundnut and groundnut products.

The methods used for reducing AF in Ghana were mainly post-harvest treatments which require drying, sorting and storage. The studies showed that drying to less than 12 percent moisture could almost reduce AF contamination to acceptable standards of less than 4pp and prevent financial losses. Sorting of the nuts were costly and did not enhance profitability. Proper storage was essential for post-harvest handling and reduced the quantity of spoilt nuts. Proper drying could reduce the level AF to zero. The studies: Amoako_Attah, I. R.T. Awuah and **C. M. Jolly** (2011) Efficacy of clove((*Syzygium aromaticum* (L) Merr and Perry); Powder as a protectant of Groundnut kernels in storage; *African Journal of Food Agriculture Nutrition and Development* (AJFAND) ; 2013; Vol. 11 no. 2: The study by Awuah also showed that costs could be reduced by reducing moisture in stored products: Amoako-Attah, R.T. Awuah, K.A. Kpodo, S.C. Fialor and **C. M. Jolly**. 2007. “Cost effectiveness of Selected Post Harvest Pod Handling Techniques Against Damage, Moldiness and Aflatoxin contamination of Shelled Groundnut in Ghana.” *Journal of Science and Technology*, Volume 27 no. (1):1-17.

Objective 2: Determine the factors influencing the adoption of techniques to reduce the levels of contamination of stored groundnuts.

Farmers who belonged to a cooperative were more likely to adopt new storage technologies while farmers who had farming experience were more likely to recognize the difference between traditional and improved storage technologies. Farmers who were aware of the ill-effects of contaminated nuts on human health were more likely to store their groundnuts in well-aerated and well-covered groundnut storage bins than those who were unaware. Farmers who belonged to a cooperative were more likely to store their groundnuts in a well-ventilated storage bin. Those who belonged to a cooperative and those who had farming experience were more likely to adopt storage techniques to reduce AF levels. Levels of awareness and membership in groups where knowledge of the effects of AF on AF reduction were important in the adoption of technologies to reduce AF levels.

Objective 3:) Estimate the perceived health risks and the costs to human health of consuming AF contaminated groundnut in Ghana.

We examined the relationship between AF levels in contaminated groundnuts and found that there is a link between AF levels of contamination and the levels of poverty as indicated by levels of per capita household income. Poorer households are more likely to believe that they are in good health than wealthier households. They are less likely to sort their peanuts before consumption; they are less likely to feed the AF suspected contaminated peanuts to animals and they are less likely to inspect the peanuts before consumption.

Objective 4: Compare improved storage techniques with traditional methods of stored groundnuts.

Improved storage requires a large investment costs. The study results indicate an increase in rice of peanuts is needed to encourage farmers to adopt new storage technologies.

Objective 5: Evaluate the effects of aflatoxin contamination reduction on the groundnut industry and the agricultural sector.

This research determines price and quantity effects owing to introduction of AF regulations in the Ghanaian peanut sector. Stricter standards raises costs and amount of groundnuts discarded of over 50% of edible peanuts in order to adopt EU, WHO, and US. A high correlation between AF contaminated groundnuts and maize AF contamination at the household level.

A rise in consumer price implies consumer welfare losses while a drop in producer price suggests a decrease in producer welfare. Generally, AF standards introduce additional (compliance) costs into the peanut industry. The compliance cost effects are borne by both producers and consumers depending on demand and supply elasticities as well as the importance of international trade in the peanut sector. Consumers and producers share consequences of strict AF standards enforcement (i.e. increased compliance costs) with distribution critically determined by relative magnitude of supply and demand elasticities.