Cost implications of African swine fever in smallholder farrow-to-finish units: economic benefits of disease prevention through biosecurity

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Summary

African swine fever remains the greatest limitation to the development of the pig industry in Africa, and parts of Asia and Europe. It is especially important in West and Central African countries where the disease has become endemic. Biosecurity is the implementation of a set of measures that reduce the risk of infection through segregation, cleaning and disinfection. Using a 122-sow piggery unit, a financial model and costing were used to estimate the economic benefits of effective biosecurity against African swine fever. The outcomes suggests that pig production is a profitable venture that can generate a profit of approximately US$109,637.40 per annum and that an outbreak of African swine fever (ASF) has the potential to cause losses of up to US$910,836.70 in a single year. The implementation of biosecurity and its effective monitoring can prevent losses due to ASF and is calculated to give a benefit cost ratio of 29. A full implementation of biosecurity will result in a 9.70% reduction in total annual profit, but is justified in view of the substantial costs incurred in the event of an ASF outbreak. Biosecurity implementation is robust and capable of withstanding changes in input costs including moderate feed price increases, higher management costs and marginal reductions in total outputs. It is concluded that biosecurity is a key to successful pig production in an endemic situation.

Keywords: African swine fever, Biosecurity, pigs, benefit-cost analysis.

Introduction

African swine fever virus infected the Nigerian pig population in 1997 with heavy mortalities and huge economic/social impacts (El-Hicheri, 1998). Both the subsistence and commercial pig raising activities were severely disrupted by these infections. The virus continues to circulate causing sporadic or sometimes sustained infections in Nigerian pigs with further significant impacts on the swine industry (Babalobi, *et al*., 2007; Fasina *et al*., 2010). Possible reasons for the persistence of the virus in the Nigerian pig population include continuous presence of persistently-infected and carrier sero-positive pigs on farms, uncontrolled breeding programmes, pig product movements, traders and middlemen operations and most importantly the lack of or poorly implemented biosecurity measures (Olugasa and Ijagbone, 2007).

Field observations and opinion polls of some 95 smallholder pig farmers [Mean herd size =71, Range = 5-450 pigs; 1st quartile = 17; 3rd quartile = 84] in parts of Nigeria revealed a huge deficiency in the understanding and implementation of basic concepts of biosecurity at farm level. These farmers despite reporting implementation of principles of hygiene in their farms and having experienced shared infections continued to keep/sell survivor pigs, slaughtered infected pigs on their premises, visited infected premises and slaughter slabs within the communities without taking precautionary measures, sometimes shared equipment, permitted the entrance of farm-gate buyers into the farm premises and did not make an effort to ascertain the ASF status in their immediate community.

Profitability (the excess of incomes over expenses) remains the principal driver for involvement in pig rearing, hence the understanding of this factor and its use in the introduction and maintenance of principles of biosecurity at farm level becomes important for controlling ASF at farm level, most especially in the small to medium scale piggeries and farming communities.

Furthermore, for the farmers to take a decision to implement and provide sustained support for disease management programs like ASF, financial considerations (profit and or benefit arising from such a decision) is often important, in addition to the following factors:

- Additional workload on the workers and whether this can be adopted easily into the current farm operations
- Complexities in changes in management procedures due to the new protocols
- Requirements for increased levels of investment
- Cheaper alternatives that achieve the same proposed solution (biosecure environment)
- Availability of funds and means to implement the proposed measures
- Commitment of staff including necessary training, understanding of the risk of infection and its severity,
- Incentives to offset the burden placed on workers to ensure proper implementation and secure their involvement
- Cost of compliance and monitoring following implementation
- Laws and regulations that permit or negate such proposed intervention

Based on the above, an understanding of total cost determination is the critical starting point for any positive intervention to be implemented at farm level. For any intervention to survive the keen competitive environment of limited resources, the value or benefit must be clear and the application easy and suited to the local conditions.

The use of economics has been advocated as an effective tool in the management of transboundary animal diseases and a previous study has demonstrated that the understanding of economics of animal diseases including the management and intervention options at herd-level remains a key strategy for rapid implementation of animal disease control (Marsh, 1999; FAO, 2001). Babalobi *et al*. (2007) previously investigated the cost implications of ASF outbreaks in south-west Nigeria using a cost analysis, but to date, no farm level study has been conducted to determine the impact and benefits of intervention in smallholder operations. Benefit-cost analysis represents the most comprehensive standard financial analysis to evaluate animal disease situations with positive outcomes (Marsh, 1999; Tambi *et al*., 1999; Tisdell, 1999; FAO, 2001).

The aim of this study was to estimate the profitability of biosecurity implementation using a 122-sow farrow-to-finish pig farm model to determine the benefit-cost effects of required interventions. The results are expected to serve as basic guidelines to assist farmers in measuring profitability of farm operations so that they can make informed decisions regarding biosecurity implementation in against the backdrop ofmany competing financial interests.

Materials and method

Choice of farm

Selected farms were visited and evaluated including small-scale operators (<100-sow units), medium-scale operators (101 to 250-sow units) and large-scale operators (>250-sow units) to compare and contrast production parameters and industry standards. Standardized production data were collected using available literature (Carr, 1998; Stalder *et al*., 2011) and farm data were collated by personal interviews with farmers and careful examination of farm records. Farm data were further confirmed with pig farm consultants and assessed against published data to check for consistency. Critical values where farmers/consultants need to intervene to ensure optimum productivity were also determined and are presented in Table 1. Based on economic feasibility and detailed records of farm operations, a 122-sow farrow-to-finish unit producing porkers (70kg liveweight pigs) was ultimately selected for the model.

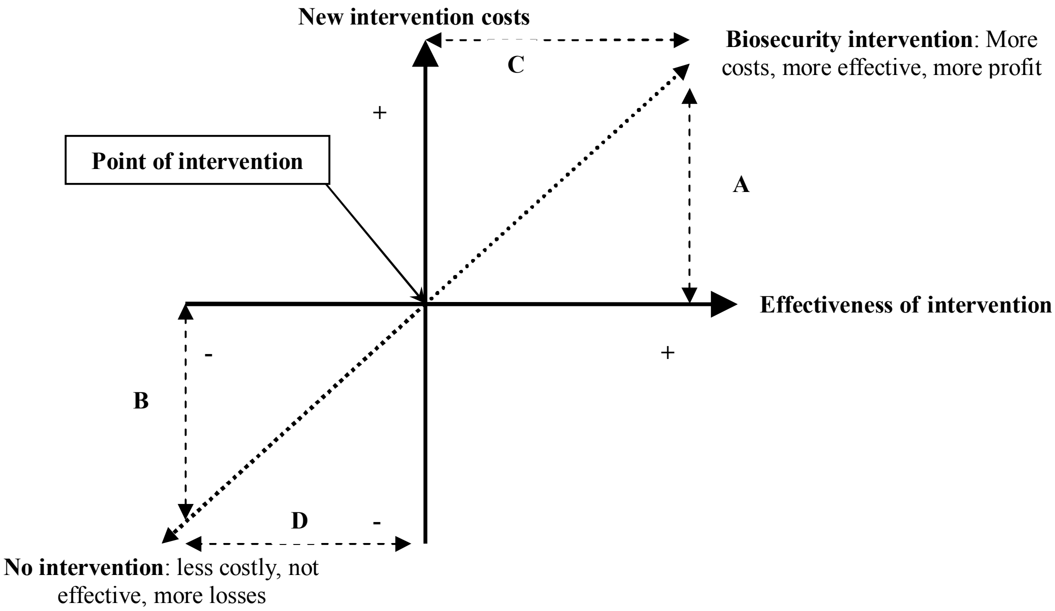

Figure 1. Model of intervention with biosecurity and no intervention in a 122-sow farrow-to-finish pig farm. Biosecurity intervention will maximize gain while no intervention will attract extra losses due to ASF outbreak. **A** represents increased costs of biosecurity implementation; **B** is decreased costs of no intervention; **C** is increased benefits of intervention and **D** represents increased losses associated with no intervention.

Identification of risk factors associated with African swine fever virus introduction

When considering possible means of disease introduction, the following were identified as potential routes for African swine fever virus introduction:

- Soft-shelled eyeless ticks (*Ornithodoros moubata* complex) present in the community. This vector has never been implicated in the outbreaks of ASF in West Africa. However, a recent study indicates the presence of an *Ornithodoros* species that may play a role in the epidemiology of ASF in West Africa (Vial *et al*., 2007).
- Warthogs, bushpigs, red-river hogs presence. All three wild suid species occur in the West African sub-region (Jori & Bastos 2009). Contact with domestic pigs kept under intensive management is, however, unlikely.

- Infected pigs present in the farm
- Infected or in-contact pigs bought into the farm without quarantine
- Infected service boars used for natural mating or AI
- Mixing of pigs from different origins and exposures including those from farms, agricultural shows, markets and those returned to the farm through no sale.
- Feeding of raw swill, infected meat scraps from homes or from international carriers (air, water)
- Exchanging of feed bags at the feed mills
- Farm workers raising pigs at home
- Farm workers and managers consulting for other farms
- Farm workers and managers visiting pig abattoirs especially with farm clothes and boots.
- Input suppliers / marketing personnel visiting multiple farms/location/villages/herds per day
- Farm gate buyers visiting several farms/herds/markets to select animals to buy
- Animal health workers and veterinarians consulting for several farms per day
- Contaminated vehicles used to transport input supplies and feed
- Contaminated vehicles used to transport pork and other abattoir waste
- Contaminated farm equipment and implements being used at multiple farms / sites
- Improper disposal of pig by-products including manure and slurry, intestinal content, abattoir waste and blood
- Free-range/scavenging pigs in contact with farms.
- Inadequate access to quality veterinary services and advice.
- Biosecurity lapses in cleaning, disinfection and decontamination.
- Lack of compensation for culled animals.

Based on the above ASF infection risk factors for a 122-sow farrow-to-finish pig farm, the biosecurity measures considered in this study were included to ensure maintenance of a closed herds, easy integration into current farming practices, enhanced farm operations that instil pride in workers, certification to ensure that animal entering and leaving the farm are free of infection, prevention of direct contact with possible infected sources (ticks, wild pigs and free-range pigs), prevention of indirect contact (formites, tools, tyres etc), prevention of within-farm (pen-to-pen) and inter-farm/inter-site spread of infection

Specifically, the following biosecurity measures were considered to be applicable to the pig farms:

Segregation: Erection of fence and gate, control and monitoring of physical barrier, enforcement of change of footwear and clothing, and restricting the entry of vehicles or dipping of tyres in case of necessary entrance.

Cleaning: Daily sweeping, routine washing of the pen with copious amount of water, thorough washing with soap, water and brush to ensure that no visible dirt is seen on the surface of building and materials, dry cleaning of all material that are not water-resistant.

Disinfection: Usage of appropriate disinfectant to sanitize washed and dry-cleaned materials (FAO, 2010). The costs of the selected items above are presented in Table 7. These costs were determined from details available from the farms.

Parameters and assumptions

The parameters and figures used in the calculations are available in Table 1 and the assumptions used are listed below:

Table 1. Farm targets for a 122-sow farrow-to-finish unit.

Production Parameters	Target	Farm used	Interference
Reproduction			
Number of productive sows	140	122	<95%
Farrowing interval	147 days	150 days	>190 days
Farrowing index	2.35	2.25	<2.0 and >2.4
Weaning to service interval	5 days	5 days	>16 and <26 days
Repeat mating (return to heat 18-24 days post-mating)	10%	12%	>15%
Empty days/sow/annum	34 days	36 days	<24 and >40 days
Abortion	<1%	2%	>5%
False pregnancy detected (after 70-80 days)	1%	2%	
Farrowing rate	>87%	96%	<75%
Sow parity at culling*	6-7	12	
Sow death per annum	2%	1%	>5%
Number of boars (service, sniff and replacement)	9	9	>11
Number of mating per week	7	7	<3 and >9
Replacement rate (sow)*	33% (1/3 per years)	25%	<25 and >50%
Replacement rate (boars)*	50% (1/2 per year)	20%	<30 and >60%
Number of replacement gilt per annum	33% (47)	32.8% (40)	<28% and >50%
Age at first service (gilts)	240	270	<240 and >300
Number of replacement boars per annum*	5	2	<3 and >7
Farrowing house performance			
Number of litter/sow/year	2.35	2.25	<2.0 and >2.4
Number of piglets/litter born alive (23/annum)	11	10.25	<8
Number of stillborn and mummies (1/litter)	7%	2%	>10%
Piglet mortality before weaning (2.31/sow/year)*	10%	22%	>15%
Total piglets weaned/sow/year (9.75/sow/litter)	23.27	≈22	<18
Age at weaning (piglets)	4 weeks	4 weeks	
Age at transfer to weaner house (piglets)	4 weeks	4 weeks	>6-8 weeks
Total numbers of piglets born alive/122 sows/year (2.35 × 0.96 × 122 × 11)	3,028	2,701	2,202
Total weaners/122 sows/year (2.25 × 0.96 × 122 × 9.75)	2,839	2,569	2,196
Feeding herd performance			
Percentage loss of weaners before sale as porkers	0- <1%	<0.05%	>3%
Percentage of porkers sold	>99%	≈100%	<97%
Porkers sold per sow per year	≈ 21	≈ 22	<18
Total number of porkers sold/year	2562	2569	
Feed			
Feed/sow/annum (including input for piglets)	1.20tons	1.25tons	>1.4tons
Feed per 122 sow-unit per year (1.2 ton/sow/year) including feed for boars	146.4tons	152.5tons	>170.8tons
Feed for 9 boars per annum	Included in sow and boar feed.		
Piglets (Creep feed @ 1kg per litter)	≈ 287kg	≈ 275kg	<244kg
Feed per porkers (weaner to porker at 1.4kg/day)	225kg	199.7kg	262.5kg
Feed for all porkers (weaner to porker)	57.65tons	51.30tons	
Mean annual cost per kilogramme of meat from porkers (at 71.5 - 75% meat from live weight, a 70kg pig will yield ≈50kg of pork)			US$2.47/kg
Mean annual cost per kilogramme of meat from culled sows (at 74 - 75% meat from live weight, a 250kg boar will yield ≈185kg of pork)			US$1.35/kg
Mean annual cost per kilogramme of meat from culled boar (at 75 - 77% meat from live weight, a 280kg pig will yield ≈210kg of pork)			US$0.45/kg

*Parameters with asterisk (*) indicate that the values from the used farm are either too high or too low. In such circumstances, standard values from the target were substituted for used farm values.

Production parameters were adapted using Carr, (1998); Stalder et al., (2010) or from personal communication with experts and field survey of selected farms.

The exchange rates of Nigerian Naira (₦.k) of ₦152.00 =US$1.00 was used for all calculations.

1. Each sow will produce an average of 10.25 piglets per litter and wean 9.75 piglets. A 2% case of stillborn/mummies will occur per sow on average in the farm (Table 1).
2. All cases of sudden death for the period of the assessment will be directly as a result of ASF or causes associated with it. ASF will ultimately lead to 100% mortality in infected farms either due to direct mortality caused by the disease or stamping-out policy implemented on the farm.
3. The sow will be replaced after the sixth parity and at an average age of ≈ 3 years. The boar will be replaced after 2 years of age.
4. Each porker will have a finishing liveweight of ≈ 70kg at 150 days. Culled sows will have a liveweight of ≈ 250kg while the culled boar will have a liveweight of ≈ 280kg. The prevailing price of prime cut for porkers of US$2.47, culled sow (US$1.35) and culled boars (US$0.45) will remain constant.
5. The lifespan of a standard fence erected will be 20 years. Depreciation is calculated using linear equation and mean valuation (1x + 2x + 3x + 4x +5x + 6x + 7x + 8x + 9x + 10x……….. 20x) whereas the total value of such materials will be divided by the lifespan of the materials and the mean value will be deducted in each year. The value of the fence will be zero after 20 years and that of the cemented tyre dip will be zero after the 10th year.
6. Depreciation in stock values was determined by deducting the final market value of each stock from the initial value and dividing the total loss of value over 6-monthly periods (Table 2).
7. Since it is known that the outbreak can occur at any period during the operational year, a mid-year value was obtained and used for all farm stock.

8. Implementation of biosecurity will be 100% effective against the risk of infection with ASF.

Profit was assessed by deducting all input values and costs from output values and incomes (Tables 3, 4 & 5). Year outputs per input as well as operation mean year total over a three-year period were also calculated. Details of the calculations are available in tables 3-5.

Assuming that African swine fever outbreak will cause massive mortality approaching 100%, or that the remaining stock will be depopulated following an outbreak, a potential loss associated with ASF was calculated and is presented in table 6. The bases for the calculations are available as footnotes to the tables.

From the above costs, values and outputs, the benefit cost analysis (BCA) of implementation of biosecurity against ASF was evaluated and presented.

Sensitivity analysis

Since the annual farm operation exists in a dynamic environment and changes in other variables may affect the annual profitability of farm operations and consequently that of the BCA, a sensitivity analysis was conducted to assess the effect of biosecurity implementation on overall profitability in the event that:

1. Cost of biosecurity increases by 100%,
2. Feed price increases by 30 up to 75%,
3. Management cost (input costs excluding feed) increases by between 25 and 75%, and
4. Total margins from outputs are reduced by 10 up to 25%.

Results

Profitability of the 122-sow farrow-to-finish farm and losses associated with potential ASF infection

The annual mean costs of operation was US$295,075.80 and feed costs accounted for 71.99% of the total variable costs while fixed costs represented 31.13% of the total costs (Table 3). Labour cost accounted for 86.30% of the total fixed cost in this study. A mean output of US$404,713.30 was generated and the porkers (weaner grown in the farm to finisher stage) accounted for 82.38% of this total output (Table 4). Annual profit gradually increased from US$107,923.70 to US$111,126.30 over a three year period with a mean annual profit of US$109,637.40 (Table 5).

Should ASF infect a non-biosecure farm in the first year of operation, the farm will lose a total of US$910,836.70. It should be noted that part of this amount does not represent real incomes since the whole sum is inclusive of potential incomes associated with the expected outputs from the farm in the second and third years of operation. If the infection occurs in the second year, there is a possibility of losing up to US$579,312.50 while an infection of the farm in the third year will result in the loss of approximately US$233,690.70 (Table 6). The losses will include the costs of wasted inputs (feeds, veterinary costs, drugs, vaccines, transportation, bills and utilities), clean-up costs, pay-off to staff, facility rental cost, and some maintenance costs in addition to real and potential outputs expected from the farm.

Table 2. Six-monthly depreciation rates (in percentage) in the value of pigs based on expert survey and prevailing prices.

	Initial	Mid-year 1	End of year 1	Mid-year 2	End of year 2	Mid-year 3	End of year 3
Sow (10.06% every 6 months)	US$628.74	US$565.49	US$502.24	US$438.99	US$375.74	US$312.49	US$249.23
Boar (22.38% every 6 months)	US$898.20	US$697.23	US$498.95	US$297.98	US$97.01	**US$697.23**	**US$498.95**

Sows will experience a devaluation of 60.36% over a three year period equivalent to 10.06% every half year. Boars will experience a devaluation of 89.50% over a two year period equivalent to 22.38% per half year. Boar's value drops drastically because of boar taint that is expressed in meat from boar. It is assumed that new sets of stud boars will have completely replaced the old boars by the end of year two hence the reversion to year 1 rates for the third year (indicated in bold).

Table 3. Mid-year values of stock and costs of other inputs over a three-year farm operation period

	Year 1	Year 2	Year 3	Mean total-year cost	Comments
Stock					The estimates for year two and three were all calculated based on an annual inflation rate of 5%, with the exception of labour costs.
Purchase value of 122 sows in production mid year	US$68,989.78	US$53,556.78 + US$2,677.84 (5% inflation margin)	US$38,123.78 + US$1,906.19 (5% inflation margin)	US$165,254.37 divided by 3 = **US$55,084.79**	Mid-year value of sow was estimated using 10.06% depreciation value/6 months of the cost of 1 gilt (US$628.74). After 3 years, the sow will have depreciated by a total of 60.36% (US$379.51) of the original cost to US$249.23. For the sow, the total mid-year mean cost will be (Year 1 + Year 2 + Year 3 costs) divided by three
Purchase value of 9 stud/sniff boars mid year	US$6,275.07	US$2,681.82 + US$134.09 (inflation margin)	US$6,275.07 + US$313.75 (inflation margin)	US$15,679.80 divided by 3 = **US$5,226.60**	Mid-year value of boar was estimated using 22.38% depreciation value/6 month of the cost of 1 new stud boar (US$898.20). After 2 years, the boar will have depreciated by a total of 89.50% (US$801.19) of the original cost to US$97.01 largely due to boar taint. In the third year, a new set of boar will be valued. For the boar, the total mid-year mean cost will be (Year 1 + Year 2 + Year 3 costs) divided by three
Purchase of 40 replacement gilts	US$25,149.60	US$26,407.08	US$27,727.43	**US$26,428.04**	At US$628.74 per in-gilt.
Purchase of 5 replacement boars	US$4,491.00	US$4,715.55	US$4,951.33	**US$4,719.29**	At US$898.20 per stud boar.
Subtotal	**US$104,905.50**	**US$90,173.20**	**US$79,297.60**	**US$91,458.70**	
Variable costs (feed)					
Feed per 122 sow per year (1.25 ton/sow/year) including 9 boars	US$57,073.13	US$59,926.79	US$62,923.13	**US$59,974.35**	152.5 tons @ US$374.25/ton
Piglets (Creep feed @ 1kg per litter)	US$288.17	US$302.58	US$317.71	**US$302.82**	At US$1,047.90/ton. A total of 275kg is needed per year at the current level of productivity.
Feed for the porkers (28 to 150 days)	US$19,199.03	US$20,158.98	US$21,166.93	**US$20,174.98**	51.30tons at US$374.25/ton
Subtotal	**US$76,560.30**	**US$80,388.40**	**US$84,407.80**	**US$80,452.20**	
Variable costs (others)					
Veterinary services + Medicines and vaccination	US$11,676.65	US$12,260.48	US$12,773.50	**US$12,270.21**	Based on 6 veterinary consultations per annum at a cost of US$449.10 per visit. Drugs, medicaments and vaccination cost US$8,982.04.
Transport	US$8,982.04	US$9,431.14	US$9,902.70	**US$9,438.63**	
Utilities	US$17,964.07	US$18,862.27	US$19,805.38	**US$18,877.24**	
Other miscellaneous expenses	US$2,838.54	US$2,980.47	US$3,129.49	**US$2,982.83**	
Subtotal	**US$29,784.70**	**US$31,273.90**	**US$32,837.60**	**US$31,298.70**	
Fixed costs					
Labour	US$71,856.29	US$79,041.92	US$86,946.11	**US$79,281.44**	Labour cost were calculated based on an annual increase of 10%
Facility rentals at US$374.25/month	US$4,491.02	US$4,715.57	US$4,951.35	**US$4,719.31**	Fixed at US$374.25/month
Maintenance costs and Repairs	US$7,485.03	US$7,859.28	US$8,252.24	**US$7,865.52**	
Subtotal	**US$83,832.30**	**US$91,616.80**	**US$100,149.70**	**US$91,866.30**	
Gross total of all expenses and costs	**US$295,082.80**	**US$293,452.30**	**US$296,692.70**	**US$295,075.90**	

An annual inflation of 5% was factored into all calculations, unless stated otherwise.

Table 4. Mid-year values of stock and prices of other outputs over a three-year farm operation period

Farm outputs and prices	Year 1	Year 2	Year 3	Mean total-year price	Comments
Price of total meat from porkers sold/year	US$317,279.19	US$333,143.15	US$349,800.31	**US$333,407.57**	Mean annual cost per kilogramme of meat from porkers is US$2.47/kg (at 71.5% meat from live weight, a 70kg pig will yield 50kg of pork). A total of 2,569 will be produced per annum.
Price of total culled sows (40)	US$9,990.00	US$10,489.50	US$11,013.98	**US$10,497.83**	Mean annual cost per kilogramme of meat from culled sows is US$1.35/kg (at 74% meat from live weight, a 250kg boar will yield 185kg of pork)
Price of total culled boar (5)	US$472.50	US$496.13	US$520.94	**US$496.52**	Mean annual cost per kilogramme of meat from culled boar is US$0.45/kg (at 75% meat from live weight, a 280kg culled boar will yield 210kg of pork) Price per kg of pork from culled boar
Purchase value of 122 sow in production mid year	US$68,989.78	US$53,556.78 + US$2,677.84 (5% inflation margin)	US$38,123.78 + US$1,906.19 (5% inflation margin)	US$165,254.37 divided by 3 = **US$55,084.79**	Mid-year value of sow was estimated using 10.06% depreciation value/6 months of the cost of 1 gilt (US$628.74). After 3 years, the sow will have depreciated by a total of 60.36% (US$379.51) of the original cost to US$249.23. For the sow, the total mid-year mean cost will be (Year 1 + Year 2 + Year 3 costs) divided by three
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Total sales value per annum	**US$403,006.50**	**US$403,179.30**	**US$407,954.00**	**US$404,713.30**	

All input and output costs and prices were based on the prevailing costs and prices. All costs and prices were translated in American Dollars and rounded off to the nearest Cent. The exchange rates of Nigerian Naira (₦.k) of ₦152.00 =US$1.00 was used for all calculations.

Table 5. Profit margins per annum over the three-year operation period

Parameter	Year 1	Year 2	Year 3	Mean year-total
Outputs	US$403,006.50	US$403,179.30	US$407,954.00	US$404,713.30
Inputs	US$295,082.80	US$293,452.20	US$296,692.70	US$295,075.90
Profit	**US$107,923.70**	**US$109,727.10**	**US$111,126.30**	**US$109,637.40**
Year Output/Input	1.366	1.374	1.375	1.372

Table 6. Potential losses associated with ASF outbreaks

Outbreak period	Potential losses	Output losses	Input losses	Total potential losses
Year 1	Lose ½ year 1 total outputs + some year 1 inputs + potential porkers from year 2 and year 3 without inputs of year 2 and 3	US$201,503.27 US$333,143.15 US$349,800.31	US$26,390.01	**US$910,836.70**
Year 2	Lose ½ year 2 total outputs + some year 2 inputs + potential porkers from year 3 outputs without inputs of year 3.	US$201,589.66 US$349,800.31	US$28,008.92	**US$579,312.50**
Year 3	Lose ½ year 3 outputs + some year 3 inputs	US$203,977.01	US$29,713.71	**US$233,690.70**

Mid-year values were used for all calculations. Inputs lost include the following: 1 month supply of feed (1/12); ¼ of cost of veterinary services and drugs as cost of breach of retainership contract; 1/6 of cost of transport as part of clean-up costs; ¼ of cost of utilities (in reduced bills and levies); 1 month cost of labour as pay-off to staff; total annual cost of renting of facility and 1 month maintenance costs (1/12).

Table 7. List and costs of items needed for biosecurity

Item	**Unit cost**	**Total cost**
Complete fencing of the piggery plus installation of doors and controlled access	US$22,455.09 for 20 years	US$1,122.75/annum.
Tyre dip for incoming vehicles	US$2,245.51 for 10 years	US$224.55/annum.
Cost of farm disinfectant per annum at the rate of 5L of disinfectant per month	US$35.95 per 5L	US$431.40/annum.
Cost of quarantine for incoming pigs per annum	Part of building cost/rented facility	
Provision of boots and clothes for 6 workers, 2 visitors, a manager and the farm director, total=10.	US$35.93 per overall and US$20.96 per pair of gumboot.	US$568.88/annum
Extra labour needed to ensure compliance	5% of normal labour cost	US$3,592.81/annum
Incentives to workers for compliance	2.5% normal labour cost	US$1,796.41/annum
Rat and other animals/insect control		US$500.00/annum
Correct disposal of farm mortalities and waste. Construction of a waste pit plus cover. It is assumed that a pit will be filled in three years.	Cost of pit = US$598.80	US$199.60/annum
Provision of hand and body washing facilities. 5L of hand disinfectant every 2 months and 12 bars of antiseptic soap every month.	US$89.37 per 5L hand disinfectant and US$160 per 144 bars of antiseptic soap.	US$696.22/annum
Placement of restriction access notices	US$100.00	US$100.00
Secured feed store	Part of building cost	
Total		**US$9,232.62**

Based on a 5% annual inflation rate, the costs for biosecurity in the second and third year are US$9,694.25 and US$10,178.96 respectively. The potential cumulative costs of biosecurity for the 1st, 2nd, and 3rd year will be US$29,105.83, US$19,873.21 and US$10,178.96 respectively. The mean cost of Biosecurity over the three year period was US$9,701.94

Benefit of biosecurity against African swine fever compared to no-biosecurity using benefit-cost analysis (BCA)

The benefit cost ratio (BCR) of implementing biosecurity in a 122-sow farrow-to-finish unit can be determined in one of two ways:

BCR = {[Increase in net incomes + Decrease costs of operation] – [Decrease in net incomes + Increase cost of operation due to biosecurity]}. This formula is suitable for diseases that do not lead to 100% mortality of the herd.

Or

BCR = [Total losses per annum / total potential cost of biosecurity for that year], since it was assumed that no pig will be left after infection by ASF either due to ASF-associated mortality or stamping out policy.

Where the:

Increase in net incomes = profit retained, downtime cost saved, wasted feed and labour and other costs saved.

Decrease costs of operation = cost of disease management and clean-up costs.

Decrease in net incomes = extra costs of implementing biosecurity

Increase cost of operation due to biosecurity = assumed profit saved without biosecurity, value of total animal saved without biosecurity.

Since it was assumed that ASF will cause 100% mortality, the BCR of no-biosecurity will amount to zero because no animal will be saved for evaluation purposes. However, the BCR of biosecurity against an infection of ASF in the first year of operation will be US$910,836.70/US$29,105.80) = **31.29**

In the second year of operation, this value of biosecurity implementation against ASF is US$579,312.50/US$19,873.20 = **29.15**

In the third year of operation, this value will be US$233,690.70/US$10,179.00 = **22.96**

Over a three year operation, the BCR of biosecurity against ASF will be:

US$(910,836.70 + 579,312.50 + 233,690.70)/ US$(29,105.80 + 19,873.20 + 10,179.00) =

US$1,723,839.90/US$59,158.00 = **29.14**

Sensitivity analysis

The inclusion of biosecurity in the farm operation will reduce the mean annual profit by 9.70%, however, this is justified in view of the potential benefit of 29 times expected over a three year period compared to not implementing biosecurity. If the cost of biosecurity increases by 100%, the mean annual profit will reduce by 19.42% while a 30% increase in cost of feed will reduce the mean annual profit by 33.86%. A 25% increase in cost of other variable and fixed costs will reduce the profit by 40.52% while a 75% increase in these costs will lead to loss of 102.14% (total loss of profit and an addition of 2.14%). If the incomes from the outputs are reduced by 10%, there will be a 50.21% loss in profit while a 25% loss in total outputs will lead to a loss of 110.95% of profit (Table 8).

Table 8. Sensitivity analyses of the implementation of biosecurity against ASF and price changes in a 122-sow farrow-to-finish piggery

Percentage change (Item)	Mean feed cost (US$)	Other variables (US$)	Fixed costs (US$)	Biosecurity cost (US$)	Purchase values of pigs (US$)	Mean total costs (US$)	Mean total outputs (US$)	New anual profit (US$)	Initial profit without cost of biosecurity (US$)	Change in mean profit in US$	% reduction in profit
Current mean over three years	80,452.15	31,298.70	91,866.27	9,701.94	9,1458.72	304,777.78	404,713.3	99,935.52	109,637.46	9,701.94	9.70*
Cost of biosecurity increase by 100%	80,452.15	31,298.70	91,866.27	**19,403.88**	9,1458.72	314,479.72	404,713.3	90,233.58	109,637.46	19,403.88	19.42
Feed price increase by 30%	**104,587.80**	31,298.70	91,866.27	9,701.94	9,1458.72	328,913.43	404,713.3	75,799.87	109,637.46	33,837.59	33.86
Feed price increase by 50%	**120,678.23**	31,298.70	91,866.27	9,701.94	9,1458.72	345,003.86	404,713.3	59,709.44	109,637.46	49,928.02	49.96
Feed price increase by 75%	**140,791.26**	31,298.70	91,866.27	9,701.94	9,1458.72	365,116.89	404,713.3	39,596.41	109,637.46	70,041.05	70.09
25% increase in cost of management (other variables and fixed costs)	80,452.15	**39,123.38**	**114,832.84**	9,701.94	9,1458.72	335,569.03	404,713.3	69,144.27	109,637.46	40,493.19	40.52
50% increase in cost of management (other variables and fixed costs)	80,452.15	**46,948.05**	**137,799.41**	9,701.94	9,1458.72	366,360.27	404,713.3	38,353.03	109,637.46	71,284.43	71.33
75% increase in cost of management (other variables and fixed costs)	80,452.15	**54,772.73**	**160,765.97**	9,701.94	9,1458.72	397,151.51	404,713.3	7,561.79	109,637.46	102,075.67	102.14
Total margin from outputs is reduced by 10%	80,452.15	31,298.70	91,866.27	9,701.94	9,1458.72	304,777.78	**364,241.97**	59,464.19	109,637.46	50,173.27	50.21
Total margin from outputs is reduced by 15%	80,452.15	31,298.70	91,866.27	9,701.94	9,1458.72	304,777.78	**344,006.31**	39,228.53	109,637.46	70,408.93	70.45
Total margin from outputs is reduced by 20%	80,452.15	31,298.70	91,866.27	9,701.94	9,1458.72	304,777.78	**323,770.64**	18,992.86	109,637.46	90,644.60	90.70
Total margin from outputs is reduced by 25%	80,452.15	31,298.70	91,866.27	9,701.94	9,1458.72	304,777.78	**303,534.98**	-1,242.80	109,637.46	110,880.26	110.95

*Mean values of all costs and outputs over the three-year period were used for the sensitivity analysis viz. the cumulative addition of costs from year 1, 2 and 3 divided by three. *Changes in the mean profit for the current situation was due to the integration of costs of biosecurity which was not included in the initial calculations without biosecurity (see Tables 3, 5 and 7) .*

Discussion

In this study, we have demonstrated the profitability of a 122-sow pig farm and described an economic approach to preventing ASF virus infection at farm level. We are aware that farm profitability may not always be based on optimum productivity as the interplay of various factors may affect farm operations and lower maximum profitability; this effect is reduced in this analysis by the use of real farm data as the template to simulate profitability. An attempt to examine the cost effectiveness of intervention using biosecurity and a situation of no intervention for a probable African swine fever virus infection of the 122-sow unit indicated that intervention at farm level using biosecurity to prevent the introduction of ASF was far more effective than taking no action (benefit-cost ratio: 29.14).

Since ASF is currently endemic in Nigeria and in most of the West African states, and no vaccine is available to control the disease, it will be important to focus on preventing ASF infection using biosecurity. It should however be borne in mind that prevention of outbreaks of a disease like ASF is an interplay of diverse factors, including the effectiveness of biosecurity. Despite the fact that the facilities and tools needed for the implementation of farm-level biosecurity will come at a cost, the investment is justified in view of the outcomes that are derived from implementation of these measures. Furthermore, some of these facilities including fencing and tyre dips will be useful for a long time and for other purposes other than biosecurity. While the study focused on the benefit of biosecurity in preventing ASF infection alone, the biosecurity implementation will also prevent other infectious diseases like foot-and-mouth disease (FMD), classical swine fever (CSF), Aujeszky's disease, swine vesicular disease (SVD), porcine circoviruses (PCV) and porcine reproductive and respiratory syndrome virus (PRRS).

Thus, the total overall benefits of biosecurity are likely to far outweigh the cost benefit analysis done in this study.

Babalobi and colleagues (2007) had previously described a combined mortality of over 91% in 306 pig farms in southwest Nigeria, and field observation has confirmed similar figures. A situation of this magnitude will come with loss of trade, redundancy of facility, psychosocial stress on the farmer and the potential to infect neighbouring farms. The cost of destruction of the remaining pigs and burying, as well as the disinfection of the farm following outbreaks of ASF will also add to the burden of ASF virus infection. The information provided by the result of this work will guide sound decision-making related to the allocation of funds to biosecurity implementation, in the face of other competing interests.

The benefit-cost analysis of biosecurity indicates that it is justified on economic grounds. In the smallholder farms survey earlier mentioned, we confirmed that there have been several/repeated outbreaks of ASF and currently, there are a combined total of less than 100,000 pigs in the survey area, the ASF status of which is unknown to the farmers. However, the recent findings of Fasina *et al*. (2010) revealed that the prevalence of ASF on the farms is very high (50% seropositivity and 97% positive for ASF virus genome). Although we used a value of 100% mortality to calculate our values in this analysis, other workers have reported similar or lesser percentages of mortality in severe cases (Dixon *et al*., 1994; Penrith *et al*., 2004; Bastos *et al*., 2004; Babalobi *et al*., 2007), and we are aware that less acute forms of ASF exist, a situation that may perpetuate itself in pig farms and cause reduced but continuous economic losses (Penrith *et al*., 2004). It is our opinion that biosecurity at farm level will be better than no intervention irrespective of the form of ASF virus infecting a farm.

The sensitivity analysis of this model has proved that even with the inclusion of biosecurity in the farm operation, the proposed project will survive the additional variations that may cause foreclosure. A 100% increase in cost of biosecurity will cause a 19.42% reduction in profit (US$19,403.90) and this may save a potential value of US$910,836.70 in stock and farm operations. However a greater than 50% increase in cost of feed as well as an output margin reduced by 15% or more will have a negative effect on the implementation of biosecurity at farm level. It is unlikely that this margin of increase on feed cost will happen without government intervention in view of the similar food resources required by humans and pigs.

Although the focus of this study is on economic analysis alone, other forms of losses which can not be quantified in economic terms exist. The psychosocial stress, loss of health and human (pig farmers) death following the complete loss of livelihood is difficult to quantify. If it were possible to quantify the above impacts economically, we believe that the benefit-cost of biosecurity would rise significantly.

This model of biosecurity herein reported can be favourably implemented at smallholder farm-level since it is easily adaptable, less costly and socially acceptable (Ekue and Wilkinson, 1990). This model if combined with good management practices will be of tremendous benefit to the farmers. It should be possible to train extension agents, veterinarians and government agricultural workers to communicate the message of biosecurity, including its financial benefit to pig farmers. The use of community leaders and cooperative unions may also assist in this regard. Finally, a case of ASF on a farm, if left uncontrolled will result in a huge loss of investment on a national scale since inter-farm and inter-regional spread is inevitable (Mannelli *et al*., 1997).

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References

Babalobi, O.O., B.O. Olugasa, D.O. Oluwayelo, I.F. Ijagbone, G.O. Ayoade, S.A. Agbede, 2007: Analysis and evaluation of mortality losses of the 2001 African swine fever outbreak, Ibadan, Nigeria. *Trop. Anim. Hlth Prod* 39, 533-542.

Bastos, A.D.S., M.-L. Penrith, F. Macome, F. Pinto, G.R. Thomson, 2004: Co-circulation of two genetically distinct viruses in an outbreak of African swine fever in Mozambique: no evidence for individual co-infection. *Vet. Microbiol.* 103, 169–182.

Carr, J., 1998: Farms targets per 100 sows. In: *Garth Pig Stockmanship Standards.* 5M Enterprises Ltd., Sheffield, UK.

Dixon, L. K., S. R. F. Twigg, S. A. Baylis, S. Vydelingum, C. Bristow, J. M. Hammond, G. L. Smith, 1994: Nucleotide sequence of a 55 kbp region from the right end of the genome of a pathogenic African swine fever virus isolate (Malawi LIL20/1). *J Gen Virol.* 75:1655-1684.

Ekue, N. F., P. J. Wilkinson, 1990: Absence of *Ornithodoros moubata*, the vector of African swine fever virus, from the main pig producing area of Cameroon. *Trop Anim Health Prod.* 22(2):127-31.

El-Hicheri K., 1998: Emergency Assistance on control and eradication of an outbreak of African swine fever in Western Nigeria. *Report of the FAO Consultancy Mission to Nigeria.* TCP/NIR/7822(E). FAO, Rome, December, 1998.

Fasina, F. O., D. Shamaki, A. A. Makinde, L. H. Lombin, D. D. Lazarus, S. A. Rufai, S. S. Adamu, D. Agom, V. Pelayo, A. Soler, A. Simón, A. J. Adedeji, M. B. Yakubu, S. Mantip, A. J. Benshak, I. Okeke, P. Anagor, D. C. Mandeng, B. O. Akanbi, A. A. Ajibade, I. Faramade, M. M. Kazeem, L. U. Enurah, R. Bishop, R. Anchuelo, J. H. Martin, C. Gallardo, 2010: Surveillance for African Swine Fever in Nigeria, 2006-2009. *Transboundary Emerging Dis,* 57(4): 244-253.

Food and Agricultural Organization of the United Nations, 2001: *The State of Food and Agriculture 2001*. FAO, Rome, Italy. Also available online at http://www.fao.org/docrep/003/x9800e/x9800e00.htm. Accessed on August 24, 2010.

Food and Agricultural Organization of the United Nations /World Organization for Animal Health (FAO/OIE), 2010: *Good Practices for Biosecurity in the Pig Sector: Issues and Options in Developing and Transition Countries*. FAO Animal Production and Health paper 169. FAO, Rome, 2010. Also available online at www.fao.org/docrep/012/i1435e/i1435e00.pdf. Accessed on August 24, 2010.

Jori, F., Bastos, A.D.S. 2009: Role of wild suids in the epidemiology of African swine fever. *EcoHealth*., 6:296-310.

Marsh W., 1999: The economics of animal health in farmed livestock at the herd level. *Rev. sci tech Off int Epiz.,* 18(2):357-366.

Mannelli, A., S. Sotgia, C. Patta, A. Sarria, P. Madrau, L. Sanna, A. Firinu, A. Laddomada, 1997: Effect of husbandry methods on seropositivity to African swine fever virus in Sardinian swine herds. *Prev vet Med*. 32:235-241

Olugasa, B. O., I. F. Ijagbone, 2007: Pattern of spread of African swine fever in south-western Nigeria. *Veterinaria Italiana* 43(3):621-628

Penrith, M-L., G. R. Thomson, A. D. S. Bastos, 2004: African swine fever. In: Coetzer, J. A. W., Tustin, R. C. (Eds.), *Infectious Diseases of Livestock with Special Reference to Southern Africa*, 2nd ed. Oxford University Press, Cape Town, pp 1087–1119.

Stalder, K., L. Engblom, J. Mabry, 2010: Benchmarking sow lifetime productivity. Available at http://www.benchmark.farms.com/Benchmarking_Sow_Lifetime_Productivity.html. Accessed on August 22, 2010.

Tambi, E. N., O. W. Maina, A. W. Mukhebi, T. F. Randolph, 1999: Economic impact assessment of rinderpest control in Africa. *Rev. sci tech Off int Epiz.,* 18(2):458-477.

Tisdell, C. A., S. R. Harrison, G. C. Ramsay, 1999: The economic impacts of endemic diseases and disease control programmes. *Rev. sci tech Off int Epiz*. 18(2):380-398.

Vial, L., B. Wieland, F. Jori, E. Etter, L. Dixon, F. Roger, 2007: African swine fever virus DNA in soft ticks, Senegal. *Emerg Infect Dis*. 13(12):1928-1931.