

Factors affecting the intervention to increase the biosecurity levels of poultry production clusters (PPCs) in Thailand

Worapol Aengwanich^{1, *}, Thongchai Boonsorn¹ and Komvut Thammasar²

¹Stress and Oxidative Stress in Animal Research Unit, Faculty of Veterinary Science, Mahasarakham University, Maha Sarakham 44000, Thailand

²Nakhon Phanom Provincial Livestock Office, Nakhon Phanom 48000, Thailand

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Abstract - The purpose of this study is to investigate the factors affecting the intervention to increase the biosecurity levels of poultry farms in Nong Khai province, Thailand. Research participants were 80 farms from three districts. The research was conducted from July to October, 2013. Before, during, and after the interventions, we studied the results of the two parts: The first part involves the factors affecting changes in farmers' behavior to improve the biosecurity levels, the second involves the biosecurity levels as well as morbidity and mortality number of chickens both before and after the interventions. The results showed that factors contributing to the success of the interventions to enable farmers make improvements to increase the biosecurity levels in their poultry farms were education, locations of the poultry production clusters and network, leaders of the clusters, gender, performance of government officials, poultry diseases and epidemics on farms, and combine works between the researcher, government officials and farmers. Moreover, it was found that after the interventions, there was a statistically significant increase ($P < 0.05$) in the biosecurity levels of poultry farms in Nong Khai province. At the same time, when biosecurity increased, the morbidity and mortality number of chickens in poultry farms decreased significantly ($P < 0.05$). This phenomenon indicated that many combine factors affect the success of intervention for improving biosecurity level in poultry farms and biosecurity levels affected to morbidity and mortality number of chickens in poultry farms.

Keywords: Biosecurity, poultry production cluster, PPCs, intervention, Nong Khai, Thailand

1. Introduction

Poultry is very important to the population of developing countries. In 2010 the Food and Agriculture Organization of the United Nations (FAO) estimated that from 1980 to 2010, the world's standing population of chickens increased by 272 percent, from 7.21 to 19.60 billion, while the number of chickens slaughtered rose by 305 percent, from 18.43 to 56.20 billion (FAO, 2013). Based on the number of animals, poultry represents the largest domestic animal stock in the world. For the past 20 years, the Thai poultry industry has continued to grow, especially broilers. In 2002, Thailand was the world's 4th largest exporter of chicken meat (Souris, 2014). The avian influenza outbreaks in Asia began late 2003 and continued till early 2004. The first outbreak of H5N1 avian influenza in Thailand was reported in a layer chicken farm in the central region of Thailand in January 2004 (Aengwanich *et al.*, 2012). The last occurrence of H5N1 HPAI outbreak in Thailand was declared to the World Organization for Animal Health (OIE) in November 2008 (Souris, 2014). Whereas, in 2017, OIE reported that H5N1 avian influenza outbreak in

Cambodia and other country such as China, Japan, India etc. but different types. The importance cause of AI outbreak is a low biosecurity in poultry farm (Aengwanich *et al.*, 2012). FAO (2008) defined the term 'biosecurity' as "the implementation of measures that reduce the risk of the introduction and spread of disease agents; it 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". This is comprised of three steps: segregation, cleaning, and disinfection. Aengwanich *et al.* (2012) conducted a study of the characteristics of poultry production clusters in Nong Khai province and found that the farms were located near large water sources and farmers used the water for their fish farm and raised layer chickens in poultry houses constructed over the fish ponds. Farmers used poultry manure to feed the fishes in the ponds. Poultry production clusters in Nong Khai province invested in a biosecurity system only for some items, such as, fencing and spraying disinfectant on entering the farms. Some farms required boots to be worn before entering the poultry sheds. During the outbreaks of

H5N1, the farmers strictly practiced disease control, but did less when the outbreaks alleviated. Wei and Aengwanich (2012) compared biosecurity systems among poultry production clusters in three provinces in Thailand namely: Maha Sarakham, Nakhon Phanom, and Nong Khai and found that poultry farms in Nong Khai province had the lowest biosecurity levels with very low scores in the following indicators: attractiveness to wild birds, measures for visitors, measures for traders, measures for equipment and vehicles, capacity to clean and disinfect the farm and measures taken at the entrance to poultry sheds. The low scores on these indicators implied that the farms were at risk of the spread of infectious poultry diseases. Therefore, this study investigated factors affecting the interventions and used the intervention processes to increase the biosecurity levels of poultry farms in Nong Khai province. The results of the study would then be used as a guideline to determine policies that will prevent the transmission of infectious diseases among poultry, poultry diseases that are communicable to humans, and to develop good practices that will be executed in other locations.

2. Methods

This research study has already been approved by the Research Ethics Committee of Maha Sarakham University (Approval Number: MSU-0001). The research duration was between July and October, 2013.

2.1 Research sites

Nong Khai province is located in the upper northeastern region of Thailand. In Nong Khai province area, the main poultry raised are layer chickens and most of the farms are located in the three main districts including Muang district (Wiang Kook village, n=20 and Kok Plafang village, n=20), Tha Bo district (Thon village, n=20 and Thasamran village, n=20) and Sri Chiang Mai district (9 farms)). A total of 300 farms, dispersed near natural water sources such as large lakes, areas with irrigation systems and drainage systems, or on one's own land. A notable characteristic of the layer chickens production in Nong Khai province is that they keep fishes with the hens, building housing on fish ponds. The roof of the barn is made of grass or metal and the walls are made of bamboo. The floor of the barn is built to leave holes to allow the chicken feces of the chickens to fall into the ponds, serving as fish feed. Thus, the farmers have two sources of income: the layer chickens and the fish.

2.2 Concept of intervention and study of the factors contributing to the changes in behavior to improve biosecurity system

In this intervention, the research team used eco-health approaches to health concept mentioned by Charron (2012) as a model. This concept connected ideas of environmental and social determinants of health with those of ecology and system thinking in an action research framework. Ecosystem approaches to health focuses on the interactions between the ecological and socio-economic dimensions of a given situation, and their influence on human health. These approaches emphasized three pillars that is, trans-disciplinarity, multi-stakeholder participation, gender and

social analysis. Our research team members in the intervention were scientists in the field of veterinary and animal science. The project carried out studies in both science and social science. However, we had specialists in social science for consultation throughout the period of the project. In the case of multi-stakeholder participation, the research team worked jointly with government officials that were veterinarians caring for animal health and farmers in the poultry production clusters being studied. In this intervention, the researchers served as facilitators coordinating and arranging meetings, providing knowledge and supporting the activities of the government officials in caring for the poultry in cooperation with farmers. At the same time, the government officials would use government mechanisms to do their jobs and promote the farmers' ability to prevent and control animal diseases and keep their animals healthy. Furthermore, the government officials were allocated with budgets to effectively prevent and control the diseases and encourage farmers to increase the biosecurity levels of their farms. Therefore, this research required joint performance between the researchers, government officials and poultry farmers.

Besides, the researchers that performed intervention in biosecurity aspect to household level of farmers and provincial livestock officials were not the same. This action was according to multi-layered social resilience concept that was reported by Obrist *et al.* (2010). The methods and actions to both of these stakeholders, showed in intervention procedures part. In case of social aspect and gender, the research team used social power (French and Raven, 1959) and the principle of social stratification (Davis and Moore, 1949; Tumin, 1953), were basic theory and concept for analysis of phenomena in the field sites, respectively.

2.3 Intervention procedures

The process of carrying out the interventions involved three phases, Phase 1: Building understanding to stakeholders; Phase 2: Listening to the ideas of stakeholders and presenting policies to government officials and farmers with instruction on topics of interest for farmers; and Phase 3: Intervention for improving biosecurity of the poultry farms. All three phases involved cooperative work efforts including the research team, the Department of Livestock Development officials and the farmers, as well as various groups of stakeholders such as community leaders, local administration organization leaders and public health officials. The details of the processes involved in each phase are as follows:

Phase 1: Building understanding to stakeholders.

This stage involved arranging meetings to present the previous research findings to the chief of the provincial government sectors, stakeholders (veterinarian officers, poultry farmer, group leaders, community leaders, sub-district organization administration officials and district and provincial livestock office officials). These were held to inform them about the facts obtained by the researchers, to have them acknowledge the problems in the area, to answer questions and to hold meetings for brainstorming the solutions for the issues of interest for the Provincial Livestock Development officials and the actions the

aforementioned would like to see taken in the future. In addition, the researchers visited the areas of each cluster to present their research findings to the farmers to acknowledge the problems and needs of the farmers. At this phase, meetings were held for training in the use of questionnaires on biosecurity systems for the officials and the farmers.

Phase 2: Listening to ideas of stakeholders and the presentation of policies to government officials and farmers with instruction on topics of interest for farmers. Once the activities in Phase 1 had been carried out, phase 2 evaluated overall conditions between the research findings from the field and the opinions and directions for development of the Provincial Livestock Development Office, as well as the farmers. Next, policy recommendations were developed for the Provincial Livestock Development Office with directions for the performance of interventions in concurrence with the policies for the farmers. Then periodic meetings were held to hear ideas from both parties to make preparations for the intervention in Phase 3. Training was carried out using biosecurity system evaluation forms for the officials and farmers.

Phase 3: Intervention for biosecurity improvement. This phase involved the performance, including the trial usage of the biosecurity system evaluation form for the officials and the farmers. Besides, in this phase, the research team performed, the instruction on biosecurity systems, correct poultry raising methods, farm management, poultry health management, correct and proper vaccine usage and so on to farmers for improving their knowledge and biosecurity in poultry farms.

2.4 Study of the factors contributing to changes in behavior to improve biosecurity system

Factors contributing to poultry farmers' improvement of the biosecurity system were studied at the same time that the interventions were conducted with the purpose of identifying factors that cause farmers to change their behavior and improve their farm biosecurity levels. Data were collected from poultry farmers in the four villages (Wiang Kook village, Kok Plafang village, Thon village, and Thasamran village), amounting to a total of 80 families of 300 families in the province, by structural interviews with those involved in the poultry production cluster in each village that are, poultry farmer group leaders, community leaders, sub-district organization administration officials and, district and provincial livestock office officials. The researcher also collected data through participative observation. Then, the data collected were used in focus group discussions. The data were then synthesized and presented in a descriptive form.

2.5 Measurement of biosecurity levels before and after the interventions

Before and after the interventions, the biosecurity score form developed by Wei and Aengwanich (2012) was used to measure the biosecurity levels among four poultry production clusters (research team translated biosecurity score form from English to Thai for evaluation of biosecurity level from original version that was developed by Wei and

Aengwanich (2012). The translation was validated by using back-translation test). A total of 80 farms were evaluated. The farms in this research were randomly selected from each poultry production cluster in the province, including Wiang Kook village (20 farms), Kok Plafang village (20 farms), Thon village (20 farms), and Thasamran village poultry production clusters (20 farms), totaling 80 farms of 300 farms in the province. Scores on each indicator specified in the biosecurity score form were determined and recorded by clusters.

2.6 Determination of morbidity and mortality number of chickens before and after interventions

Before and after interventions, the morbidity and mortality number of chickens in poultry production clusters were collected in 30 farms (n=30) from 80 farms that performed the interventions for increasing biosecurity by random sampling.

2.7 Statistical analysis

Information on indicators of biosecurity levels and, the morbidity and mortality number of chickens in poultry farm were analyzed to identify the differences before and after the interventions. The comparisons of biosecurity levels were carried out among each of the poultry production clusters (n = 20) and for the whole province (n = 80). The comparisons of the morbidity and mortality number of chickens were carried out for the whole province (n=30). *T-test*, difference-scores was performed to analyze and compare the scores of biosecurity indicators before and after the interventions. *F-test* was performed to analyze and compare the scores of biosecurity indicators among 4 poultry production clusters in 2 districts by using SPSS (version 20). Analysis results were presented in the form of Mean + SD.

3. Results and discussion

Results of the study on factors causing farmers to change their behavior and improve their farm biosecurity system and a comparison of poultry farm biosecurity levels before and after the interventions are shown below:

3.1 Factors causing farmers of poultry production clusters in Nong Khai province to change behavior and improve their farm biosecurity system

Based on ecological and socio-economic data of the poultry production clusters in Nong Khai province, it was found that there were many factors affecting the poultry farmers' behavior and the success of the interventions in making the farmers improve to increase their poultry farm biosecurity levels. The factors that made farmers change their attitude and improve their farm biosecurity system were education and ecological factors: gave providing education in ecology aspect and location of the cluster and network, social factors: gender, social stratification in poultry production cluster (PPCs) and performance of relevant government officials and economic factors: loss from epidemic of disease in poultry farms. These factors affected expenditures and incomes of the farms. Details of each factor are described below:

3.1.1 Education and ecological factors (providing education in ecology aspect and location of the cluster and network)

3.1.1.1 Providing education in ecological aspect

The original version of the biosecurity score form that was used for evaluating biosecurity level of PPC in this study, was developed from the characteristics of ecology inside and surrounding poultry farm in PPCs and national or international biosecurity standard. During the intervention, the research team and the provincial livestock officers educated farmers in the ecology aspect of poultry farm and helped them plan to adjust the ecology in their farms to meet the biosecurity standard. Therefore, one of important factor is that research team and the provincial livestock officers worked together in the field sites to educate farmers to know the ecology in their farm and adjust ecology for improving biosecurity. It is difficult to motivate them to adjust or change the ecology in their farm to meet biosecurity standard without this process.

3.1.1.2 Location of the cluster and network

A comparison of biosecurity observations before and after the interventions among the four poultry production clusters in Nong Khai province revealed that, after the interventions, the scores on all indicators were higher. The poultry farmers could be divided into two groups. For the *first group*, the scores of seven indicators before and after the interventions were significantly different and this group consisted Wiang Kook village and Kok Plafang village poultry production clusters, both were located in Muang district. The scores of significantly different indicators for both clusters were consistent. For the *second group*, the scores of 11 indicators before and after the interventions were significantly different and such indicators were the same for both clusters, including Thon village and Thasamran village poultry production clusters, located in Tha Bo district. According to the above-mentioned details, the scores of biosecurity indicators that were significantly different after the interventions were the same or consistent for poultry production clusters located in the same district, especially those in Tha Bo district. Thus, it can be seen that the location of the poultry production clusters affected the interventions, which might be because of the same care and suggestions given by officials in the same area.

A study on origins and duration of the establishment of poultry production clusters, showed that the first poultry production cluster in Nong Khai province was in Kok Plafang village. This was followed not long after that by Wiang Kook village poultry production cluster, which was also located in Muang district and not far from the former cluster. The first poultry production cluster in Tha Bo district was in Thasamran village, followed by Thon village. Therefore, if the poultry production clusters were to be categorized by their time of establishment, they could be divided into two groups: original and new ones. Based on scores of biosecurity indicators that were significantly different before and after the interventions, it was found that the indicators tend to change in the same direction after the interventions for the original and new poultry production clusters in the same area. This means that the original and new poultry production clusters in

Muang district shared the same tendency of change in scores of biosecurity indicators after the interventions and it was the case for poultry production clusters in Tha Bo district. The factor contributing to such a phenomenon could be that the clusters in the same area learned and received information from the networks that were historically related. Therefore, a factor having impact on farmers' behavior as a result of the location of the poultry production clusters was a bond between the original cluster and the imitations, resulting in the exchange of information between farmers in nearby areas.

3.1.2 Social factor (gender, social stratification in PPCs and performance of relevant government officials)

3.1.2.1 Gender

For the poultry farming society in Nong Khai at the family level, gender role among family members was as follows: Male fed and gave water to the chickens, tended the chickens, vaccinated the chickens and gave them medicines, collected eggs, mowed the grass, took care of the fish farming, sold eggs and attended meetings arranged by the DLD; Female collected and sold eggs, counted the money and did the accounting, placed orders and made payments, helped with the vaccination of chickens, cooked, took care of the children, planted trees and attended meetings arranged by the DLD when male could not attend.

When comparing the role of gender between male and female outside the household or during meeting with research team and government officials by questions and observation found that both the male and female had authority to decision for improving biosecurity system in their farm. However, inside the household, in every decision, female always proposed the situation of money of household to male before making a decision. That means, female has power to make decisions to improve biosecurity system in poultry farms in PPCs within the household higher than male on the condition female holds money and makes payment.

3.1.2.2 Social stratification in PPCs

In the communities, cluster leaders were the first in each cluster to raise poultry, so when other people wanted to raise poultry, they were likely to ask for advice or learn from the first farm. As a result, more people followed in the footsteps of the first farmer. When the researchers worked with the provincial livestock officers in carrying out intervention activities, the cluster leaders were the ones to begin with by getting them to realize the importance of biosecurity systems and their benefits. When the cluster leaders agreed to follow the instructions, all other members of the cluster would learn from and follow their leaders. It could be seen that Thon village and Thasamran village poultry production clusters in Tha Bo district were more eager to improve their farm biosecurity than those poultry production clusters in Muang district, since leaders of the former were enthusiastic to make biosecurity improvements and the cluster members followed the leaders' example. As a result, after the interventions, 11 indicators had scores that were significantly different. This phenomenon was in accordance with the principle of stratification that was reported by Davis and Moore (1945) and Tumin

(1953). During the intervention, the research team used information and coercive power (French and Raven 1959) of the PPC's leader for communicating the importance of biosecurity system to PPC's members and controlling PPC's members during intervention processes, respectively.

3.1.2.3 Performance of relevant government officials

Officials from the Department of Livestock Development were very vital in carrying out the intervention activities to encourage farmers to improve their farm biosecurity system, since they had lawful power and responsibility to control and prevent diseases. Moreover, they had the duty to promote poultry farming, control farm standards and prevent diseases in farms. Farmers were required to follow instructions provided by the officials and apply for permission to operate poultry farms. If the farmers did not follow the officials' instructions, they might not be allowed to raise poultry. Therefore, the officials had a crucial role in giving recommendations for improving poultry farm biosecurity system. One of the researcher's intervention efforts was to work with the provincial livestock officials to encourage the farmers to comply with applicable rules and regulations on the control of diseases on poultry farms. A comparison of intervention results in each district showed that changes in biosecurity indicators of poultry production cluster farms in the same district were not different, meaning that a factor affecting the farmers' improvement of their poultry farm biosecurity system was the government officials in charge of that area. In the case of the factor from the government official, research team used reference power (French and Raven, 1959) of the provincial livestock office officials for motivating the intervention processes. That means government officials as a representative of research team. Moreover, the research team also used coercive power (French and Raven, 1959) from the provincial livestock officers through policy recommendation that the research team proposed to the provincial livestock office for controlling farmers during intervention.

3.1.3 Economic factor (loss from epidemic of disease in poultry farms)

According to interviews with the officials of Nong Khai Provincial Livestock Office in relation to occurrence of poultry diseases in farms, it was found that Thon village and Thasamran village poultry production clusters in Tha Bo district had more incidents of poultry diseases compared to Wiang Kook village and Kok Plafang village poultry production clusters in Muang district. The livestock officials occasionally visited the farms to provide the farmers suggestions on how to care for the animals and prevent these diseases. The farmers suffered economic loss as a result of the poultry illness and death. They had to pay for drugs and chemical supplies and this was a limitation to the quantity of poultry they were allowed to raise. Therefore, Thon village and Thasamran village poultry production cluster farmers were more active in improving their farm biosecurity than those farmers in Muang district because they needed to minimize potential damages. When comparing the number of indicators that were different before and after the implementation of the interventions,

it was found that the number of significantly different biosecurity indicators of poultry production cluster farms in Tha Bo district was more than that of poultry production cluster farms in Muang district. It could be concluded that the loss of money in the prevention (vaccination) and treatment (chemicals and drugs) of sick poultry forced the farmers to work harder to improve their farm biosecurity levels.

3.2 Biosecurity levels

The results of the interventions to increase the biosecurity levels in poultry farms of four poultry production clusters in Nong Khai province based on a comparison of scores of indicators before and after the interventions, are described below.

3.2.1 Biosecurity level of Wiang Kook village poultry production cluster

An evaluation of biosecurity levels of 20 Wiang Kook village poultry production cluster farms before and after the interventions, showed that the scores of the biosecurity indicators after the interventions which includes wild-bird protection, measures related to staffs in the farm, measures for incoming poultry (including fighting cocks), measures for equipment and vehicles, source and treatment of water, source of feed and biosecurity plans, were significantly higher than those before the interventions ($P < 0.05$). However, the scores of other indicators of Wiang Kook village poultry production cluster farms, including attractiveness to wild birds, measures for visitors, measures for traders, local environment: Distance from the road and other farm, types of poultry in the farm, capacity to clean and disinfect the farm and measures taken at the entrance to poultry sheds, were not significantly different ($P > 0.05$) as shown in Table 2.

3.2.2 Biosecurity levels of Kok Plafang village poultry production cluster

An evaluation of biosecurity levels of 20 Kok Plafang village poultry production cluster farms before and after the interventions, showed that the scores of the biosecurity indicators after the interventions includes: attractiveness to wild birds, wild-bird protection, measures for incoming poultry (including fighting cocks), measures for equipment and vehicles, source and treatment of water, source of feed, and types of poultry in the farm — were significantly higher than those before the interventions ($P < 0.05$). However, the scores of other indicators, including measures related to staffs in the farm, measures for visitors, measures for traders, local environment: Distance from the road and other farm, capacity to clean and disinfect the farm, measures taken at the entrance to poultry sheds, and biosecurity plans, were not significantly different ($P > 0.05$) as shown in Table 2.

3.2.3 Biosecurity levels of Thon village poultry production cluster

An evaluation of the biosecurity levels of 20 Thon village poultry production cluster farms before and after the interventions showed that the scores of the biosecurity indicators after the interventions includes: wild-bird protection, measures for incoming poultry (including fighting cocks),

measures for visitors, measures for traders, measures for equipment and vehicles, source and treatment of water, source of feed, types of poultry in the farm, capacity to clean and disinfect the farm, measures taken at the entrance to poultry sheds and biosecurity plans, were significantly higher than those before the interventions ($P<0.05$). However, the scores of other indicators, including attractiveness to wild birds, measures related to staffs in the farm, local environment: Distance from the road and other farm, were not significantly different ($P>0.05$), as shown in Table 2.

3.2.4 Biosecurity levels of Thasamran village poultry production cluster

An evaluation of biosecurity levels of 20 Thasamran village poultry production cluster farms before and after the interventions, showed that the scores of the biosecurity indicators after the interventions includes: wild-bird protection, measures for incoming poultry (including fighting cocks), measures for visitors, measures for traders, measures for equipment and vehicles, source and treatment of water, source of feed, types of poultry in the farm, capacity to clean and disinfect the farm, measures taken at the entrance to poultry sheds and biosecurity plans, were significantly higher than those before the interventions ($P<0.05$). However, the scores of other indicators, including attractiveness to wild birds, measures related to staffs in the farm, local environment: Distance from the road and other farm, were not significantly different ($P>0.05$), as shown in Table 2.

3.2.5 Biosecurity levels of poultry production clusters in Nong Khai province (overall)

An evaluation of biosecurity levels of 80 farms in the poultry production clusters in Nong Khai province as a whole before and after the interventions, showed that the

scores of the biosecurity indicators after the interventions includes: attractiveness to wild birds, wild-bird protection, measures related to staffs in the farm, measures for incoming poultry (including fighting cocks), measures for visitors, measures for traders, measures for equipment and vehicles, source and treatment of water, source of feed, types of poultry in the farm, measures taken at the entrance to poultry sheds, and biosecurity plans, were significantly higher than those before the interventions ($P<0.05$). However, the scores of other indicators, including local environment: Distance from the road and other farm, capacity to clean and disinfect the farm, were not significantly different ($P>0.05$) as shown in Table 2.

3.2.6 The comparison of biosecurity indicators scores between 2 districts (Muang and Tha Bo district) from the difference among 4 poultry production clusters before intervention

The comparison of biosecurity indicators scores between the two studies districts which are, Muang and Tha Bo districts was performed using results illustrated in Table 1. The biosecurity indicators scores before the interventions includes: attractiveness to wild birds, wild-bird protection, measures related to staffs in the farm, measures for incoming poultry (including fighting cocks), measures for visitors, measures for traders, types of poultry in the farm, measures taken at the entrance to poultry sheds and biosecurity plans of poultry production clusters in Muang district, were significantly higher than poultry production clusters in Tha Bo district, Thon and Thasamran village ($P<0.05$). However, the biosecurity indicators scores which is the source and treatment of water of poultry production clusters in Tha Bo district was significantly higher than poultry production clusters in Muang district ($P<0.05$) as shown in Table 1.

Table 1. Comparison of biosecurity indicators scores of poultry production cluster villages in 2 districts which are, Muang district (Wiang Kook village, n=20 and Kok Plafang village, n=20) and Tha Bo district (Thon village, n=20 and Thasamran village, n=20) in 2 dimensions which were before and after intervention, and among 4 clusters (before intervention) in Nong Khai province, Thailand.

No.	Biosecurity indicators on the farms	Name of PPC	Before intervention (20 farms)	After intervention (20 farms)
1.	Attractiveness to wild birds	1.) Wiang Kook village	1.05±0.61 ^A	1.50±0.59
		2.) Kok Plafang village	0.30±0.47 ^{BB}	1.10±0.31 ^a
		3.) Thon village	0.00±0.00 ^C	0.15±0.37
		4.) Thasamran village	0.00±0.00 ^{bC}	0.35±0.49 ^a
		Average (80 farms)	0.34±0.57 ^b	0.69±0.63 ^a
2.	Wild-bird protection	1.) Wiang Kook village	1.85±0.37 ^{BA}	2.25±0.79 ^a
		2.) Kok Plafang village	1.85±0.37 ^{BA}	2.35±0.67 ^a
		3.) Thon village	0.90±0.45 ^{BB}	2.45±0.69 ^a
		4.) Thasamran village	0.90±0.45 ^{BB}	2.50±0.69 ^a
		Average (80 farms)	1.38±0.66 ^b	2.39±0.68 ^a
3.	Measures related to staffs in the farm	1.) Wiang Kook village	1.50±0.51 ^{BA}	2.25±0.79 ^a
		2.) Kok Plafang village	1.85±0.75 ^A	2.20±0.62
		3.) Thon village	0.75±0.71 ^{BB}	1.60±0.50
		4.) Thasamran village	1.05±0.51 ^{BB}	1.60±0.50
		Average (80 farms)	1.28±0.75 ^b	1.55±0.51 ^a
4.	Measures for incoming poultry (incl. fighting cocks)	1.) Wiang Kook village	1.50±0.51 ^{BB}	2.24±0.82 ^a
		2.) Kok Plafang village	2.35±0.49 ^{BA}	1.65±0.49 ^a
		3.) Thon village	0.85±0.59 ^{bC}	1.70±0.47 ^a
		4.) Thasamran village	0.95±0.39 ^{bC}	1.70±0.47 ^a
		Average (80 farms)	1.41±0.78 ^b	1.86±0.65 ^a

Table 1. Comparison of biosecurity indicators scores of poultry production cluster villages in 2 districts which are, Muang district (Wiang Kook village, n=20 and Kok Plafang village, n=20) and Tha Bo district (Thon village, n=20 and Thasamran village, n=20) in 2 dimensions which were before and after intervention, and among 4 clusters (before intervention) in Nong Khai province, Thailand. (Cont.)

No.	Biosecurity indicators on the farms	Name of PPC	Before intervention (20 farms)	After intervention (20 farms)
5.	Measures for visitors	1.) Wiang Kook village	1.60±0.68 ^B	2.15±1.23
		2.) Kok Plafang village	2.00±0.00 ^A	2.35±1.18
		3.) Thon village	0.20±0.41 ^{bD}	2.60±0.82 ^a
		4.) Thasamran village	0.50±0.51 ^{bC}	2.40±1.10 ^a
		Average (80 farms)	1.08±0.88 ^b	2.38±1.08 ^a
6.	Measures for traders	1.) Wiang Kook village	2.55±0.61 ^A	2.55±0.76
		2.) Kok Plafang village	2.40±0.50 ^A	2.65±0.67
		3.) Thon village	1.00±0.80 ^{bB}	2.80±0.41 ^a
		4.) Thasamran village	1.15±0.81 ^{bB}	2.50±0.76 ^a
		Average (80 farms)	1.78±0.98 ^b	2.63±0.66 ^a
7.	Measures for equipment and vehicles	1.) Wiang Kook village	1.95±0.22 ^{bA}	2.55±0.69 ^a
		2.) Kok Plafang village	2.00±0.00 ^{bA}	2.65±0.59 ^a
		3.) Thon village	2.10±0.30 ^{bA}	2.65±0.49 ^a
		4.) Thasamran village	1.45±0.83 ^{bB}	2.55±0.60 ^a
		Average (80 farms)	1.87±0.51 ^b	2.60±0.59 ^a
8.	Source and treatment of water	1.) Wiang Kook village	1.25±0.45 ^{bB}	2.75±0.45 ^a
		2.) Kok Plafang village	1.25±0.44 ^B	2.10±0.72 ^a
		3.) Thon village	2.15±0.37 ^{bA}	2.70±0.47 ^a
		4.) Thasamran village	2.35±0.59 ^{bA}	2.70±0.47 ^a
		Average (80 farms)	1.75±0.68 ^b	2.56±0.59 ^a
9.	Source of feed	1.) Wiang Kook village	1.85±0.99 ^{bB}	2.75±0.45 ^a
		2.) Kok Plafang village	2.65±0.49 ^{bA}	2.95±0.22 ^a
		3.) Thon village	2.80±0.41 ^{bA}	3.00±0.00 ^a
		4.) Thasamran village	2.80±0.41 ^{bA}	3.00±0.00 ^a
		Average (80 farms)	2.53±0.73 ^b	2.93±0.27 ^a
10.	Local environment: Distance from the road and other farm	1.) Wiang Kook village	1.50±0.69	1.35±0.67
		2.) Kok Plafang village	1.65±0.59	1.20±0.83
		3.) Thon village	1.25±0.79	1.05±0.69
		4.) Thasamran village	1.10±0.72	1.75±0.85
		Average (80 farms)	1.38±0.72	1.34±0.80
11.	Types of poultry in the farm	1.) Wiang Kook village	2.95±0.22 ^A	2.55±0.83
		2.) Kok Plafang village	2.60±0.82 ^{bA}	3.00±0.00 ^a
		3.) Thon village	1.70±0.98 ^{bB}	2.75±0.55 ^a
		4.) Thasamran village	1.20±0.83 ^{bC}	2.60±0.75 ^a
		Average (80 farms)	2.11±1.03 ^b	2.73±0.64 ^a
12.	Capacity to clean and disinfect the farm	1.) Wiang Kook village	2.10±0.79 ^A	2.00±0.47
		2.) Kok Plafang village	1.55±0.51 ^{BC}	1.75±0.55
		3.) Thon village	1.25±0.44 ^{bC}	1.95±0.61 ^a
		4.) Thasamran village	1.65±0.50 ^B	1.65±0.50
		Average (80 farms)	1.64±0.64	1.81±0.57
13.	Measures taken at the entrance to poultry sheds	1.) Wiang Kook village	1.95±0.69 ^A	1.70±0.48
		2.) Kok Plafang village	1.85±0.37 ^A	1.75±0.44
		3.) Thon village	1.00±0.00 ^{bB}	1.85±0.37 ^a
		4.) Thasamran village	1.05±0.22 ^{bB}	1.65±0.49 ^a
		Average (80 farms)	1.46±0.59 ^b	1.74±0.44 ^a
14.	Biosecurity plans	1.) Wiang Kook village	2.25±0.79 ^{bB}	2.50±0.53 ^a
		2.) Kok Plafang village	2.75±0.44 ^A	2.75±0.44
		3.) Thon village	1.25±0.44 ^{bD}	2.70±0.47 ^a
		4.) Thasamran village	1.70±0.47 ^{bC}	2.30±0.47 ^a
		Average (80 farms)	1.99±0.79 ^b	2.57±0.50 ^a

^a and ^b indicate horizontal differences with statistical significance (P<0.05).

^{A,B,C} and ^D indicate statistical significance (P<0.05) for each indicator within the same column (before intervention)

3.3 Morbidity and mortality number of chickens

We found in the comparison of the morbidity and mortality number in chickens before and after interventions in the poultry farms (n=30) in this study that the morbidity and

mortality number of chickens before the interventions were significantly higher than after the interventions (P<0.05), as shown in Table 2.

Table 2. Comparison of the morbidity and mortality number of chickens in poultry production cluster before and after the interventions (n=30 farms).

No.	Lists	Before interventions	After interventions
1	Morbidity of chickens (per year)	719.72±920.31 ^a	78.82±78.21 ^b
2	Mortality of chickens (per year)	418.23±789.30 ^a	35.67±48.39 ^b

^a and ^b are letters with the same horizontal differences with statistical significance (P<0.05).

There were many factors causing farmers to change their attitude and behavior regarding the improvement of their farm biosecurity system. In this study, we proposed education, locations and network, durations of establishment of poultry production clusters, gender, leaders of the clusters, performance of relevant government officials and, poultry illness and epidemics in the farms, the details are shown in the 'Results and Discussion' section above. Based on the information obtained, it is apparent that poultry farmers were encouraged to improve their biosecurity system because of ecological, economic, and social factors, as well as poultry illness and the spread of local diseases in farms. However, all of these three main factors were correlated. That is, farmers aimed to generate more income for their families, so they invested in poultry farming. In the beginning, they had no knowledge of poultry farming, so they practiced and learnt from those farmers who had raised poultry earlier and were successful. As a result, these new farmers accepted the general ideas of farming and farm management from model farms. It was also found that most farmers learnt from the model farms located near them and eventually developed good relationships with one another. They shared information and helped each other in their farm network. The study revealed that in those clusters with strong leaders who gained respect of the members, when the leaders accepted any ideas and persuaded cluster members to improve the biosecurity system, the members followed the leaders' example, resulting in the effectiveness of the intervention activities introduced.

Furthermore, government officials responsible for livestock promotion played a significant role in promoting and encouraging farmers in their respective areas to prevent and control diseases. As a result, biosecurity indicators of farmers in the same district after the interventions were quite similar. Poultry illness and occurrence of local epidemics in farms prompted the farmers to improve their farm biosecurity system because, the illness or epidemics caused the farmers to suffer losses in two ways, including loss of income from their products and expenses of drugs and chemicals used to treat sick poultry. One of the reasons poultry farmers in the area of Tha Bo district were more eager to improve the biosecurity system than those in Muang district was that there were more sick animals in Tha Bo district than those in Muang district. The farmers'

perception of the effect of poultry illness and death on their incomes and expenses was a good stimulant to urge them to invest in the improvement of the farms. Such investment would have long-term benefits.

When considering the scores of biosecurity that were significantly different before and after the interventions among the four poultry production clusters in Nong Khai province, it was found that there were biosecurity indicators with similar increase in scores after the interventions they include: wild-bird protection, measures for incoming poultry (including fighting cocks), measures for equipment and vehicles, source and treatment of water. All of these five indicators were consistent with farm standards of the Department of Livestock Development and basic policies of Nong Khai Livestock Development Office that all farms had to comply with. Therefore, when the interventions were introduced, the scores of these indicators increased and were different from before the interventions. Furthermore, when comparing the indicators between the two districts, it was found that the scores on the indicators which include: types of poultry in the farm, capacity to clean and disinfect the farm, measures taken at the entrance to poultry sheds, and biosecurity plans, clusters in Tha Bo district increased after the interventions. Meanwhile, the scores on these indicators were indifferent for Wiang Kook village and Kok Plafang village poultry production clusters in Muang district both before and after the interventions (except for the indicator of biosecurity system planning inside farms of Wiang Kook village poultry production cluster, which had increased scores after the interventions). Summary of each biosecurity indicators that were significantly different before and after the interventions shown in Table 3. The scores of biosecurity indicators of poultry production clusters in Tha Bo district increased after the interventions as a result of the above-mentioned factors, including visionary cluster leaders, performance of government officials, poultry illness and frequent occurrence of epidemics in farms, which caused the farmers to agree to improve the farm biosecurity system. The score on biosecurity plans of Wiang Kook village poultry production cluster increased after the interventions because, they had visionary leaders who encouraged the members to improve their farm biosecurity system.

Table 3. Biosecurity indicators that were significantly different before and after the interventions among the four poultry production clusters in Nong Khai province.

Indicators	WK	KPF	BT	TSR
1. Attractiveness to wild birds	-	+	-	-
2. Wild-bird protection	+	+	+	+
3. Measures related to staffs in the farm	+	-	-	-
4. Measures for incoming poultry (incl. fighting cocks)	+	+	+	+
5. Measures for visitors	-	-	+	+
6. Measures for traders	-	-	+	+
7. Measures for equipment and vehicles	+	+	+	+
8. Source and treatment of water	+	+	+	+
9. Source of feed	+	+	+	+
10. Types of poultry in the farm	-	+	+	+
11. Capacity to clean and disinfect the farm	-	-	+	+
12. Measures taken at the entrance to poultry sheds	-	-	+	+
13. Biosecurity plans	+	-	+	+

Notes: 1.) WK = Wiang Kook village; KPF = Kok Plafang village; BT = Thon village; TSR = Thasamran village

2.) + = Significantly different; - = Not significantly different

When considering the biosecurity indicators that were not significantly different before and after the interventions among the four poultry production clusters in Nong Khai province, it was found that the indicators whose scores were not significantly different both before and after the interventions for all of the four poultry production clusters were local environment: Distance from the road and other farm. This was because the improvement of major structures within the farms could not be made, since the farms were located on the farmers' land and could not be moved to a public land where everyone was able to share benefits. Therefore, the scores on such indicators for all the four clusters were not different before and after the interventions. With regard to the indicator of attractiveness to wild birds, it was found that the scores for three clusters, Wiang Kook village, Thon village, and Thasamran village poultry production clusters were not significantly different before and after the interventions. This is because these three poultry production clusters raised poultry over fish ponds and there were plants everywhere on the farms, making it impossible for the farmers to change their poultry farming pattern, resulting in indifferent scores before and after the interventions. When considering measures for visitors, measures for traders, capacity to clean and disinfect the farm, and measures taken at the entrance to poultry sheds of Wiang Kook village and Kok Plafang village poultry production clusters, it was found that the scores were not significantly different before and after the interventions. Such phenomenon might be because these two poultry production clusters started their layer farms before other clusters and were not familiar with the prevention and control of diseases. When the interventions were conducted for only a short period, they were unable to make any changes. It was necessary to spend more time to make changes. This could be proven by the case of Kok Plafang village poultry production cluster, which was one of the first poultry production clusters in the province. After the interventions, there were no changes in the indicator of biosecurity plans. Thus, it could be seen that acceptance of changes involved several factors.

When considering the difference of biosecurity indicators scores between Muang and Tha Bo district, it was found that before the intervention, 6 biosecurity indicators scores of Muang district was higher than Tha Bo district. This phenomenon indicated that biosecurity level of poultry farms in Muang district was higher than Tha Bo district. Exempt indicator namely attractiveness to wild birds of Tha Bo district was higher than Muang district, the higher score of this indicator meant that poultry farm in Muang district are at risk to transmissible disease such as avian influenza than Tha Bo district because wild birds were carrier of the avian influenza virus. Aengwanich (2014) reported that before interventions the relationship between officials and farmers in Nong Khai province worsen during the avian influenza outbreak of 2003–2004, because the Thai government had a control policy of culling infected poultry to halt the epidemics. At that time, millions of poultry were killed and farmers lost out from this policy. This worsened the relations between them. After the outbreak declined, the relationship was still strained until the interventions (in 2012). During the interventions, the research team encouraged officials to use government mechanisms in doing their jobs and promoting the farmers' ability to prevent and control animal diseases. This fostered a good relationship between farmers and officials, meetings where organized to build understanding and hear about various ideas and problems among stakeholders; instruction; having the farmers perform self-evaluations of the level of biosecurity on the farms; and other measures for motivating them. Therefore, the relationship between farmers and officials became better after the interventions. Besides, farmers were willing to improve the biosecurity system in their farms. It was found that when considering the morbidity and mortality of chickens in poultry production clusters after the interventions, two indicators decreased when biosecurity in the poultry farms increased. Before the interventions, biosecurity of poultry farm in this province was quite low because farmers did not know about biosecurity system and disease prevention. Moreover, biosecurity system involved high investment and was more

complicated.

Finally, in Table 3, the variability of data (morbidity and mortality number of chickens) before intervention was very high. Especially, standard deviation of both morbidity and mortality data were higher than their mean. The high variability could be explained as follows: Before intervention, the biosecurity level of poultry farms in Nong Khai was lower than Department of Livestock Development (DLD) standard (Aengwanich, 2014) because farmers in this province lacked knowledge in disease management and vaccination. Therefore, the incidence of both morbidity and mortality of chickens in PPC of this province was quite high. Generally, in the poor disease management farm, morbidity or mortality numbers of chickens in this province was between 60-80% in the farm. On the other hand, in the good disease management farm, morbidity or mortality numbers of chickens were below 20% in the farm. Moreover, level of disease management in poultry production cluster in Nong Khai was different among farms. Therefore, the variability of data before intervention was very high and caused standard deviation to be higher than its mean. Whereas, after intervention, the variability of data decreased because morbidity and mortality number of chicken did not fluctuate, it decreased by 90% when compared with previous intervention.

4. Conclusions

There were many factors causing farmers to change their attitude and behavior regarding the improvement of their farms' biosecurity system, including education, locations, durations of establishment of poultry production clusters and network, gender, leaders of the clusters, performance of relevant government officials, poultry illness and epidemics in the farms. Such factors affected the income and expenditure of the farms. This study revealed that the process to improve farmers' understanding of biosecurity systems, listening to farmers' opinions and joint operations of the researchers, government officials and farmers were essential to an increase in poultry farm biosecurity levels. Finally, the morbidity and mortality number of chickens in poultry farms decreased in correspondence with the increase of biosecurity levels in poultry farms after interventions.

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