The cost-benefit of biosecurity measures on infectious diseases in the Egyptian Household Poultry

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Abstract

Increased animal intensification presents with increasing risks of animal diseases. The Egyptian household poultry is peculiar in its management style and housing and this present with particular challenges of risk of infection to both the flock and humans. Biosecurity remains one of the most important means of reducing risks of infection in the household poultry, however not much information is available to support its feasibility at the household level of production. In this study financial feasibilities of biosecurity were modeled and evaluated based on certain production parameters. Risks of particular importance to the household poultry were categorized and highly pathogenic avian influenza H5N1 was the most risky disease while people-related risk was the most important risk category. It was observed that basic biosecurity measures were applicable in the household poultry and it would be 8.45 times better to implement biosecurity than to do nothing against HPAI H5N1;

4.88 times better against Newcastle disease and 1.49 times better against coccidiosis. Sensitivity analyses proved that the household poultry project was robust and would withstand various uncertainties. An uptake pathway for basic biosecurity was suggested. The outcome of this work should support decisions to implement biosecurity at the household sector of poultry production.

Keywords: Egypt, Biosecurity, Financial, Technical, Feasibility, Household Poultry, Profitability.

Introduction

The Egyptian poultry industry experienced tremendous changes in the past three decades with the development of large scale operations with high level of intensification. These changes have been comprehensively described in available literatures and reports (CAPMAS, 2006; Hosny, 2006; Geerlings et al., 2007). The Egyptian household poultry industry remains very important and represents a major economic activity. It is intensive in nature , usually done on rooftops or in empty rooms in-house and involves close human-animal interaction. It is not comparable to the scavenging-type of management practiced by household poultry producers in many developing economies.

It has been proved that a higher degree of intensification (increasing population density within an increasingly reduced available space) is often associated with higher burdens and risks of infection with animal pathogens (Graham et al., 2008), and it is virtually impossible to achieve zero risk in the extensive or intensive system of management. In Egypt, the poultry industry is affected by a number of poultry diseases including the zoonotic Highly Pathogenic Avian Influenza A H5N1 (HPAI H5N1).

The challenge of high levels of poultry infections, with huge economic consequences and chanced human infections, therefore necessitated major interventions from the Egyptian health and agricultural authorities including the following: control of wildlife reservoirs, stamping out, quarantine, movement control, screening, vaccination in response to outbreaks and disinfection of premises amongst others (OIE, 2011). Other interventions were widespread public health and extension messages, training and specific biosecurity projects implemented at various levels. However, to date outbreaks are still being reported, including in the household poultry (HHP).

Biosecurity is defined here as the implementation of a set of measures that reduces the risks of the introduction and spread of disease agents in animals. The three principal elements of biosecurity are segregation, cleaning and disinfection. Segregation is the creation and maintenance of physical or virtual barriers to limit the potential opportunities for infected animals and contaminated materials to enter an uninfected site. This step, properly applied, will prevent most infection. Cleaning will remove most of the contaminating virus. Properly applied, disinfection will inactivate any virus that is present on materials that have already been thoroughly cleaned. Biosecurity requires the adoption of a set of attitudes and behaviors by people to reduce risk in all activities involving domestic, captive exotic and wild birds and their products (FAO, 2008).

Biosecurity has been proposed as a good intervention strategy to reduce the continuing spread of poultry diseases in the HHP in Egypt.

While the proposal was taken as acceptable and a possible long-term solution to the recurring cases of HPAI H5N1 in Egypt, its implementation and adoption in the HHP was seen as difficult in view of its seeming technicalities, the cost involved and the possibility of recouping invested funds within the project period. The control and eradication efforts aimed at poultry diseases in Egypt may be better achieved by involving all the stakeholders, including the HHP producers. However, to convince poultry producers to implement biosecurity measures, it will be important to show a cost-benefit analysis, emphasizing the benefits of spending more resources on biosecurity.

The aim of this study was to assess the current level of implementation of biosecurity measures in HHP and whether or not their implementation is beneficial in term of costs using a model. A financial risk analysis was done by subjecting the model to a variety of changes that may occur in the course of the annual HHP project cycle.

Materials and Method

Model development

To assess the impact and cost-benefit of the implementation of biosecurity measures in household poultry, a schematic representation of cumulative annual profit (Figure 1) was developed with the following assumptions:

1. There will be a linear growth in cumulative profit for a year operation (12 months) totaling LE 2,389.67 (US$415.05) (Fasina et al., 2010; Appendix 1).
2. While some birds (laying birds and geese) will remain in the flock for the whole year, fattener birds and young birds will revolve 3-4 times (based on field observations).
3. In the theoretical situation where none of the proposed biosecurity measures are implemented, both HPAI H5N1 and Newcastle disease would occur twice a year in

the flock and coccidiosis will occur with every batch within a year, based on field observations. These estimates take into account the 20% HPAI H5N1 vaccination coverage and 10% flock immunity reported for HHP by GOVS in Egypt (unpublished report), and the level of endemicity of each disease in the country.

4. Biosecurity will be introduced in the earlier part of annual farm operation.
5. Disease agents can be introduced, get established within the flock and cause outbreak at any period within the one-year operation.
6. Disease may cause minimal/graded reduction in levels of profit [1] or [2], prevent further profit but allow the farm to operate at break-even level [3], cause moderate losses [4], or cause losses above and beyond the profit made before the outbreak [5] (see Figure 1).
7. Biosecurity intervention will minimize losses [B], but some "gains" will also be made even in the absence of biosecurity intervention especially in a disease situation where 100% mortality will not be recorded [C]. [A] represents total costs spent on biosecurity for the whole year operation (Figure 1).

All calculations were done using the Egyptian Pound (LE). The exchange rate at the time of analysis was 5.7575LE = US$1.00.

Assessment of actual production parameters

To collect production and other quantitative parameters, a field survey was conducted in Qalyubia, Gharbia and Menoufia governorates based on a pretested and validated questionnaire. Governorates are equivalent to States or Provinces; it is a second level of government administration which is below the national or federal government system and above the local government or provincial administration.

The choice of the governorates was based on their relative importance in poultry production in Egypt in general and in household poultry production in particular. Details of the selection criteria have been described elsewhere (Fasina et al., 2010).

A total of 191 household interviews were conducted in the selected governorates but three with inconsistent answers were excluded and 188 interviews were used in the analysis. Fifteen (15) villages were sampled in all. To ensure the reliability of data collected from the farmers, physical observations/counting of the flocks and photographic documentations were done. These were correlated with the interview responses. Where minimal disparities were noticed, observed data were used. It should be noted that household producers are sometimes unwilling to disclose certain information for fear of possible taxation/surcharge or governmental intervention in culling of the flock should HPAI H5N1 supervene.

Though pigeons are also widely kept in the households, pigeon production was not included in this study as they usually do not mix with poultry.

Based on the numbers of households in these governorates (2,808,982) and an assumption that approximately 95% of the rural households have poultry (2,668,533) (Geerlings et al., 2007), a minimum of 146 households was needed. The calculation of sample size was done using the formula:

$$\text{Sample size } \boldsymbol{n} = \mathbf{[DEFF*Np(1-p)]/\ [(d^2/Z^2_{1-\alpha/2}*(N-1)+p*(1-p)]}$$

Where N = Population size (for finite population correction factor or fpc); p = Hypothesized % frequency of outcome factor in the population =95%±5; d = Confidence limits as % of 100 (absolute +/- %) = 5%; and the Design effect (for cluster surveys-DEFF) =1 (http://www.openepi.com/OE2.3/SampleSize/SSPropor.htm).

Experts' opinions survey: The following information was required for the analysis:

- Risk of introduction of major poultry diseases to the household flock without biosecurity.
- Associated mortality with each of the selected diseases.
- Associated income losses with each of the selected diseases.
- People-related risks for household poultry (people-related risks are risks of infection in the poultry flocks that are to a large extent directly related to human activities, e.g poultry manager taking care of other farms).
- Environment/flock-related risks for the household poultry (environment/flock-related risks are risks of infection that are associated with the flocks directly or their micro-environment, e.g multi-age or multi-species birds managed together).
- Other birds and other animal-related risks for the household poultry [these risks are those that are associated with other bird species (wild, free flying or scavenging) and other animals].

A list of national poultry experts was obtained from the national consultant. Ten experts were selected based on the following criterias: 2 each of poultry consultants, government veterinarians, private veterinarians, academia and poultry farm leaders, spread across governorates and districts. The opinions of all the 10 selected experts were sought using Delphi survey tools.

Delphi opinion surveys have been used in previous studies to evaluate the risks of poultry diseases but also for other studies where hard data were not available (Verhagen et al., 1998; Vaillancourt, 2002; Ferri et al., 2006). In this instance, the questionnaire was mailed electronically to each of the selected experts. 100% (10/10) returned the completed documents. All receipts were harmonized and a mean score arising from each question was statistically evaluated, calculated and tabulated against each expert score. This was mailed back to each expert to signify the degree of agreement or disagreement. Phone calls were employed to get a good return rate at the second instance. Ninety percent (90% or 9/10) approved the final questionnaire comparing the initial response of each expert to the mean experts' score individually. The last expert was not available for the approval of the questionnaire. There was a 93% agreement score for all evaluated responses. Field validation of the scores was obtained through personal interviews with rural and district veterinarians in selected locations where farmers' interviews (to collect production parameters) were held. Similarly, the answers were compared with those available in the literature (Table 2b). There was a high degree of agreement between the experts' opinions, field surveys and the literature.

Statistics

All the descriptive statistics (means, medians, modes, quartiles, standard deviations and percentages) were evaluated at 95% confidence levels using Graphpad Quickcalcs® (statistical calculator, http://www.graphpad.com/quickcalcs/index.cfm). Means, medians, modes, quartiles and percentages were used for the production parameters used and disease risks. Biosecurity cost and other costs were evaluated using means and standard deviations. Analysis of variance (ANOVA) was used to compare means of category risks using Openepi® (http://www.openepi.com/OE2.3/Menu/OpenEpiMenu.htm).

Benefit-cost assessment and sensitivity analysis

Based on the annual profitability of a household poultry project with a mixed flock size of 73, and the outcomes of experts' opinion survey, an assessment of the effect of biosecurity in a household poultry project was undertaken using partial budgeting (Chase, 2010) to evaluate the benefits and costs of the project. The choice of a flock size of 73 and mean annual profitability was based on previous assessment of mean flock size of household poultry in Egypt. Details have been reported elsewhere (Fasina et al., 2010; Box 1; Appendix 1 & 2).

Partial budgeting is a planning and decision-making framework used to compare the costs and benefits of alternatives faced by a farm business. It focuses mainly on changes in incomes and expenses that would result from the implementation of a specific alternative (PSU, 2002). Benefit-costs analysis has previously been used for evaluating the effect of biosecurity (Gifford et al, 1987) and other interventions in poultry (Sen et al., 1998, Fasina et al., 2007). In the present study, we used the tool to evaluate benefit-cost of biosecurity on highly pathogenic avian influenza (HPAI H5N1) but also Newcastle disease and coccidiosis. These three diseases were selected as representative disease situations based on the following factors:

- Rapidly fatal disease that will cause major production losses, lead to stamping-out of the remaining flock and closure of facilities with consequent downtime costs-**HPAI H5N1**.
- Important poultry disease that will cause economic loss (not in the magnitude of Highly pathogenic avian influenza), but is currently endemic in the Egyptian poultry populations-**Newcastle disease**.
- An endemic disease that will not cause major mortality but will reduce profitability continuously throughout the production cycle if not checked-**Coccidiosis**.

Biosecurity costs were estimated for the "**observed biosecurity-**the current level of application of biosecurity practices observed in the flocks surveyed", (Figure 2 and Table 1) and for the desirable level of biosecurity "**desirable biosecurity-**mimimum acceptable standards expected to be implemented to ensure effective protection for the flock", using the prevailing prices.

A list of basic biosecurity measures applicable to the household poultry production was drawn based on available documents (Nespeca et al., 1997; Pagani and Kilany, 2007; FAO, 2008 and Negro-Calduch, 2010) and evaluated on each farm (Table 1). The adherence to the complete list as outlined in Table 1 was taken as "desirable biosecurity" while partial application of these measures as observed on each farm was termed as "observed biosecurity". The annual financial involvement in all observed biosecurity per each household was calculated based on available information and a mean annual cost of observed biosecurity was derived from this evaluation (Figure 2). To enable the estimation of the real cost of desirable level of biosecurity per annum, the quantitative data were evaluated in financial terms and these evaluation included measures not currently adopted by the farmers. On measures whose cost was not available from the household producers, a market appraisal was undertaken to cost such items and these were added to the overall annual cost of biosecurity.

Sensitivity analysis

The model was subjected to a selected list among the variety of factors that have the potential of affecting the profitability of the household poultry including 10% up to 80% increase in feed and grain prices sustained over a 1 year period (an unlikely event), 100% increase in biosecurity costs per annum, 50% increase in costs of other inputs per annum, 10% increase in the egg price, 10% decrease in the egg price and 10% increase in the price of day-old-ducks. These sensitivity assessments were done using the costs for the observed level of biosecurity and repeated using the cost for the desirable level of biosecurity for the household poultry.

Other factors that can affect the profitability of the project and the implementation of a biosecurity system include:

1. Human-related factors: Illness or death of the husband or wife, other individuals and organizations that contribute to the project.
2. Operation-related factors: Disruption to input-output supply balance in the poultry industry, loss of access to essential assets especially from the man, failure in distribution network of day-old birds, feed and other things.
3. Procedure-related factors: Failure of accountability especially in the commercially oriented household poultry, lack of complete internal systems and control including record keeping.
4. Project failure-related factors: Cost over-runs, extended periods of projects e.g delayed start of lay, delayed maturity, insufficient outputs and other products.
5. Nature-related factors: Weather change, natural disasters, accident and disease.
6. Political-related factors: change in governmental policies, change in tax systems, public opinion about household poultry and foreign influence.

Results

Experts' opinion survey

The outcome of the experts' opinion survey indicated that the risk of introduction of coccidiosis for the household poultry was 64% while those of Newcastle disease, HPAI H5N1, fowl pox, fowl cholera and endoparasitosis were 75%, 95%, 27%, 46% and 30% respectively (Table 2a). Associated mortality was highest in HPAI H5N1 with a mean score of 76.67% and lowest in endoparasitosis with a mean score of 2.40% (Table 2a). Similarly, HPAI H5N1 received the highest score of 83.33% in associated income losses as against the minimum score of 6.94% recorded for endoparasitosis (Table 2a).

People-related risks (risks of infection in the poultry flocks that are to large extent directly related to human activities) remained by far the most important risk category to the household poultry production with a score of 88.42%, while environment/flock-related risks had a score of 72.81% and other birds/other animal-related risks scored 68.00%. Although, an intra-category mean difference exists within each category, there was a statistically significant difference among the three risk categories with a *p*-value of 0.001 (Table 3).

Benefit-cost analysis

From the combination of partial budgeting and benefit-cost analysis, the implementation of all biosecurity measures (desirable level) will generate an increase in net annual income of 4386.16LE (US$761.82) for risk of HPAI H5N1 infection alone. Without biosecurity, a total of zero to 1451.59LE (US$252.13) in net annual income may be saved depending on the severity of the infection (Table 4). The benefit-cost ratio of implementing biosecurity is 8.45. For Newcastle disease, the increase in net income is 2534.26LE (US$440.17) with a benefit-cost ratio of 4.88. In the case of coccidiosis, the increase in net income is 772.10LE (US$134.10) with a benefit-cost ratio of 1.49. Details are available in Tables 4, 5 and 6. Note that it has not been possible to do a benefit-cost analysis comparing current production practices (observed biosecurity) with a situation where desirable biosecurity will be implemented. This is because a situation of partial biosecurity is equivalent to a no-biosecurity since a breach in the complete protocol will still expose the birds to high risk of infection. Moreover, benefit-cost analysis was assessed for each disease separately. The real benefit-cost ratio for the producer will be higher than that as all farms are exposed to all diseases..

Sensitivity analysis

Subjecting the model to a variety of input and output changes revealed that the household poultry project is robust and will withstand a wide variation in prices of inputs and outputs. For the case of observed biosecurity, a 10% sustained all-year round increase in prices of feed and grains will decrease the profit margin by 17.80% while sustained feed and grain price increases of 55% will reduce profit by 97.78%. However, any increase in the price of feed and grains beyond the margin of 56% will tend to losses for the project (Table 7).

A 100% increase in costs of observed biosecurity will only reduce the profit margin by 4.46% while a 50% increase in prices of other inputs will reduce profit by 11.20%. A ten percent (10%) increase in price of eggs and day-old-ducks will reflect positively on the project by increasing the profit 5.32% and 7.39% respectively while a 10% decrease in egg price will also reduce profit by 5.32% (Table 7, Appendix 2).

Using the same parameters for the desirable level of biosecurity, a 10% sustained all-year round increase in prices of feed and grains will decrease the profit margin by 21.76% while a sustained feed and grain price increase of 40% will reduce profit by 87.05%. In this case, any sustained increase in the price of feed and grains beyond the margin of 46% will tend to losses for the project (Table 8).

A 100% increase in costs of desirable biosecurity will reduce the profit margin by 27.74% while a 50% increase in prices of other inputs will reduce profit by 13.69%. A ten percent (10%) increase in the price of eggs and day-old-ducks will reflect positively on the project by increasing the profit 6.50% and 9.04% respectively while a 10% decrease in egg pricewill also reduce profit by 6.50% (Table 8).

Overall, a huge increase in the price of feed and grains (over 40%) that is sustained over a period of time may force the closure of the poultry business as it has the most significant single effect on the project in the event of the implementation of biosecurity.

Discussion

The in-house poultry production and its intensity in Egyptian households present with some specific challenges for animal disease control as had been reported in other places (Cristalli and Capua, 2007). The current management practices provide for highly connected poultry networks within villages, districts and governorates. Within such networks, on-farm (in-house) and community-mediated biosecurity are vital components of disease prevention and control (Nespeca et al., 1997; Hogerwerf, 2010; Dorea et al., 2010). These preventative measures are especially more important in view of the likelihood of human infections should zoonotic poultry disease outbreak occur within the household (Fiebig et al., 2009). In this study, we modeled a real field situation of biosecurity implementation in the household poultry and assessed its cost-effectiveness. Implementation of all biosecurity measures will generate a higher net annual income and there is a 8.45 benefit-cost ratio for implementation of desirable biosecurity, for highly pathogenic avian influenza H5N1 alone; the ratio is 5 and 1.5 for Newcastle disease and Coccidiosis respectively.

Although the application of some biosecurity measures is part of current husbandry practices within household poultry production in Egypt (Figure 2; Appendix 2), the non-implementation of other measures will limit the impact of those implemented. The differing levels of adoption by different household poultry producers have implications for the overall breach in biosecurity with the consequent risks of infection in the household. Low frequencies of adoption of a comprehensive biosecurity package have been confirmed in previous studies to contribute significantly to disease outbreaks on farms (Bos et al., 2007; East, 2007; Kung et al., 2007; McQuiston et al., 2005; Thomas et al., 2005; Dorea et al., 2010; Fasina et al., 2011The adoption of certain measures however indicated that given the right atmosphere, the household producers were willing to improve their management and disease control practices.

In our submission, certain items of biosecurity which are practical elsewhere, for example composting are incompatible with the Egyptian household poultry. Wilkinson had earlier identified the risks associated with such measures at farm level (Wilkinson, 2007). It will be necessary to critically assess, identify, implement and monitor practicable biosecurity measures (others with the exception of composting, see Table 1) within the Egyptian HHP and in other places where such policies are being implemented.

While the authorities may want to implement important control programmes such as prohibition/punishment including the confiscation of poultry, bans on rural poultry and vaccination alone as means of mitigation, these measures will have a negative effect on control and eradication of poultry diseases, especially at the household level. It should be understood that control and eradication policies should not be made to the exclusion of the socio-cultural value systems of the society, as such policies are bound to fail from inception (Scoones and Forster, 2010).

Since household poultry production is the way of the people, the reorganization of the Egyptian poultry industry, including the entrenchment of key aspects of biosecurity at all sectors of the industry, will yield positive results if introduced in a way that enables smooth adoption and gradual replacement or improvement on the current management and hygiene practices observed in these household flocks (FAO, 2011).

For the household poultry in particular, it will be essential to create a "biosecurity uptake pathway" that will reinforce those measures that currently have wide adoptions amongst household producers (Figure 2) and gradually introduce those whose current levels of compliance are lower. In the present circumstances, these can begin with the implementation of gates for the household; safe disposal of dead birds and faeces in polythene bags to exclude the carrion eaters, stray animals, insects and rodents; cleaning but also disinfection of drinkers and feeders, and farmers consultations with village-based veterinarians;. Subsequently, other measures can then be introduced (Figure 2). In particular, the district and village veterinarians should be used to continuously impress the messages of biosecurity to the HHP producers since they have the confidence of rural farmers, they are regularly consulted and their opinions are well respected by the latter.

Though we agreed that the evaluation of risks, associated mortalities and income losses in the household poultry based on expert opinion may be skewed, subjective and based purely on the current endemicity and waves of outbreaks in poultry in Egypt, the analytic tool (Delphi opinion survey) used in this study is time-tested and had been cited at least 2000 times in agricultural, clinical, epidemiological and social science-related research (Verhagen et al., 1998; Linstone and Turrof, 2002; Ferri et al., 2006; Halvorson and Hueston, 2006).

Furthermore, in this study the collated data from the survey were assessed against field evaluation and surveyed literatures and was also statistically analyzed, and comparable results were obtained. HPAI H5N1, but also Newcastle disease and coccidiosis, are diseases identified as posing the greatest risks to the HHP production system. While major income losses will result from an HPAI H5N1 outbreak, graded reduction in profit was associated with Newcastle disease and coccidiosis in this assessment (Table 2a). Vaccination is cited as being responsible for a reduced associated mortality in the case of Newcastle disease (Personal communication with field experts). However, biosecurity can reduce the risk of outbreak of these diseases by huge margins of up to 95% in certain cases and generate higher incomes (Table 4-6).

Since the people-related risks were identified as significantly related to infections in the HHP (p-value = 0.001), effort should be directed to immediately implement those measures that will control people's access to HHP in Egypt (Vaillancourt, 2002). Only essential persons in the HHPP system should be allowed access to the birds and these individuals must observe implemented measures. Kung and colleagues had previously advocated for similar measures in Hong Kong (Kung et al., 2007). The adoption of such measures in the Egyptian household is currently fair to good as observed in the field (≤100%) but will need to be enhanced and reinforced (Table 3 & Figure 2).

The individual and cumulative benefits-cost of biosecurity implementation is huge in the HHP in view of its effects on the different diseases assessed and this justifies the need to carry out these measures in the Egyptian poultry industry (Table 4-6). While the measures will protect the HHP, it will also greatly reduce the risks of human infection. Though cost associated with the loss of human lives arising from poultry zoonotic infections like HPAI H5N1 is difficult to estimate in this study, we believe such cost will further strengthen the reason for the implementation of biosecurity at the HHP production sector. This is aside from the outbreak-associated costs that will be borne by the government and other sectors including direct production costs, poultry traders, feed mills and breeder losses, culling and control costs, export-import bans, reduced consumption, reduced trade and economic activities, cost of vaccination, medication, hiring, clean-up and compensation.

The HHP production is robust and will withstand very severe price variation (Table 7). In our assessment, even a sustained annual increase in the price of major items like feed and grains up to a total of 56% per annum will only reduce profit marginally. It is highly unlikely that the price of grain and poultry feed will remain at that level for a whole year without government intervention since grain remains a key item in Egyptian meals. Adopting desirable/improved biosecurity measures as outlined in Table 1 will not gravely affect the profitability of the business (Table 8). It will therefore be essential to up the level of basic biosecurity in the Egyptian HHP and farmers should be willing to adopt the various measures.

The current study has identified in financial terms that the implementation of basic biosecurity measures will contribute to the overall objective of household poultry production in Egypt. However, field trials (in the form of a controlled study) may be essential to validate the effectiveness of the model presented herein in the field (Nespeca et al., 1997).

Finally, to the best of our knowledge, this work represents the first attempt that used a combination of epidemiological techniques to explore the possibility of adapting biosecurity measures to the household poultry production system.

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References

Bell, J.G., Fotzoa, T.M., Amara, A., Agbede, G., 1995. A field trial of the heat resistant V4 vaccine against Newcastle disease by eye-drop inoculation in village poultry in Cameroon. Prev. Vet. Med. 25, 19-25

Bos, M.E., Van Boven, M., Nielen, M., Bouma, A., Elbers, A.R., Nodelijk, G., Koch, G., Stegeman, A., De Jong, M.C., 2007. Estimating the day of highly pathogenic avian influenza (H7N7) virus introduction into a poultry flock based on mortality data. Vet. Res. 38, 493–504.

Central Agency for Public Mobilization and Statistics (CAPMAS), 2006. The final results of population and housing census, 2006. Available at: http://www.msrintranet.capmas.gov.eg/pls/fdl/ab2?lang=0&lname=FREE (accessed 04 April 2011).

Chase, C., 2010. Evaluating market outlets using whole-farm records. Ames, Iowa. Iowa State University Extension, Agricultural Decision Maker Bulletin, C5-32.

Choudhury, K.A., Amin, M.M., Rahman A., Ali, M.R., 1985. Investigation of natural outbreak of fowl cholera. Bangladesh Vet. J. 19, 49-56.

Cristalli, A., Capua, I., 2007. Practical problems in controlling H5N1 high pathogenic avian influenza at village level in Vietnam and introduction of biosecurity measures. Avian Dis. 51(S1), 461-462

Dana, S.S., Rathore, B.S., Kaul, P.N., 2000. Morbidity and mortality in Desi chicken reared by the Santal tribe of West Bengal. Indian J. Anim. Res. 34(1), 49-51.

Dorea, F.C., Berghaus, R., Hofacre, C., Cole, D.J., 2010. Survey of biosecurity protocols and practices adopted by growers on commercial poultry farms in Georgia, USA. Avian Dis. 54, 1007-1015.

East, I.J., 2007. Adoption of biosecurity practices in the Australian poultry industries. Aust. Vet. J. 85, 107–112.

Fasina, F.O., Meseko, A.C., Joannis, T.M., Shittu, A.I., Ularamu, H.G., Egbuji, A.N., Sulaiman, L.K., Onyekonwu, N.O., 2007. Control versus no control: Options for avian influenza H5N1 in Nigeria. Zoonoses Public Health 54, 173-176.

Fasina, F.O., Ali, A.H., Jobre Y.M., Thieme, O. Ankers, P., 2010. *Technical and Financial Feasibilities of Biosecurity implementation in the Household Poultry Production, Egypt* (GCP/INT/197/IFA). Final Report of a Consultative mission to FAO-ECTAD, Egypt..

Fasina, F.O., Rivas, A.L., Bisschop, S.P.R., Stegeman, A.J. Hernandez, A.J., 2011. Identification of risk factors associated with highly pathogenic avian influenza H5N1 virus infection in poultry farms, in Nigeria during the epidemic of 2006-2007. Prev. Vet. Med. 98, 204-208.

Food and Agricultural Organization (FAO)., 2008. *Biosecurity for Highly Pathogenic Avian Influenza: Issues and Options*. FAO Animal Production and Health Technical Paper Series No. 165, FAO, Rome, Italy. 71p

Food and Agricultural Organization (FAO)., 2011. *Approach to Controlling, Preventing and Eliminating H5N1 Highly Pathogenic Avian Influenza in Endemic Countries*. FAO Animal Production and Health Technical Paper Series No. 171, FAO, Rome, Italy. 97p.

Ferri, C., Prince, M., Brayne, C., Brodaty, H., Fratiglioni, L., Ganguli, M., Hall, K., Hasegawa, K., Hendrie, H., Huang, Y., 2006. Global prevalence of dementia: a Delphi consensus study. Lancet 366(9503), 2112-2117.

Fiebig, L., Smieszek, T., Saurina, J., Hattendorf, J. and Zinsstag, J., 2009. Contacts between poultry farms, their spatial dimension and their relevance for avian influenza preparedness. Geospatial Health 4(1), 79-95.

Geerlings, E., Albrechtsen, L., Rushton, J. 2007. *Highly Pathogenic Avian Influenza: A Rapid Assessment of the Socio-economic Impact on Vulnerable Households in Egypt*. Final Report of a Consultative mission to FAO-ECTAD, Egypt.

Gifford, D.H., Shane, S.M., Hugh-Jones, M. Weigler, B.J., 1987. Evaluation of biosecurity in broiler breeders. Avian Dis. 31(2), 339-344.

Graham, J.P., Leibler, J.H., Price, L.C., Otte, J.M., Pfeiffer, D.U., Tiensin, T., Silbergeld, E.K., 2008. The animal-human interface and infectious disease in industrial food animal production: Rethinking biosecurity and biocontainment. Public Health Rep. 123, 282-299.

Graphpad QuickCalcs (free Statistical Calculator). Available at: http://www.graphpad.com/quickcalcs/index.cfm (accessed 30 March 2011).

Halvorson, D.A. Hueston, W.D., 2006. The development of an exposure risk index as a rational guide for biosecurity programs. Avian Dis., 50, 516-519.

Hogerwerf, L., Wallace, R.G., Ottaviani, D., Slingenbergh, J., Prosser, D., Bergmann, L. Gilbert, M., 2010. Persistence of highly pathogenic avian influenza H5N1 virus defined by agro-ecological niche. Ecohealth DOI: 10.1007/s10393-010-0324-z.

Hosny, F. A., 2008. *Poultry Sector Country Review: Egypt*. Final Report of a Consultative mission to FAO-ECTAD, Egypt.

Khan, S.Z., Ahmad, M., Ayaz, M., Raziq, F. Ali, M. I., 1999. Evaluation of four gumboro vaccine strains in broilers. J. Anim. Health Pro. (Pakistan) 19 (3-4), 21-26.

Kinung'hi, S.M., Tilahun, G., Hafez, H.M., Woldemeskel, M., Kyule, M., Grainer, M. Baumann, M.P.O., 2004. Assessment of economic impact caused by poultry coccidiosis in small and large scale poultry farms in Debre Zeit, Ethiopia. Int. J. Poultry Sci. 3 (11), 715-718.

Kung, N.Y., Morris, R.S., Perkins, N.R., Sims, L.D., Ellis, T.M., Bissett, L., Chow, M., Shortridge, K.F., Guan, Y., Peiris, M.J., 2007. Risk for infection with highly pathogenic influenza A virus (H5N1) in chickens, Hong Kong, 2002. Emerg. Infect. Dis. 13, 412–418.

Linstone, H.A. Turrof, M., 2002. *The Delphi Methods: Techniques and Applications*. 618 p. Online book available at: http://is.njit.edu/pubs/delphibook/delphibook.pdf (accessed 01 April 2011).

McMullin, P., 2004. Diseases and Syndromes: Chickens and various species. In: *Pocket Guide to Poultry Health and Diseases*. Rev Ed. 5M Enterprises, Yorkshire, UK. 278p.

McQuiston, J.H., Garber, L.P., Porter-Spalding, B.A., Hahn, J.W., Pierson, F.W., Wainwright, S.H., Senne, D.A., Brignole, T.J., Akey, B.L. Holt, T. J., 2005. Evaluation of risk factors for the spread of low pathogenicity H7N2 avian influenza virus among commercial poultry farms. *J. Am. Vet. Med. A*. 226, 767–772.

Morris, M.P., Fletcher, O.J., 1988. Estimate of economic impact of fowl cholera in turkeys in Georgia in 1986. Avian Dis. 32(4), 718-721.

Negro-Calduch, E., 2010. *Assessment of Biosecurity Practices in Small-scale Commercial Poultry Production*. Final Report of a Consultative mission to FAO-ECTAD, Egypt.

Nespeca, R., Vaillancourt, J-P., Morrow, W.E.M., 1997. Validation of a poultry biosecurity survey. Prev. Vet. Med. 31, 73-86.

Open Source Epidemiologic Statistics for Public Health (OpenEpi V 2.3.1). Available at: http://www.openepi.com/OE2.3/Menu/OpenEpiMenu.htm (accessed 30 March 2011).

Pagani, P. Kilany, W.H., 2007. *Intervention for improving bio-security of small-scale poultry producers in Egypt*. Final Report of a Consultative Mission to FAO-ECTAD, Egypt.

Pennsylvania State University., 2002. Partial Budgeting for Agricultural Businesses. College of Agricultural Sciences Agricultural Research and Cooperative Extension Bulletin. Available at: http://agmarketing.extension.psu.edu/Business/PDFs/PartlBudgetAgBus.pdf. (accessed 17 April, 2011)

Permin, A., Esmann, J.B., Hoj, C.H., Hove, T., Mukaratiwa, S., 2002. Ecto-, endo- and haemoparasites in free-range chickens in the Goromonzi District in Zimbabwe. Prev. Vet. Med. 54, 213-224.

Scoones, I. Forster, P., 2010. Unpacking the international response to avian influenza: Actors, networks and narratives. In: *Avian Influenza: Science, Policy and Politics*, I. Scoones (ed). 1st Ed, Earthscan Ltd, London, UK, pp 19-64.

Sen, S., Shane, S.M., Scholl, D.T., Hugh-Jones, M.E., Gillespie, J.M., 1998. Evaluation of alternative strategies to prevent Newcastle disease in Cambodia. Prev. Vet. Med. 35, 283-295.

Sonaiya, E.B. Swan, S.E.J., 2004. *Small-scale poultry production - Technical guide*. FAO Animal Production and Health Manual 1.

Steensels, M., Van Borm, S., Boschmans, M., Van den Berg, T., 2007. Lethality and Molecular Characterization of an HPAI H5N1 Virus Isolated from Eagles Smuggled from Thailand into Europe. Avian Dis. 51 (s1), 401-407.

Thomas, M.E., Bouma, A., Ekker, H.M., Fonken, A.J., Stegeman, J.A., Nielen, M., 2005. Risk factors for the introduction of high pathogenicity avian influenza virus into poultry farms during the epidemic in the Netherlands in 2003. Prev. Vet. Med. 69, 1–11.

Vaillancourt J-P. (2002). How do you determine the cost-benefit of a biosecurity system? Available at: http://www.veterinaria.uchile.cl/publicacion/VIIIpatologia/SEMINARIOS/semi3.pdf. (accessed 04 April 2011).

Verhagen, A.P., de Vet, H.C.W., de Bie, R.A., Kessels, A.G.H., Boers, M., Bouter, L.M. Knipschild, P.G. 1998. The Delphi list: A criteria list for quality assessment of randomized clinical trials for conducting systematic reviews developed by Delphi consensus. J. Clin. Epidemiol. 51(12), 1235–1241.

Wilkinson, K.G. 2007. The biosecurity of on-farm mortality composting. J. Applied Microbiol. 102 (3), 609-618.

World Organization for Animal Health (OIE)., 2011. Final report on HPAI H5N1 (endemic), Report Date: 07/07/2008, Country: Egypt. Available at: http://www.oie.int/downld/AVIAN%20INFLUENZA/Egypt_followup7_final%20report.pdf (accessed 31 March 2011).

Table 1. Description of basic biosecurity as observed amongst the Household poultry producers in Qalyubia, Menoufia and Gharbia Governorates, Egypt.

s/no.	**Biosecurity**	**Description**
1	Restricted access	Most poultry exist on rooftops or within fenced yards. Permission of the household is needed to access birds. This is taken as restricted access.
2	Fence around premises	Household fence sufficed for poultry fence
3	Gate at entrance	Household gate sufficed for poultry gate
4	Composting litter before removal	No producer compost.
5	Wire mesh window	These are provided but inadequate because it is torn in certain cases without immediate replacement.
6	Foot pans for disinfection before the house	Small wide-based household basin can be adapted to suit this purpose.
7	Record keeping	Provision of a simple exercise book to track visitors and activities in the poultry
8	Food and water control	Exclusion of feed and water from direct access by wild birds and other animals.
9	Terminal (Post cycle) cleaning	Thorough end-of-cycle cleaning.
10	Routine (regular) cleaning	Sweeping with broom and packing-off of debris.
11	Safe disposal of faeces and dead birds (is animal and insect proof)	Faeces and dead birds are removed in tightly sealed bags, delivered to refuse collector who take them away far from the premises
12	Quarantine new purchased birds for at least 10 days	Have a small section of the farm or a cage for new birds before further mixing with the flock.
13	Regular cleaning and disinfection of feeders and drinkers	Washing is done mainly by the use of water. Only in 17% cases was soap used in addition to water.
14	Sufficient feeding and watering space available for all birds	Freedom of each bird to access water and feed easily.
15	Sufficient space for each bird (No overcrowding)	Freedom to move without restrictions within the poultry and perch if necessary
16	Remove manure and litter routinely.	Routine is dependent on flock size and perception of the owner. No scheduled cleaning exists.
17	Usage of Disinfectant after cleaning	Usage of standardized disinfectants like phenols, quaternary ammonium etc
18	Lock for each house	Padlock or firmly secured entrance/door
19	Assess Health status of birds coming in	Assessment is only based on observation of brightness and conformation to normal birds. No empirically based assessment is done.
20	Do not mix different ages	Raised young birds separate from older birds. However, grouping was not based on sharply divided age but based on groups of 0-9 weeks and > 9weeks.
21	Do not mix different species	Have separate pens for rearing ducks and chickens. However, physical barriers between these two are not wide enough in several cases and may still permit spread of inter-species infection.
22	All-in all-out production	Clearly defined end of production cycle.
23	Hand sanitizer, gloves and washing	Only 4.2% use gloves in addition to hand sanitization. Usage of gloves is not regular also.
24	Going from young to older birds	The house is arranged so that young birds are visited first.
25	Change clothing when going in/out	Comprise mainly of old clothes. Though this may exist for the farmer, it is non-existent for the visitors.
26	Separate sick birds	Have a form of physical barrier for sick bird's isolation.
27	Consult with a veterinarian in case of sick birds	Usage of cheap or non-cost district veterinarian services
28	Change rubber boots/slippers	Have at least one pair of rubber slippers. Minimum of 2 pairs is desirable to permit twin changes or accommodate visitors.
29	Wash/disinfect equipment and tools	Most washing were done with water and none reported regular/routine washing using disinfectants
30	Do not borrow equipment from neighbors	Represents only poultry-related simple farm equipment.
31	Downtime $\geq$ 2 weeks	Observed minimum of 2 weeks downtime post one cycle. Most of the farmer observed forced biosecurity following outbreaks but not as part of the routine management system.
32	Pest control (rodents & insects)	Rodent poisons but also cats are used for pest rodent control. Rarely no effort is made to control insect pests
33	Prompt dead bird disposal from the farm	Removal of carcass as soon as sighted and packaging as part of the items for disposal to exclude further contacts.
34	Removing litter after each flock	End-of-cycle litter removal for use on farms.

35	Change solution in foot pans regularly	Application of disinfectants as foot dip and regular usage and maintenance of the prepared solution.
36	Auditing: incentives, education, adherence (encourage assistants to adhere to biosecurity)	Take care to observe that assistants (children, or other household that works in the poultry) including visitors observe the simple biosecurity rules set for the poultry.

*Compliance rate only indicated the percentage of farmers observed in the field who displayed some level of adoption of the stated biosecurity measure.

It is good to assume that measures that have a score of 70% and above can be easily adopted or intensified/improved, those with scores between 30 and 69% may need some effort to get it across to farmers and see it adopted, while those with scores below 30% will really need intensive education to get them entrenched in the poultry operation at the household level. Actually, some of them may not be adaptable to the current poultry practice in the household production sector.

Table 2a. Risks, associated mortalities and losses of selected poultry diseases in farms without biosecurity based on experts' opinions, Egypt

	Mean Experts' scores (range) at 95% confidence level		
Disease	**Percentage risk of introduction* ±Standard deviation (Range)**	**Percentage associated mortality ±Standard deviation (Range)**	**Percentage associated income loss ±Standard deviation (Range)**
Coccidiosis	**64±35.9** (37-91)	**11.83±10.8** (3-40)	**21.67±15.9** (0-50)
Newcastle disease	**75±21.8** (55-95)	**30.56±16.4** (5-60)	**35.55±8.3** (20-50)
HPAI H5N1	**95±10.8** (83-100)	**76.67±19.6** (20-100)	**83.33±18.3** (40-100)
Fowl pox	**27±14.1** (16-38)	**11.60±8.0** (1-25)	**16.39±11.2** (5-40)
Fowl Cholera	**46±23.5** (29-64)	**19.50±12.7** (1-40)	**24.44±11.1** (10-40)
Endoparasitosis	**30±19.6** (9-58)	**2.40±1.9** (0-5)	**6.94±3.4** (0-10)

*Zero risk is virtually impossible even in a farm with maximum biosecurity. Associated mortality is taken as percentage of total flock and associated income loss is taken as percentage of total income from poultry.

Table 2b. Risks, associated mortalities and losses of selected poultry diseases based on surveyed literatures

Diseases	Percentage risk of introduction (Range)	Percentage associated mortality	Percentage associated income loss	Source
Coccidiosis	NA	14.5%	11.86% of total income	Dana et al., 2000; Kinung'hi et al., 2004
Newcastle disease	≥70 to ≤ 100%	≤80%	30% of total income	Sen et al., 1998; Bell et al., 1995; Dana et al., 2000;
HPAI H5N1	≥70 to ≤ 100%	100%	80-100% total income and downtime costs	Fasina et al., 2007; Steensels et al., 2007
Fowl pox	NA	0-50% (5.1%)	NA	Dana et al., 2000; McMullin P., 2004; Sonaiya and Swan, 2004
Fowl Cholera	NA	25-35% (18%)	US$0.015/Kg meat	Choudhury et al., 1985; Morris and Fletcher,1988
Endoparasitosis	≥90 to ≤ 100%	1.0-78% (2.5%) Varied	≤30% of total income	Khan et al., 1999; Permin et al., 2002; Sonaiya and Swan, 2004

Table 3. Risk scoring and categorization based on experts' opinions, Egypt.

Risk Category	Risks	Percentage Mean Experts' score ± Standard deviation (range) at 95% confidence level	Percentage Category score ± Standard deviation (range) at 95% confidence level
People related	Poultry caretaker or manager own other birds	**98±6.4** (93.4 -100)	88.4±6.0[a] (80.86 – 95.94)
	Poultry owner visit live bird markets	**86±21.2** (70.8 -100)	
	Family member of poultry owner work in other farms/poultry	**82±14.8** (71.4 – 92.6)	
	Poultry owner visit other poultry	**86±16.4** (74.2- 97.8)	
	Poultry owner own other birds	**90±10.6** (82.4 – 97.6)	
Environment/flock related	Multi-aged birds kept together	**72±21.4** (56.6 – 87.4)	72.8±13.6 (63.06 – 82.54)
	Multi-sourced birds kept together	**60±21.0** (45.0 – 75.0)	
	Multi-breed birds kept together	**52±25.2** (34.0 – 70.0)	
	High density of household poultry in the area	**72±19.4** (58.2 – 85.8)	
	High density of small scale or commercial farms in the area	**66±25** (48.0 – 84.0)	
	Presence of another household producers within 250 metres	**60±13.4** (50.4 -69.6)	
	Dead bird disposal in water canal	**88±10.4** (80.6 – 95.4)	
	Workers (vaccinators, gas supplier, farm gate buyers etc)	**94±9.6** (87.0 - 100)	
	Lack of biosecurity awareness by poultry owner	**80±16.4** (68.4 – 91.6)	
	Sick and dead birds are not separated promptly	**84±15.8** (72.8 – 95.2)	
Other birds and other animal related	Rats and mice are present in the farm	**64±20.6** (49.2 – 78.8)	68.0±12.6 (47.88 – 88.12)
	Wild birds have access to poultry	**80±23.0** (63.4 – 96.6)	
	Old and new batches of birds are mixed	**86±31.0** (53.4 – 98.2)	
	Cats and dogs have access to poultry	**52±21.4** (36.6 – 67.4)	

[a]Using the analysis of variance to test for differences among the three category scores, significant difference was observed (*p*-value = 0.001) (http://www.openepi.com/OE2.3/Menu/OpenEpiMenu.htm)

Note: People related risks are risks of infection in the poultry flocks that are to large extent directly related to human activities. Environment/flock related risks are those associated with the poultry flock or their microenvironment (pen, density, multi species, multiage, closeness of pens etc). Other birds/other animal related risks are those associated with outside the bird immediate environment (wild bird, scavenging animals, rodents etc)

Table 4. Overall Incomes and Costs from biosecurity implementation against HPAI H5N1

Increase in net incomes		Decrease in net incomes	
Total profit from birds due to biosecurity intervention	1891.66LE (US$ 328.55)	Cost of biosecurity implementation per annum	519.00LE (US$90.14)
Downtime cost from disease (HPAI)	46.67LE (US$8.11) x 2		
Disease management and eradication costs at farm level*	71.00LE (US$12.33)		
Wasted feeds/other supplies (1 month supplies)	339.29LE (US$58.93)x 2		
Sub total	**2734.58LE (US$474.96)**	**Sub total**	**519.00LE (US$90.14)**
Decrease costs		**Increase costs**	
Losses associated with the disease	3622.17LE (US$629.12)	Assumed profit from birds without intervention	498.00LE (US$86.50)
		Value of total costs saved without intervention of biosecurity	953.59LE (US$165.63)
Sub total	**3622.17LE (US$629.12)**	**Sub total**	**1451.59LE (US$252.13)**
Overall increase in net income	**6356.75LE (US$1104.08)**	**Overall decrease in net income**	**1970.59LE (US$342.26)**
Change in net income due to biosecurity intervention			**4386.16LE (US$761.82)**
BENEFITS OF BIOSECURITY AGAINST HPAI H5N1			
Total net benefits of implementing biosecurity			4386.16LE (US$761.82)
Total costs of implementing biosecurity			519.00LE (US$90.14)
Benefit/cost of biosecurity			**8.45**

All calculations were done in Egyptian pounds (LE) with US dollars equivalent in parenthesis. It is about eight and a half times better (845%) to implement biosecurity that not to do so against avian influenza H5N1.
Benefit cost = Net benefit divided by cost of biosecurity.
*Note the government will also bear the larger disease management costs.
Using a realistic value for biosecurity to cover all of the items listed for biosecurity, an estimate of 519LE/annum was achieved. Assuming that biosecurity is targeted at the risk of HPAI H5N1 and the Risk of introduction of HPAI H5N1 is 95% (Experts' opinions) and if the farm is infected twice a year (50:50 chance of infection of the 4 cycle). If it is taken that biosecurity will be effective in preventing infection (since zero risk is virtually impossible, and absence of the infectious organism may also be responsible for a no-disease state), and that 83.33% income losses will be achieved in HPAI H5N1 infection (Experts' opinion), then:
Risk of introduction is 95%.
Economic losses due to HPAI H5N1 = 95% of 83.33% = **79.16%**
Total profit saved = 79.16/100 x 2389.67LE (total profit) = **1891.66LE (US$ 328.55)** (see calculation on production parameters)
Downtime cost = 100% of 100/3 (housing cost/4mnths) + 20/3 (equipment-feeders and drinkers/4mnth) + 20/3 (cages/4mnth) = **46.67LE (US$8.11)** (see calculation on production parameters)
Wasted feed (one month supply) = 4071.44/12 = **339.29LE (US$58.93)**
Management and eradication costs = **71LE (US$12.33)** (post culling cleaning, farm-level disinfection and washing)
Cost of disease = 66.67% of investment= 79.16/100 x 4575.76LE (investment per annum) = **3622.17LE (US$629.12)**
Assumed profit from bird saved without intervention= [(100-79.16) % x 2389.67] = **498.00LE (US$86.50)**
Value of total cost saved without intervention= [(100-79.16) % x 4575.76] = **953.59LE (US$165.63)**
Cost of biosecurity = **519LE (US$90.14)**
The factor of 79.16% will not come into the calculation for "assumed profit from bird saved and value of total cost saved" because without biosecurity intervention and with infection, the whole birds will be culled and no extra bird will remain. ***The exchange rate at the time of analysis was 5.7575LE = US$1.00.***

Table 5. Overall Incomes and Costs from biosecurity implementation against Newcastle disease

Increase in net incomes		Decrease in net incomes	
Total profit from birds due to biosecurity intervention	637.32LE (US$110.69)	Cost of biosecurity implementation per annum	519.00LE (US$90.14)
Downtime cost from disease (NDV)	11.67LE (US$2.03)x 2		
Disease management and eradication costs at farm level*	71.00LE (US$12.33) + 52LE (US$9.03)(13LE/qtr)		
Wasted feeds/other supplies (1 month supplies)	254.47LE (US$44.20) x 2		
Sub total	**1292.60LE (US$224.51)**	**Sub total**	**519.00LE (US$90.14)**
Decrease costs		**Increase costs**	
Losses associated with the disease	3050.66LE (US$529.86)	Assumed profit from birds without intervention	442.59LE (US$76.87)
		Value of total costs saved without intervention of biosecurity	847.41LE (US$147.18)
Sub total	**3050.66LE (US$529.86)**	**Sub total**	**1290.00LE (US$224.05)**
Overall increase in net income	**4343.26LE (US$754.37)**	**Overall decrease in net income**	**1809.00LE (US$314.20)**
Change in net income due to biosecurity intervention	**2534.26LE (US$440.17)**		
BENEFITS OF BIOSECURITY AGAINST NEWCASTLE DISEASE			
Total net benefits of implementing biosecurity			2534.26LE (US$440.17)
Total costs of implementing biosecurity			519.00LE (US$90.14)
Benefit/cost of biosecurity			**4.88**

All calculations were done in Egyptian pounds (LE) with US dollars equivalent in parenthesis. It is approximately five times better (488%) to implement biosecurity against Newcastle disease alone.
*Product saved and value of bird saved without intervention were calculated as [(100-30.56) x 26.67% x 2389.67LE or 4575.76LE] where 30.56 is percentage mortality due to Newcastle, 26.67% is 75% of 35.55% (economic losses), 2389.67LE is 100% profit per annum and 4575.76LE is value of total costs per annum. Since Newcastle will not kill all the birds and vaccination is routinely administered from the source of day-old-birds, we will assume that it will affect every other (50:50 chance) cycle (approximately 4 cycles per annum). Therefore some parameters that will be affected quarterly were multiplied by 2.
The exchange rate at the time of analysis was 5.7575LE = US$1.00.

Table 6. Overall Incomes and Costs from biosecurity implementation against Coccidiosis

Increase in net incomes		Decrease in net incomes	
Total profit from birds due to biosecurity intervention/annum	331.42LE (US$57.56)	Cost of biosecurity implementation per annum	519.00LE (US$90.14)
Downtime cost from disease (Cocci)/quarter	11.67LE (US$2.03) x 4		
Disease management and eradication costs at farm level (including vet services)	71.00LE (US$12.33) + 52LE (US$9.03)(13LE/qtr)		
Wasted feeds/other supplies (0.75 month supplies)/quarter	254.47LE (US$44.20) x 4		
Sub total	**1518.98LE (US$263.83)**	**Sub total**	**519.00LE (US$90.14)**
Decrease costs		**Increase costs**	
Losses associated with the disease/annum	634.66LE (US$110.23)	Assumed profit from birds without intervention	295.92LE* (US$51.40)
		Value of total costs saved without intervention of biosecurity	566.62LE* (US$98.41)
Sub total	**634.66LE (US$110.23)**	**Sub total**	**862.54LE (US$149.81)**
Overall increase in net income	**2153.64LE (US$374.06)**	**Overall decrease in net income**	**1381.54LE (US$239.95)**
Change in net income due to biosecurity intervention	**772.10LE (US$134.10)**		
BENEFITS OF BIOSECURITY AGAINST COCCIDIOSIS			
Total net benefits of implementing biosecurity			772.10LE (US$134.10)
Total costs of implementing biosecurity			519.00LE (US$90.14)
Benefit/cost of biosecurity			**1.49**

All calculations were done in Egyptian pounds (LE) with US dollars equivalent in parenthesis.
*Product saved and value of bird saved without intervention were calculated as [(100-10.72) x 13.87% x 2389.67LE or 4575.76LE] where 10.72 is percentage mortality due to coccidiosis, 13.87% is 64% of 21.67% (economic losses), 2389.67LE is 100% profit per annum and 4575.76LE is value of total costs per annum. Since coccidiosis will not kill all the birds, we will assume that it will affect every cycle (approximately 4 cycles per annum). Therefore some parameters that will be affected quarterly were multiplied by 4. The factor of 13.87% comes into the calculation for "assumed profit from bird saved and value of total cost saved" because the intervention is expected to save extra costs from infected birds that did not die and can still produce.
It is approximately one and a half times better (149%) to implement biosecurity against coccidiosis alone.
The exchange rate at the time of analysis was 5.7575LE = US$1.00.

Table 7. Sensitivity analyses of the household poultry project with implementation of observed/current level of biosecurity

Percentage change (Item)	Price variation (LE)	Current price (LE)	Other inputs (LE)	Sub total (LE)	Biosecurity cost (LE)	New sub total (LE)	Standard annual profit (LE)	New annual profit (LE)	Change in profit per annum (%)
Standard	**0**	4071.44	504.32	4575.76	102	4677.76	2287.67	NA	
10% increase (feed+grains)	**407.1**	4071.44	504.32	4982.86	102	5084.86	2287.67	1880.57	407.10 (17.80%)
20% increase (feed+grains)	**814.2**	4071.44	504.32	5389.96	102	5491.96	2287.67	1473.47	814.20 (35.60%)
30% increase (feed+grains)	**1221.3**	4071.44	504.32	5797.06	102	5899.06	2287.67	1066.37	1221.30 (53.39%)
40% increase (feed+grains)	**1628.4**	4071.44	504.32	6204.16	102	6306.16	2287.67	659.27	1628.40 (71.18%)
50% increase (feed+grains)	**2035.5**	4071.44	504.32	6611.26	102	6713.26	2287.67	252.17	2035.50 (88.98%)
55% increase (feed+grains)	**2239.05**	4071.44	504.32	6814.81	102	6916.81	2287.67	48.62	2239.05 (97.78%)
56% increase (feed+grains)	**2279.76**	4071.44	504.32	6855.52	102	6957.52	2287.67	7.91	2279.76 (99.65%)
57% increase (feed+grains)	**2320.47**	4071.44	504.32	6896.23	102	6998.23	2287.67	-32.8	2320.47 (101.43%)*
60% increase (feed+grains)	**2442.6**	4071.44	504.32	7018.36	102	7120.36	2287.67	-154.93	2442.60 (106.77%)*
61% increase (feed+grains)	**2483.31**	4071.44	504.32	7059.07	102	7161.07	2287.67	-195.64	2483.31 (108.55%)*
62% increase (feed+grains)	**2524.02**	4071.44	504.32	7099.78	102	7201.78	2287.67	-236.35	2524.02 (110.33%)*
63% increase (feed+grains)	**2564.73**	4071.44	504.32	7140.49	102	7242.49	2287.67	-277.06	2564.73 (112.11%)*
70% increase (feed+grains)	**2849.7**	4071.44	504.32	7425.46	102	7527.46	2287.67	-562.03	2849.70 (124.57%)*
80% increase (feed+grains)	**3256.8**	4071.44	504.32	7832.56	102	7934.56	2287.67	-969.13	3256.80 (142.63%)*
100% increase (biosecurity)	102	4071.44	504.32	4677.76	**102+102**	4881.76	2287.67	2083.67	102 (4.46%)
50% increase (other inputs)	252.16	4071.44	**504.32+252.16**	4827.92	102	4929.92	2287.67	2035.51	256.16 (11.20%)
10% increase (egg price)	**121.68**	4071.44	504.32	4575.76	102	4556.08	2287.67	**2409.35**	121.68 (5.32%)
10% decrease (egg price)	**121.68**	4071.44	504.32	4697.44	102	4799.44	2287.67	**2165.99**	121.68 (5.32%)
10% increase (DOD price)	**169.06**	4071.44	504.32	4575.76	102	4508.7	2287.67	**2456.73**	169.06 (7.39%)

All asterisks are negative values indicating losses. Bold values are the major changes introduced into the model to calculate the new annual profit margin.

The exchange rate at the time of analysis was 5.7575LE = US$1.00.

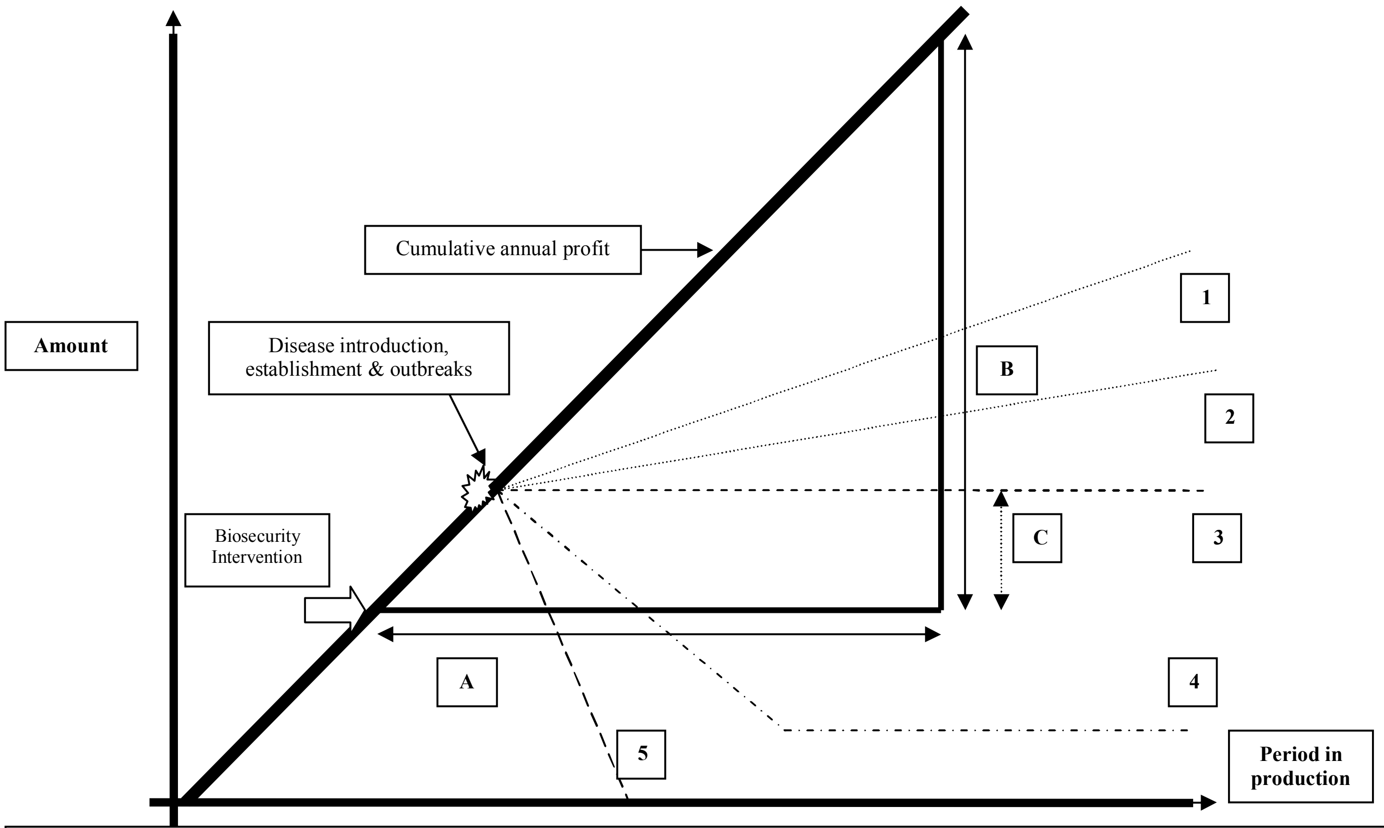
Table 8. Sensitivity analyses of the household poultry project with implementation of improved/desirable level of biosecurity

Percentage change (Item)	Price variation (LE)	Current price (LE)	Other inputs (LE)	Sub total (LE)	Biosecurity cost (LE)	New sub total (LE)	Standard annual profit (LE)	New annual profit (LE)	Change (%)
Standard	**0**	4071.44	504.32	4575.76	519	4677.76	1870.67	1870.67	
10% increase (feed+grains)	**407.1**	4071.44	504.32	4982.86	519	5501.86	1870.67	1463.57	407.10 (21.76%)
20% increase (feed+grains)	**814.2**	4071.44	504.32	5389.96	519	5908.96	1870.67	1056.47	814.20 (43.52%)
30% increase (feed+grains)	**1221.3**	4071.44	504.32	5797.06	519	6316.06	1870.67	649.37	1221.30 (65.29%)
40% increase (feed+grains)	**1628.4**	4071.44	504.32	6204.16	519	6723.16	1870.67	242.27	1628.40 (87.05%)
50% increase (feed+grains)	**2035.5**	4071.44	504.32	6611.26	519	7130.26	1870.67	**-164.83**	2035.50 (108.81%)*
55% increase (feed+grains)	**2239.05**	4071.44	504.32	6814.81	519	7333.81	1870.67	-368.38	2239.05 (119.69%)*
56% increase (feed+grains)	**2279.76**	4071.44	504.32	6855.52	519	7374.52	1870.67	-409.09	2279.76 (121.87%)*
57% increase (feed+grains)	**2320.47**	4071.44	504.32	6896.23	519	7415.23	1870.67	-449.8	2320.47 (124.04%)*
60% increase (feed+grains)	**2442.6**	4071.44	504.32	7018.36	519	7537.36	1870.67	-571.93	2442.60 (130.57%)*
61% increase (feed+grains)	**2483.31**	4071.44	504.32	7059.07	519	7578.07	1870.67	-612.64	2483.31 (132.75%)*
62% increase (feed+grains)	**2524.02**	4071.44	504.32	7099.78	519	7618.78	1870.67	-653.35	2524.02 (134.93%)*
63% increase (feed+grains)	**2564.73**	4071.44	504.32	7140.49	519	7659.49	1870.67	-694.06	2564.73 (137.10%)*
70% increase (feed+grains)	**2849.7**	4071.44	504.32	7425.46	519	7944.46	1870.67	-979.03	2849.70 (152.34%)*
80% increase (feed+grains)	**3256.8**	4071.44	504.32	7832.56	519	8351.56	1870.67	-1386.13	3256.80 (174.10%)*
100% increase (biosecurity)	519	4071.44	504.32	4677.76	**519+519**	4881.76	1870.67	1453.67	519 (27.74%)
50% increase (other inputs)	252.16	4071.44	**504.32+252.16**	4827.92	519	5346.92	1870.67	1618.51	256.16 (13.69%)
10% increase (egg price)	**121.68**	4071.44	504.32	4575.76	519	4973.08	1870.67	**1992.35**	121.68 (6.50%)
10% decrease (egg price)	**121.68**	4071.44	504.32	4697.44	519	5216.44	1870.67	**1748.99**	121.68 (6.50%)
10% increase (DOD price)	**169.06**	4071.44	504.32	4575.76	519	4925.7	1870.67	**2039.73**	169.06 (9.04%)

All asterisks are negative values indicating losses. Bold values are the major changes introduced into the model to calculate the new annual profit margin.

The exchange rate at the time of analysis was 5.7575LE = US$1.00.

Figure 1. GRAPHICAL REPRESENTATION OF THE EFFECTS OF BIOSECURITY INTERVENTION AND DISEASE SITUATIONS ON CUMULATIVE ANNUAL PROFIT IN HOUSEHOLD POULTRY PRODUCTION



Assuming that the cumulative annual profit will continue to grow linearly throughout the production period, disease may be introduce at any point and it will interfere with the linear growth in profit causing deviation and reducing maximum profit or tend to losses (1,2,3,4,5). Should Biosecurity intervention be implemented before the disease, it has a potential of preventing disease and still enable maximum profit to be achieved.

"A" represents total costs associated with the biosecurity intervention; "B" represents total benefits arising from the new intervention (discounting for benefits associated with probability of no disease "C"); "C" is benefit associated with probability of no disease without intervention. Following the point of disease introduction/outbreak, the effect on profitability may be 1, 2, 3, 4 or 5. While 1 may represent a mild/managed disease that continually reduce profitability e.g coccidiosis or endoparasitosis, 5 may represent disease like highly pathogenic avian influenza (leading to zero profit). The Benefit costs of biosecurity will be [B-C]/A

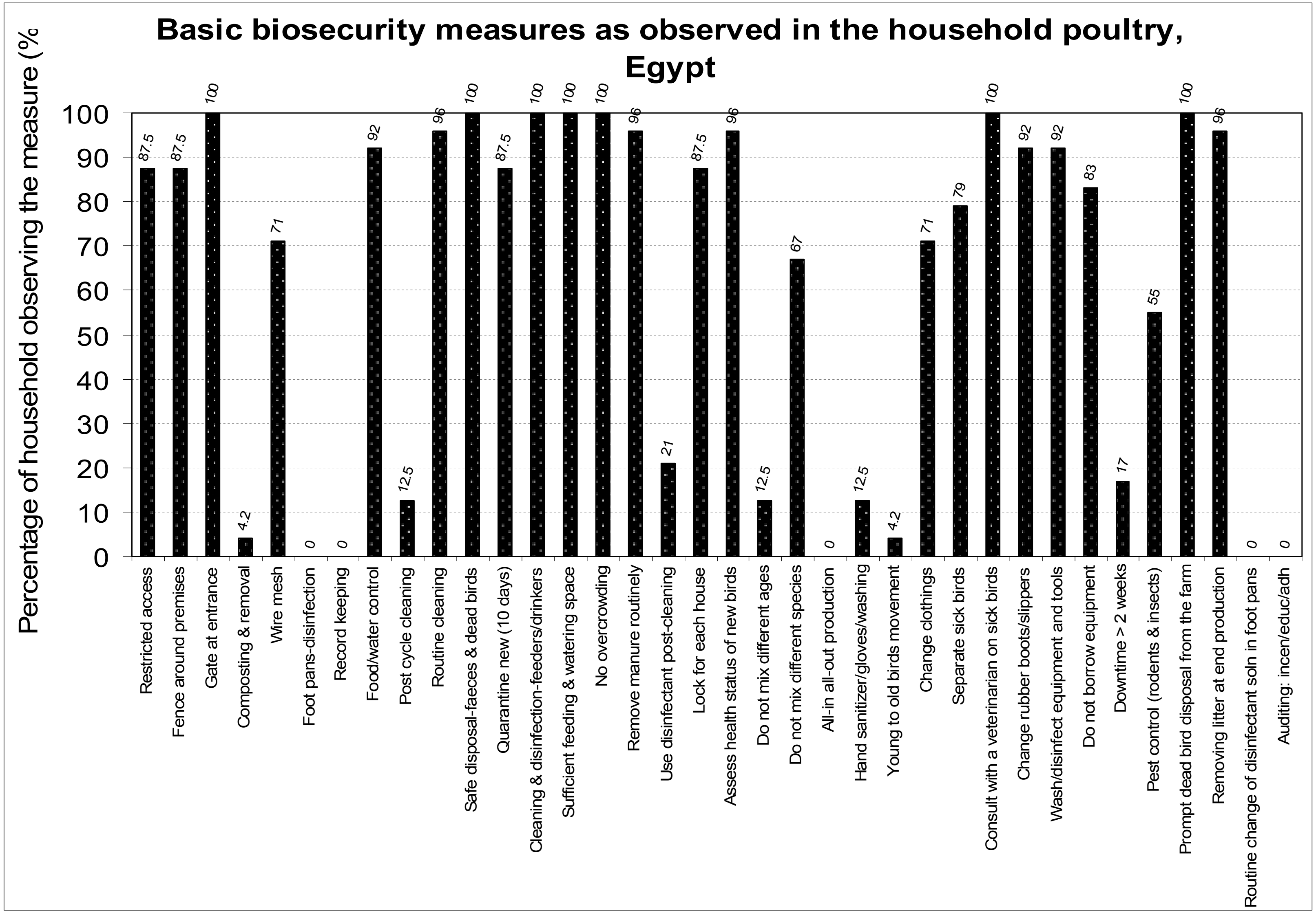


Figure 2. Basic Biosecurity measures as observed in the Egyptian household poultry.

Box 1. Summary of calculations, costs and formulas used in the analysis.

1. Total profit due to Biosecurity intervention ($_{T}$PB) = % Risk of introduction ($_{D}$R) X % Economic loss due to disease ($_{D}$E) X Expected total Profit ($_{E}$P)

2. Downtime cost = 1/3 of cost of renting the pen per annum + 1/3 cost of equipment per annum + 1/3 cost of cages per annum (based on downtime of four month should HPAI H5N1 occur) X 2 (twice chance of occurrence)

3. Wasted feed cost = total annual cost of feed / 12 (assuming 1 month stock is kept)

4. Management and eradication costs = (based on field survey for cost of cleaning materials, disinfectant and detergent)

5. Cost of disease = % Risk of introduction ($_{D}$R) X % Economic loss due to disease ($_{D}$E) X Expected total Investment or costs

6. Profit saved without intervention = Total profit – [% Risk of introduction ($_{D}$R) X % Economic loss due to disease ($_{D}$E) X Expected total Profit ($_{E}$P)]

7. Total cost saved without intervention = Total investment costs – [% Risk of introduction ($_{D}$R) X % Economic loss due to disease ($_{D}$E) X Expected total Investment or costs]

8. Cost of Biosecurity = (based on summation of field and farmers' surveys, See Fasina et al., 2010)

Information on the basic costing used in this analysis was obtained from Table 2a and Fasina et al., 2010: - Mean number of birds = 73; Maximum turnover/year = 4; Total feed cost per annum = 4071.44 LE (US$707.15); Overall total expenses including feed = 4575.76 LE (US$794.75); Observed biosecurity cost = 102 LE (US$17.72); Desirable biosecurity cost = 519 LE (US$90.14); Total output/annum = 6965.43 LE (US$1209.80); Total annual profit = 2389.67 LE (US$415.05).

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