A RISK ASSESSMENT OF THE LIKELIHHOD OF ANTHRAX INFECTED HIDES/SKINS USED ON DRUMS EXPORTED FROM GHANA

Francis Kunadu-Ampratwum[1], Mary Glover-Amengor[2] and Bernard Agyeman Boateng[3]
[1]*Veterinary Services Department, P. O. Box M161, Accra, Ghana,*
[2]*Food Research Institute, CSIR, Accra, Ghana,*
[3]*Crop Science Department, University of Ghana, Legon, Accra, Ghana.*

ABSTRACT
Anthrax is primarily a disease of domesticated and wild animals particularly herbivores. Humans become infected accidentally when they come in contact with diseased animals, which includes their flesh, hides or skins hair and excrement. In this risk analysis we have looked at the likelihood of anthrax infected hides or skins being used for drums exported from Ghana. The risk analysis considered the eleven risk factors according to US CFR 92.2 of 1999. The risk reduction procedures include animal movement control, ante-mortem inspection, and post-mortem inspection, hides/skins treatment, and laboratory culture. Computer simulations were carried out to evaluate the probability of hides/skins used in exported drums being anthrax infected. The risk of anthrax-infected skins/hides used on drums was found to be extremely low.

Keywords: Anthrax, Risk Analysis, drum, hide, skin, Ghana.

INTRODUCTION
Anthrax is an acute, non-contagious bacterial disease of mammals caused by the spore-forming bacterium, *Bacillus anthracis*. In the most common form, the disease is a septicaemia characterized by a rapidly fatal outcome. Anthrax is primarily a disease of domesticated and wild animals particularly herbivores, such as cattle, sheep, horses, mules and goats. Humans become infected accidentally when they come in contact with diseased animals, which includes their flesh, bones, hides, hair and excrement.(1) In humans, anthrax is fairly rare; the risk of infection is about 1/100,000. The most common form of the disease in humans is cutaneous anthrax, which is usually acquired via injured skin or mucous membrane. Another form of the disease, inhalation anthrax (wool sorters' disease), also results most commonly from inhalation of spore containing dust where animal hair or hides are being handled.

An American woman contracted anthrax infection in Haiti after acquiring some goat skin drums.(2) There is no evidence of person-to-person transmission of anthrax. However, it might cause public panic and social disruption. The organism that causes anthrax, *Bacillus anthracis* has a worldwide distribution with some areas of enzootic and sporadic occurrence. Although the spores have been found naturally in soil samples from around the world, the organisms cannot be regularly cultivated from soils, where there is an absence of endemic anthrax. In the United States of America there are recognised areas of infection in South Dakota, Nebraska, Arkansas, Texas, Louisiana, Mississippi and California.(1) Since the year 2000 Ghanaians have been exporters of animal skin drums, hides and other products made from animal skins and hides to a number of countries including the United States of America. Between January 2000 and June 2004 a total of eleven thousand two hundred and sixty seven (11,267) drums of animal skins and hides have been exported of which 2,072 (18%) have gone to the United States of America.(3) The total quantity exported seems small. This

notwithstanding it is still important to assess the risk that these products can pose to those who might come in contact with them with respect to cutaneous anthrax infection. This paper therefore assesses the likelihood of exporting drums made from animal skins and hides contaminated with anthrax spores to the United States of America.

MATERIALS AND METHODS

The authors have used both the qualitative and quantitative approaches in the Risk Analysis.

A. QUALITATIVE METHOD

The risk analysis considers information about the animal health situation existing in the country and the probability of the commodity being the cause of anthrax in people who will come in contact with the product (drums of animal skins/hides). The first part of the analysis focuses on the evaluation of the eleven risk factors according to US CFR 9 92.2, 1999.[4] The second part uses a quantitative analysis to determine the risk in importing drums of animal skins/hides that are contaminated with anthrax spores.

REGION RISK FACTORS INFORMATION:

The region is the Republic of Ghana.

(i) Authority, organization and infrastructure of Ghana's Veterinary Services

Ghana has a Veterinary Services Department, which is a department in the Ministry of Food and Agriculture. The department derives its authority for control of diseases from the Diseases of Animals Act, 1961, Act 83. The veterinary council regulates veterinary practice under the veterinary surgeon's law, P.N.D.C. Law 305c of 1992. There are ten administrative regions in Ghana. A government veterinarian of the rank of Principal Veterinary Officer heads each region's veterinary department. Each district in a region has a Veterinary Surgeon who is assisted by Veterinary Assistants. At the national level is the Chief Veterinary Officer (Director of Veterinary Services) who is assisted by three deputies and other veterinary surgeons of different ranks. The department operates six veterinary diagnostic laboratories. However, each region has a laboratory capable of diagnosing anthrax. There are 139 veterinary surgeons, 84 sub-professional veterinary personnel and 510 veterinary assistants. For international control of movement of livestock and animal by-products there are health inspection offices at the Tema harbour and Kotoka International Airport with official veterinary inspectors. All land entry points to the country are also manned by veterinary personnel to control overland movements of animals, animal products and by-products. The land entry points have quarantine stations.

(ii) Type and extent of disease surveillance

The Veterinary Services Department of Ghana carries out active and passive surveillance of reportable diseases of which anthrax is one. The department has in place an Emergency Preparedness Team. The team is made up of Epidemiologists and Veterinary Laboratory Investigation Officers. All reportable disease outbreaks are reported directly to the Chief Veterinary Officer by the fastest means. Slaughter facilities have official Veterinary Inspectors that inspect animals at ante and post-mortem inspections.

(iii) Diagnostic laboratory capabilities

There are ten diagnostic laboratories. The laboratory in the capital (Accra) is mandated to carry out test on skins and hides that are meant for export. This laboratory has an accreditation with the

International Atomic Energy Agency (IAEA) and is headed by a Deputy Director. This laboratory collaborates with laboratories in the sub-region.

(iv) Disease status

Anthrax has been reported in eight of the ten regions of the country. Majority of the outbreaks occur in the three Northern Regions of the country. The last reported outbreak was in March 2004 in a district in the Northern Region of Ghana.

(v) Disease control programme

There is a National Control Programme based on vaccination and movement control. Vaccinations of susceptible livestock against all scheduled and reportable diseases are compulsory.

(vi) Vaccination status

All susceptible livestock in endemic areas are vaccinated annually against anthrax. In non-endemic areas vaccination is carried out only when there is an outbreak of anthrax.

(vii) Disease status of adjacent regions

Ghana borders Burkina Faso on its northern border, Togo on the east and la Cote d'Ivoire (Ivory Coast) on the west. All the three neighboring countries have reported anthrax outbreaks. The last reported outbreaks in the three neighboring countries were in 2002[5].

(viii) Degree of separation from areas of higher risks

Geographically, there are no natural barriers which separate low risk areas from high risk areas in the country.

(ix) Control of animal movement from high risk areas

The primary means of preventing spread from high risk areas to non-endemic areas during outbreaks is by livestock movement bans. In addition to this, slaughter is strictly controlled. An important element of internal movement control is the presence of checkpoints between districts on the main highways throughout the country to ensure that official rules on movement of animals and animal products are complied with. A permit is required to move an animal from one district to another and even sometimes within the same district in outbreak situations. All these measures are to ensure that such movements do not represent animal health risk.

(x) Livestock demographics and marketing patterns

The majority of the livestock (ruminants) are in small holdings and backyard type. There are twelve livestock marketing centres in Ghana, all under veterinary control. Table 1 shows the number of ruminants in Ghana for 1996 and estimated figures for 2004.

Table 1: Population of ruminants for 1996 and 2004 in Ghana[6].

Animal	1996	2004*
Cattle	1,247,861	1,358,575
Sheep	2,418,738	3,111,644
Goats	2,532,710	3,737,240

Source: Livestock census figures, Veterinary Services Directorate. * Estimated figures.

(xi) Policies and infrastructure for animal disease control

The intention of the veterinary department is that outbreaks of anthrax are reduced to the minimum. The government is committed to implement whatever policies necessary and appropriate, including surveillance, movement control, effective ante and post-mortem inspections, laboratory testing and annual compulsory vaccination to control anthrax. The country produces its own anthrax spore vaccine. Ghana has an Emergency Preparedness Response Team established for the control of anthrax, and other reportable diseases.

PRODUCT RISK FACTORS/MITIGATIONS:

The product that is being exported to the United States of America are drums made of animal hides or skins. Since the year 2000, two thousand and seventy two (2,072) drums of animal skins/hides have been exported to the United States of America.

(i) Ghana slaughter regulations

All animals, the products of which are intended for commercial purposes are required by law to be slaughtered in government approved slaughter facilities that are under the direct supervision of full-time salaried government veterinary personnel. Animals being moved from livestock markets to slaughter facilities are required to be covered by movement permits, certifying their state of health and suitability for slaughter.

(ii) Ante-mortem and post-mortem inspections

Animals arriving at slaughter facilities are subjected to ante-mortem inspection by full-time salaried government veterinary personnel. Animals found to be fit for slaughter are allowed entry into the slaughter hall for slaughter after which they are subjected to post-mortem examination by government veterinary meat inspectors. If anthrax is suspected all slaughter activities are suspended at the slaughter facility, and all other restrictions in respect of anthrax control are put in place. If the disease is confirmed by the laboratory, the carcass, blood, hide, feet, fat and all internal organs are destroyed by incineration. The slaughter hall and instruments are thoroughly cleansed with a hot 5% solution of sodium hydroxide. Equipment that cannot be sterilized satisfactory is destroyed by burning.

(iii) Hides and skins processing

Hides and skins are mainly air dried on the ground. Some producers use wet-salting or dry salting upon specific request from importers. To prevent insect damage producers use insecticides. For example, some producers use polytrine C 186EC (a combination of cypermethrin 36 g/l. and profenofos 150 g/l.). Hides and skins used in the making of drums are not tanned. Producers use lime to remove the hairs from the skins and hides. The requirements for unrestricted entry of untanned hides and skins into the United States of America are stated in US CFR 9 95.5.[7] The US CRF 9 95.5 (e)[8] states "that untanned hides and skins may be imported without other restrictions if shown upon inspection by an inspector, or by certificate of shipper or importer satisfactory to said inspector, to have been treated with lime in such manner and for such period as to have become de-haired and to have reached the stage of preparation for immediate manufacture into products ordinarily made from raw hides".

(iv) Laboratory testing

Anthrax bacteria are difficult to isolate from sources such as bone meal, animal feeds, hides and wool that may be heavily contaminated with other micro-organisms.[9] All hides and skins on drums

and all hides and skins exported for the other purposes including making of drums are subjected to laboratory test for anthrax. Eleven thousand two hundred and sixty seven (11,267) samples have been tested between January 2000 and June 2004. Out of the total number tested only two samples have been found positive.

(v) Risk of introduction or spreading of anthrax

In general, it is recognised that movement of animals or animal products or by-products cannot be undertaken on a "zero risk" basis.[10] For humans, however, the source of infection in naturally acquired disease is through contact with infected livestock, wild animals, or contaminated animal products (including carcasses, hides, hair, wool, meat and bone meal). Person-to-person transmission is extremely unlikely and only reported with cutaneous anthrax where discharges from cutaneous lesions are potentially infectious.[11] Hides and skins, more so those on drums, are unlikely to be used as food items for animals like dogs, pigs and cats. These animals: pigs, dogs and cats are all relatively resistant to anthrax.[12,13]

B. QUANTITATIVE METHOD

Quantitative Risk Analysis (QRA) techniques have been used for many years in engineering and economics.[14, 15] The authors adopted the approach used by Astudillo *et al.*[16] QRA techniques make use of branches of science such as epidemiology, statistics, mathematics, microbiology, pathology and in this case, meat hygiene and by-product technology. A QRA involves:

a) identification of the hazard,
b) developing a scenario tree outlining the pathway of expected events and all the failures that are likely to occur,
c) gathering and documenting evidence,
d) developing equations or functions,
e) performing calculations to summarize the likelihood of the hazard occurring,
f) considering risk management options,
g) preparing a written report.

A scenario pathway used for the risk of anthrax bacillus introduction associated with the importation of drums made from animal skins and hides is shown in figure 1. The initiation of event is the request for the export of 3,000 drums made of animal skins or hides to the United States of America from Ghana. The scenario pathway consists of a sequence of events from the point of selection of a particular animal for slaughter to the use of the skins/hides for a drum.

$\mathbf{P_1}$ to $\mathbf{P_6}$ are the probabilities that events 1 – 6 ($E_1 - E_6$) may occur.

$\mathbf{P_1}$ is the probability that the animal selected for slaughter has anthrax.

$\boldsymbol{P_2}$ is the probability that inspection prior to movement to slaughter facility fails to detect anthrax infection.

$\mathbf{P_3}$ is the probability that ante-mortem inspection fails to reveal that the animal has anthrax.

$\mathbf{P_4}$ is the probability that post-mortem meat inspection fails to detect anthrax.

$\mathbf{P_5}$ is the probability that the skin/hide obtained from the animal is not processed in a manner that would destroy anthrax bacilli.

$\mathbf{P_6}$ is the probability that laboratory culture fails to detect that hide/skin is from an anthrax infected animal. Table 2 summarizes the risk mitigation process, starting with the request to export drums made from animal skins or hides.

The final probability of occurrence of anthrax is the product of $\mathbf{P_1 * P_2 * P_3 * P_4 * P_5 * P_6}$ on the assumption

that each **P** value is completely independent. Estimates can be made for each **P** according to a worst-case scenario. However, using only one estimated value gives an incomplete picture of the real risks involved, ignoring the fact that it is an estimate of only one potential outcome.

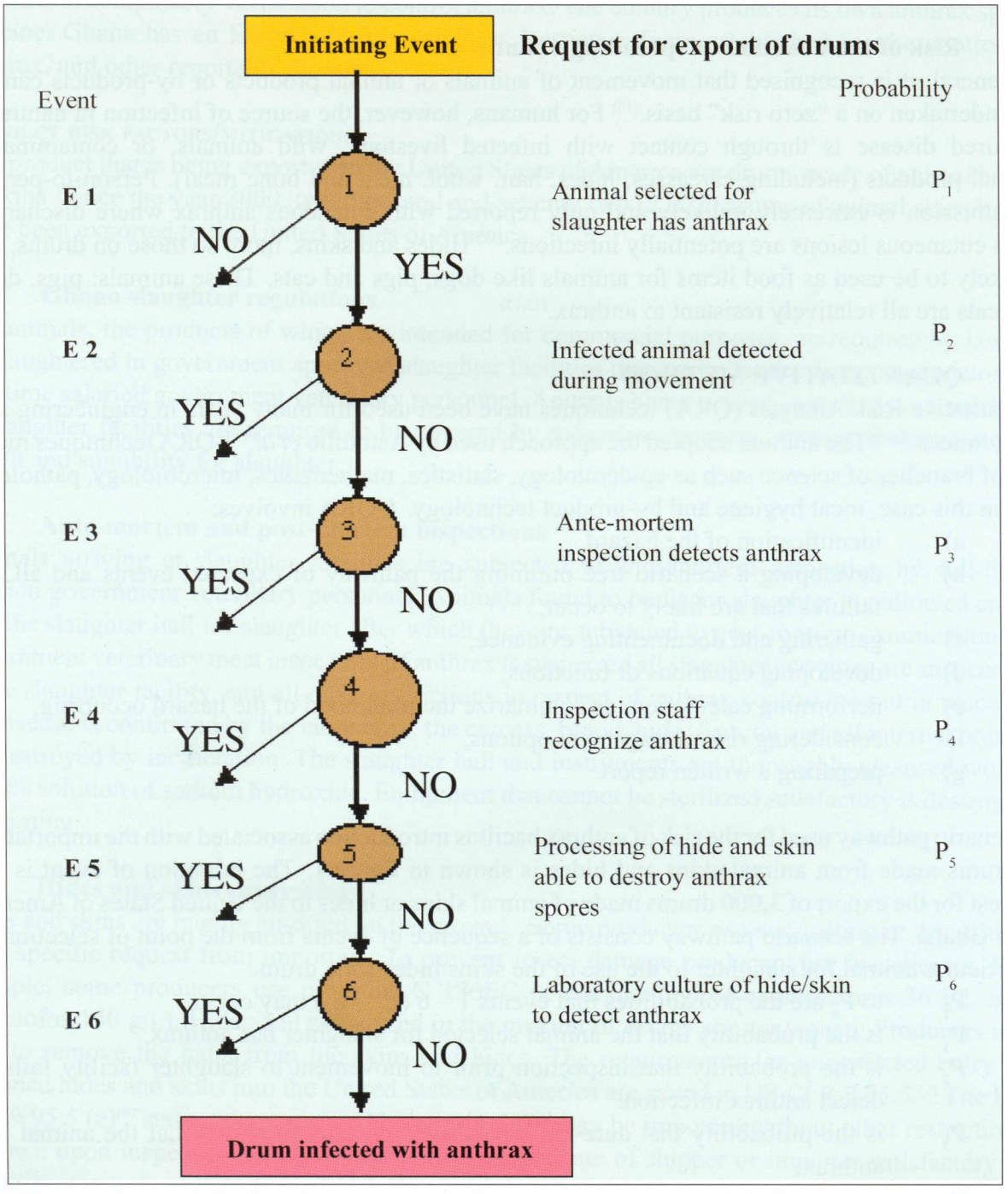

Figure 1: Risk scenario pathway of events for the production of hides/skins from animals infected with anthrax. A "YES" or "NO" answer is given for each event in the pathway If the arrow points to the left anthrax is removed if down it remains in the scenario.

A variety of values exist for each **P**, which estimates the minimum, maximum and a most-likely probability. The authors estimated values, which were used to simulate a PERT probability distribution function (PDF) for each event in the scenario pathway. Table 3 shows the estimated probability values. The PERT distribution was chosen as it provides a more natural shape than the triangular distribution and not influenced as much by the extreme (minimum and maximum) values and also because it is useful for modelling expert opinion. [17] The PDFs that were generated for each event in the scenario pathway were combined by using computerized Monte Carlo Simulation techniques. The authors used the commercially available @RISK © software to generate a cumulative PDF to represent the total risk mitigation from all the events of the complete scenario.

Probability values for each event in the scenario pathway

The estimates are based on arguments described below, on official records, and on well-informed estimates by the authors and expert opinion. In case of doubt the worst case scenario was adopted.

P_1 Probability that animal selected for slaughter is infected with anthrax bacilli:

Livestock owners are well aware of the dangers of anthrax. Animals (cattle, sheep, goats) that are normally flayed for their hides/skins usually suffer from the peracute form of the disease, with sudden onset and rapid death, at the beginning of an outbreak. During an outbreak in an area, livestock movement and slaughter are strictly controlled. Compulsory vaccination is carried out in an area of 8 km radius from the focus of the outbreak. The authors assumed that under these conditions the probability that an infected animal will be presented for slaughter is remote. However, failure to detect infected animal could occur in the chronic form of the disease, which is sometimes seen in cattle. A conservative estimate of the probability of such a situation arising was assumed to be in the range of 0.1% to 1%, with a likely value of 0.5%.

P_2 Probability that inspection prior to movement to slaughterhouse fails to detect anthrax infection:

Source of animals for slaughter are mainly livestock markets. Anthrax infection is not a contagious disease and therefore contact with other animals in a livestock market is of no consequence. However, animals are sent to the markets from different farms or locations. Those with subacute or chronic infections may not stay long enough in the market or escape movement inspection controls and consequently be transported to the slaughter facility. Movement control could also be probably less efficient. The assumed range of 1% to 5% and a most likely value of 3% reflect this situation.

P_3 Probability that ante-mortem inspection does not detect anthrax infection:

When animals arrive at a slaughter facility their movement permits are reviewed by Veterinary Services personnel. Animals do not stay in holding areas for more than 12 hours. Ante-mortem inspection is carried out on each animal and only animals determined not infected are passed for slaughter. The probability that anthrax infected animals will pass ante-mortem inspection is extremely low. Even cattle and sheep that are affected by the subacute forms show symptoms of fever, a halt to rumination, excitement, followed by depression, difficulty, uncoordinated movement, convulsions and eventual death. These symptoms are not likely to be missed at ante-mortem. However, in cattle with chronic anthrax the main symptoms are pharyngeal and lingual edema. The probability of failing to detect an anthrax infected animal at ante-mortem inspection was estimated to be 0.1% to 1% with the most likely probability of 0.5%.

P_4 Probability that anthrax infection is not detected during post-mortem inspection:
It would be difficult for an inspector to miss anthrax lesions. Hemorrhages are found in the internal organs; splenomegaly is almost always present, the pulp being dark red or blackish with a soft or semi-fluid consistency; the liver, kidneys, and lymph nodes are congested and enlarged; and the blood is blackish with little clotting tendency. Some clostridial infections may simulate anthrax, but this is especially so in pigs. On account of the very typical lesions of anthrax and the fact that an inspector would treat any doubtful lesions with suspicion until ruled out by laboratory testing, it is highly unlikely that anthrax would not be detected at post-mortem. The authors therefore assumed that the post-mortem inspection would be at least ten times more sensitive than the ante-mortem inspection. The probability of failing to detect anthrax at post-mortem inspection was estimated to be 0.01% to 0.1% while the most likely probability was estimated to be 0.05%.

P_5 Probability that anthrax bacilli in a skin/hide survive treatment and drying:
Hides and skins taken from slaughtered animals from slaughter facilities are sun-dried on the ground. It is not the usual practice to use salt or salt containing mineral acid in the process. However, some hide and skin processors use lime treatment for periods necessary to de-hair the hides and skins. In order to control insect damage insecticides are used in treating the hides and skins during drying. Since the common practice is to dry hides and skins without treatment with salt and mineral acid the authors estimated the probability of anthrax bacilli in a contaminated hide or skin to be in the range of 1% to 10% and 5% as the most likely probability.

P_6 Probability that an anthrax contaminated hide or skin will not be detected by laboratory culture:
All hides and skins either on drums or not are subjected to laboratory culture. Drums, hides and skins are presented to the Veterinary Services laboratory in Accra where samples are taken for culture. Importing countries require that all drums, hides and skins are accompanied by Veterinary Health Certificates signed by a government veterinarian. Between the year 2000 and 2004 (June) a total of eleven thousand two hundred and sixty seven (11,267) samples were tested. So far only two positive samples were found. In view of the fact that anthrax bacteria are difficult to isolate from sources such as bone meal, animal feeds, hair, hides, skins and wool that may be heavily contaminated with other micro organisms the authors estimated the probability of culture not being able to detect a positive sample to be in the range of 0.01% to 0.1%. The most likely probability was estimated to be 0.05%.

Table 2: Risk reduction scenario for the probability of exporting drums made from animal skins and hides with *Anthrax bacilli*, assuming that the hide or skin used for the drum is from an anthrax-infected animal.

Event	Description of Event	Yes/No Risk Pathway	Risk Pathway	Probability (P)
E_1	Animal for slaughter has Anthrax	No	Yes	P_1
E_2	Infected animal detected during movement control	Yes	No	P_2

Event	Description of Event	Yes/No Risk Pathway	Risk Pathway	Probability (P)
E_3	Ante-mortem inspection detects anthrax	Yes	No	P_3
E_4	Meat inspection staff recognize anthrax lesions	Yes	No	P_4
E_5	Processing of hide and skin derived from infected animal able to destory anthrax spores	Yes	No	P_5
E_6	Laboratory culture able to detect sample from drum's skin/hide as positive	Yes	No	P_6
Final product		$P_f = P_1 * P_2 * P_3 * P_4 * P_5 * P_6$		

Results of Computer Simulation

The estimated values were entered in an Excel/@RISK© worksheet (Table 3) for the simulation of the probability that anthrax bacilli might remain in the chain of events and end up in a hide/skin that is used in making a drum.

Table 3: Parameters for estimating effect of risk mitigation on Anthrax bacilli.

Node	Event	Min*	Ml	Max
N	Number of animals selected	1000	3000	6000
P_1	Anthrax not detected in selected animal	0.001	0.005	0.01
P_2	Anthrax not detected during movement control	0.01	0.03	0.05
P_3	Anthrax not detected during ante-mortem	0.001	0.005	0.01
P_4	Anthrax not detected during post-mortem	0.0001	0.0005	0.001
P_5	Anthrax not destroyed by hide treatment	0.01	0.05	0.1
P_6	Anthrax not detected by laboratory test	0.0001	0.0005	0.001

* Min = minimum, Ml = most likely, Max = maximum

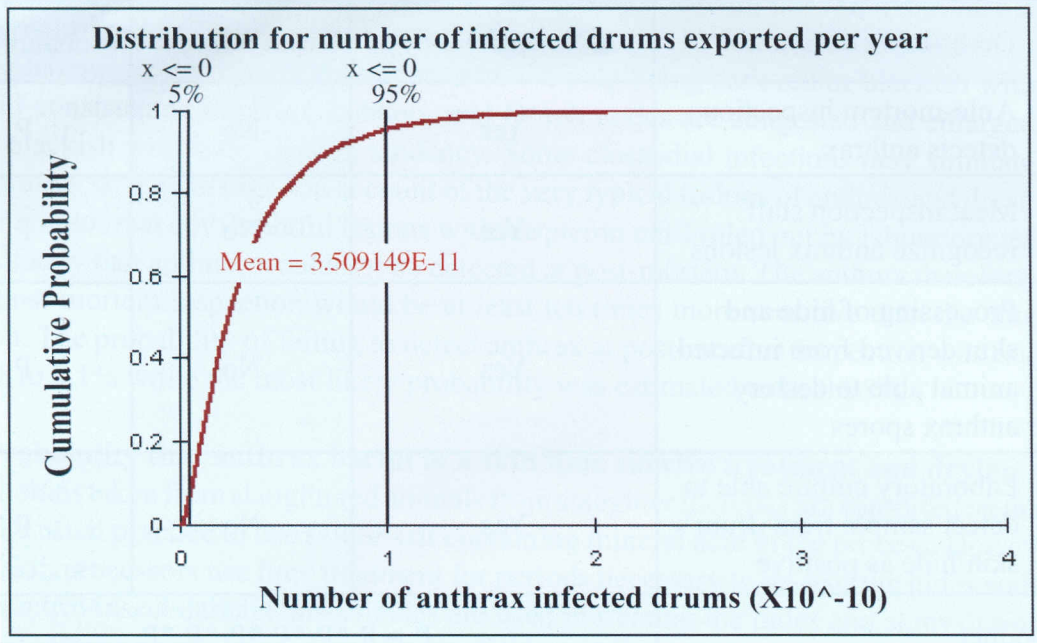

Figure 2: Distribution for number of infected drums exported per year.

RESULTS AND DISCUSSION

The qualitative analysis indicates that Ghana has adequate veterinary physical infrastructure and well-trained and competent personnel. The veterinary infrastructure is sufficient to detect and diagnose anthrax. The results from the quantitative assessment indicate that by following strict standards on movement control, ante- and post-mortem inspections and good laboratory tests, a very large mitigation factor is obtained in reducing the risk of exporting drums infected with anthrax from Ghana. The effect of risk reduction measures on the probability of anthrax bacilli introduction by the export of drums of animal skins is shown in figure 2. The cumulative graph predicts with a 95% probability that the risk will not exceed 0.99×10^{-10} or about 1 in 10 billion anthrax-infected drums. The probability estimates were more towards the worst case scenario. It is rare for a well-trained inspector to miss signs of anthrax infection during post-mortem inspections. Inspectors are trained to rule out anthrax when in doubt by laboratory test. The laboratory test as a last mitigating factor in eliminating cases where skins from 'fallen' animals or game may be used for drums as these animals would not have gone through the mitigation steps outlined above. The two positive samples mentioned in the qualitative assessment could have come from such a source.

CONCLUSIONS

Ghana has a veterinary infrastructure sufficient to detect and diagnose anthrax. The veterinary service has well-trained staff and laboratory facilities capable of identifying and diagnosing the disease. The country also produces its own anthrax spore vaccine. As there is no 'zero-risk' in the export of animals and animal products, the chances of exporting infected drums become less likely with efficient national veterinary surveillance and control of anthrax in addition to mitigation steps. The combination of these will determine the ultimate safety of Ghanaian drums on the international market.

ACKNOWLEDGEMENTS

The authors are grateful to Dr. F. K. Peterson who commented on the draft. We are also grateful to other colleagues who offered useful suggestions. The authors wish to thank Mr. Daniel T. M. Nartey, who compiled the export figures for us. Ms. Scholastica M. A. Seke, to whom we are also grateful, typed the manuscript. We would also like to express our sincere gratitude for the Tuskegee University ATRIP Project of the USAID, the USDA/APHIS for giving us the opportunity to participate in the Risk Analysis and Modelling Training Program.

REFERENCES

1. Todar, K. (2001). *Bacillus anthracis* and Anthrax. Available online at http://www.bact.wisc.edu/Bact330 lectureanthrax. Accessed on June 23 2004.
2. La Force, F. M. (1978). Report to the Pan American Sanitary Bureau, Haiti. In Zoonoses and Communicable Diseases Common to Man and Animals: *Pan American Health Organization*.
3. Export Data. *Greater Accra Veterinary Services* (2004).
4. *US* Code of Federal Regulations 1999 - *US CFR 9 92.2 1999.*
5. *Pan African Animal Health Yearbook* (2003). pp 29-30.
6. Livestock Census Figures. *Veterinary Services Directorate* (2004).
7. US Code of Federal Regulations 1999 - *US CFR 9 95.5.*
8. US Code of Federal Regulations 1999 - *US CFR 9 95.5e.*
9. Anon. (1978). Bacillus: In George E. Cottral (Ed.). Manual of Standardized Methods for Veterinary Microbiology. Ithaca: *Cornell University Press*.
10. Magalhaes, J. (1995). World trade in animals and animal products: present situation and trends. In. Selected Proceedings. 25th Congress of the World Veterinary Association, 3 to 9 September, Yokohama: *World Veterinary Association.*
11. Anthrax. *Centers for Disease Control* (2003). Available online at http://www.edu.govncidod dbmd/diseaseinfo/anthrx_t.htm. Accessed on June 23 2004.
12. Anon. (1978). Diseases caused by *Bacillus* spp. Anthrax. In D. C. Blood, I. A. Henderson, and O. M. Radostitis, *Veterinary Medicine. A Textbook of Diseases of cattle, sheep, pigs and horses*. London: Cassel Ltd.
13. Blaha, T. (1989). *Applied Veterinary Epidemiology*. Elsevier Publishers, Amsterdam, 343 pp.
14. Kapllan, S. (1991) Quantitative Risk Assessment (QRA): A tool for management and regulation. Presented to the US Department of Agriculture/Animal and Plant Health Inspection Services (USDA/APHIS). Hyattsville, Maryland:*USDA/APHIS/PPD.*
15. Morgan, M. G. (1993) - Risk Analysis and Management. *Scientific America* 268 (7), 24.
16. Astudillo, V. M., Sutmoller, P., Saraiva and Lopez, A. (1997). Risk of Introducing Foot and Mouth Disease through the Importation of Beef from South America. *Review Scientific Et. Techinique Office International des Epizooties* 16(1), 33-44.
17. OIE (2004) *Handbook on Import Risk Analysis for Animal and Animal Products*, Vol., 2 (2004) pp 48.