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## Biosecurity Evaluation of Poultry Production Cluster (PPCs) in Thailand

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**Abstract:** The objective of this study was to evaluate the biosecurity levels of Poultry Production Clusters (PPCs) in Thailand. Biosecurity levels of poultry farms in the PPCs were determined with criteria specified in biosecurity score form in 3 provinces i.e., Mahasarakham (contract farm with company), Nakhon Phanom (cooperative farm) and Nong Khai (individual farm) in the Northeast region of Thailand. In each province, biosecurity levels were evaluated both in the controlled group and in the cluster (15 farms each). Biosecurity scores were compared between farms in the controlled group and the cluster and among 3 provinces. From the results, it was found that scores of attractiveness to wild bird, measures for visitors and traders, measures for equipments and vehicles of poultry farm, local environment, measures taken at the entrances to poultry sheds in poultry farms and biosecurity plans of poultry farmers in Mahasarakham were significantly higher than in Nakhon Phanom and Nong Khai ( $p < 0.05$ ). The score of measures related to staffs of the poultry farms in Nakhon Phanom was significantly higher than those in Nong Khai ( $p < 0.05$ ). The score of feed quality in Mahasarakham and Nong Khai was significantly higher than that in Nakhon Phanom ( $p < 0.05$ ). In Mahasarakham, scores of local environment and biosecurity plans of poultry farmers of the controlled group were significantly higher than those of the cluster ( $p < 0.05$ ). In Nakhon Phanom, scores of attractiveness to wild bird, measures for incoming poultry, measures for visitors, measures taken at the entrances to poultry sheds and biosecurity plans of poultry farmers in controlled group were significantly higher than in the cluster ( $p < 0.05$ ). This demonstrated that biosecurity levels of contract farm with company were better than cooperative and individual ones. The difference of biosecurity levels was due to the farming pattern, farm's ecology, the compliance to governmental measures and policies and the ability to invest in biosecurity system of each group. As a result, the scores of biosecurity differed.

**Key words:** Biosecurity, score, poultry production cluster, PPCs, Thailand

### INTRODUCTION

The avian influenza outbreaks in Asia began in late 2003 and continued up to early 2004 (Verbiest and Castillo, 2004). The first outbreak of H5N1 avian influenza in Thailand was reported in layer chicken farms in the Central region of Thailand in January 2004. In 2005, outbreaks were still detected in the lower Northern and Central regions. They were mainly found in poultry farms which applied backyard system with low biosecurity level and none in closed housing system or other systems with high biosecurity level. The outbreaks of avian influenza during 2004-2005 had severe impacts on poultry production, social community, farmers' livelihood, human health and socioeconomics. H5N1 virus was detected not only in reared poultry but also in wild birds. Such virus was transmitted from poultry to humans and other mammals (Tiensin *et al.*, 2007). After avian influenza outbreaks in 2003, the Thai government launched many control policies including stamping out, cleaning and disinfection, surveillance, movement

control, campaigns for awareness promotion and panic reduction, improvement of the biosecurity and restructuring of poultry production. This resulted in continuous decline of the outbreaks. The policy was implemented through 4 processes namely quarantine, screening, zoning and compensation (Rushton *et al.*, 2005; Tiensin *et al.*, 2005; Tiensin *et al.*, 2007; Barbazan *et al.*, 2008; NaRanong, 2008; Heft-Neal *et al.*, 2009a; Safman, 2009; Prakarnkamanant *et al.*, 2010). However, there was no policy on vaccination in the country (Rushton *et al.*, 2005). After AI outbreak, poultry farms in Thailand were categorized by biosecurity systems into 4 sectors. *The first sector* was industry integrated production system where broilers, layers and ducks were raised in a closed house with evaporative cooling system. This system provided strict physical protection and disease control. The second sector was semi-vertical integrated production system which is known as contractual farming system. Poultry were raised in a closed house with evaporative cooling system or an

open house with nylon or metal nets to prevent birds or other animals from entering the house. The third sector was usual farming system with low biosecurity where broilers, layers and ducks were raised. The houses were open and constructed without netting. Sometimes the flocks were left outside the houses. The fourth sector was backyard or village poultry production system operated without biosecurity concern (Tiensin *et al.*, 2007).

The integration policy of poultry producers gave rise to various poultry production clusters or PPCs in general, both before and after the outbreaks of avian influenza. The definition of Poultry Production Cluster (PPCs) is "an area of concentrated poultry production in rural areas, usually separated from residential areas - where farms practice the economies of scale model and use comparative advantages of localities, resulting in improvements to and increased intensification of poultry production. The farms in the cluster apply standard biological safety and environmentally friendly practices". With integrations of poultry producers in the same area, data on biosecurity levels of the farms in these PPCs was still limited. Thus the objective of this study was to evaluate the biosecurity levels of the farms in Poultry Production Clusters (PPCs) in Thailand. The knowledge acquired will help evaluating outbreak control policies for the poultry especially the avian influenza, promoting and developing the biosecurity system of poultry farms.

## **MATERIALS AND METHODS**

**Research site information:** The study was conducted with the poultry production clusters in 3 provinces of Mahasarakham, Nakhon Phanom and Nong Khai. The details about farming pattern, farm's ecology, the compliance to governmental measures and policies and the ability to invest in biosecurity system of the PPCs in the 3 provinces were as follows:

**Poultry production cluster in Mahasarakham:** The farmers raised chicken in evaporative cooling system. The poultry raised were layers and male layers. Every farm in this system had to be approved of farm standard by the Department of Livestock Development. The biosecurity system levels were high. There would be investment in the complete biosecurity system since the beginning for the standard certification inspection e.g., fencing the farm area, disinfectant spraying system to farmers and vehicles that entered the farms, showering, cloth changing and boots were required, there would be strict farming record and the farmers strictly complied to the biosecurity system for the disease prevention and control. Staffs from the provincial livestock office would make an annual random test of the water and feed. The farmers had to take an annual health check up and get the influenza vaccine. The Poultry Production Clusters'

characteristics were vertically dispersed farms along the main road to the village. The farms established first gathered in the same area. The later farms dispersed, located away from roads in the communication and the previously established farms, yet in the same area. The farmers owned the land which used to be rice fields. There were some large trees around the farm and ponds. The ponds were small and were used for domestic plantation or fish farming.

**Poultry production cluster in Nakhon Phanom:** The farmers had been raising layers in lifted barns for over 20 years. The roof of the barn was made of grass or metal in some farms. The wall was made of bamboo with netting around the barn. When the chicken defecated, the feces would fall underneath the barn. The farms situated in the cluster. Layer barns in each farm were in farmers' own land. The farmers mixed the chicken feed for internal use with material received from cooperatives. There were large trees around the farm but no pond. Farms were near the roads but the barns would be more than 50 meters away from the roads. The newer farms were in the outer zone and away from the older farms. The farms were closed to the roads with water resources in proximity. As there used to be land excavation for the road construction, many large ponds were left which now served as water resources nearby the farms. There were large trees around some farms. The residential area, feed stocking and preparation areas and egg sorting barns would be separated from the chicken barns. The biosecurity system in the farms was promoted by the Provincial Livestock Office. One of the province administration's policies granted budget to promote the development of layers farming to be poultry production clusters. The farmers invested in biosecurity system i.e., fencing the farm area, changing the boots, disinfectant pools were available so the farmers could dip their feet, a disinfectant spraying system was arranged for vehicles entering the farms. Some farms built bathroom and changing room and visitors were not allowed to enter the barns. Yet some farms in the cluster were not so strict about the biosecurity system even though they had made investment in biosecurity.

**Poultry production cluster in Nong Khai:** Most of the farms in this cluster were located near large water resources e.g., big swamps or lakes so they irrigated the water for their fish farm and drained the waste water out of the fish ponds. Mostly a farm in the poultry production cluster of Nong Khai was situated in each farmer's area. The barns would be above fish ponds. The roof of the barn was made of grass or metal, the walls, bamboo. The floor of the barn was built to leave holes to allow the feces of the chicken to fall into the ponds, serving as fish feed. Around the fish ponds there

were trees. The farms of poultry production cluster originally formed were in the middle of the cluster and the latter farms would be in the outer area. Some poultry production clusters in Nong Khai invested in biosecurity system for some items only e.g., the fencing, disinfectant spraying upon entering the farms, some farms require that the boots were changed before entering the barns. During the outbreaks the farmers strictly practiced the disease control but did less so when the outbreaks alleviated.

**Classification of farms in the cluster and the controlled group:** The classification of farms in the cluster and the controlled group was by below criteria:

- Farms in the cluster were poultry farms in poultry production cluster which were located in the cluster area. There were dense poultry production and were among the first in raising the poultry in each cluster, with more than 5 years
- Farms in the controlled group were poultry farms in poultry production cluster (PPC) but were away from the cluster. They were new and not more than 5 years
- Biosecurity score form and collecting data

**Biosecurity score form:** This study used a simple Biosecurity score form which were developed from the concept of Dr. Les Sims and in accordance with the information about the Biosecurity system of FAO (2008) beginning with a survey of the details about biosecurity system of the poultry farms in the poultry production cluster, PPC of the three provinces. Then the details of Biosecurity score form were developed as the actual details from the fields. The Biosecurity score form was designed for a survey conducted by observation of field management and farmers' practice of the biosecurity system within the farms, including interviewing some of them. There were 14 indicators of this score form namely attractiveness to wild birds, wild-bird protection, measures related to staffs in the farm, measures for incoming poultry, measures for visitors, measures for traders, measures for equipments and vehicles, source and treatment of water, source of feed, local environment: distance from road to farm, different types of poultry in farm, capacity to clean and disinfect the farm, measures taken at the entrance to poultry sheds and biosecurity plans. For the observation scores, the development plan of biosecurity system requires interview of the biosecurity system development from the farmers for the scoring. In each scoring, there were 4 levels: scored 0, 1, 2 and 3. The highest scores were highest number and reduced orderly. (Table 1).

**Data collection:** The data was collected by observation of details presented in the farms and interview with farmers for relevant information. Each Indicator was

scored as per the Table 1, applying the Biosecurity scores form. The data collection was conducted to 30 farms from the Poultry Production Cluster in each province. There were 15 farms from the cluster and the other 15 farms from the controlled group with the total of 90 farms in the 3 provinces. The field data collection was conducted during March-May 2012.

**Statistic analysis:** Compare biosecurity scores gained from the fieldwork of each indicator for the statistical difference between the three patterns of poultry production cluster and for the difference between the poultry farms in the controlled group and in the cluster, setting the statistical reliability at  $p < 0.05$ .

## RESULTS AND DISCUSSION

Data collection was conducted by scoring biosecurity levels of the 14 indicators to evaluate the biosecurity levels of poultry farms in the poultry production cluster in the 3 provinces of Mahasarakham (contract farm with company), Nakhon Phanom (cooperative farm) and Nong Khai (individual farm raising the layers over fish ponds) in Thailand. The scores of biosecurity levels were collected from 30 farms in each province, 15 of which were from controlled group and the other 15 farms were from the cluster. The scores of biosecurity levels were compared between each farming patterns and the results were as follows:

- The PPC farms in Nong Khai were more attractive to wild bird than the PPC farms in Mahasarakham and Nakhon Phanom ( $p < 0.05$ ). The farms of PPC in Nakhon Phanom were not different from those in Mahasarakham ( $p > 0.05$ ). Poultry farms in the cluster in Nakhon Phanom were more attractive to wild bird than the controlled group ( $p < 0.05$ )
- The scores for wild bird protection of poultry farms in Mahasarakham, both in controlled and cluster group, were not significantly different from those in Nakhon Phanom ( $p > 0.05$ ). The score of wild bird protection in Mahasarakham was significantly higher than the controlled group in Nakhon Phanom and the PPCs in Nong Khai ( $p < 0.05$ ). The score of wild bird protection of controlled group in Nong Khai was significantly higher than controlled group in Nakhon Phanom and cluster group in Nong Khai ( $p < 0.05$ )
- The score of measures related to staffs in the farm of the controlled group in Mahasarakham was not significantly different from the PPC in Nakhon Phanom ( $p < 0.05$ ). The scores of PPC in Nong Khai was significantly lower than the PPC in Mahasarakham and Nakhon Phanom ( $p < 0.05$ )
- The score of measures for incoming poultry of the poultry production cluster in Nakhon Phanom was significantly lower than the controlled group and the PPC in Mahasarakham and Nong Khai ( $p < 0.05$ )

Table 1: Indicators and definition of biosecurity score in each levels

Indicators	Scores	Definition
1. Attractiveness to wild birds	3	The farm located in the non-migrated bird area. No trees or water pools within 100m.
	2	Trees surrounding the farm but no pond.
	1	Ponds nearby the farm within 50m.
	0	Both trees and ponds located within 50m.
2. Wild-bird protection	3	Poultry indoor or use bird net as shield 100%.
	2	The net can cover more than 70% of the poultry house.
	1	The net can cover more than 50% of the poultry house
	0	The bird net is not efficacious at all.
3. measures related to staffs in the farm	3	Farmers live in the farm permanently, at least for per cycle.
	2	Do not live permanently but take some measures. No birds kept as pet in the living house (nor the fighting cock). -Record everyone entering and leaving the farm. -Use disinfectant equipments when entering the farm.
	1	Taking some measures but affect so little to the poultry biosecurity.
	0	Staffs in the farm work without any control.
4. Measures for incoming poultry (incl. fighting cocks)	3	The whole farm keeps the same cycle and all the poultry comes from the same company or registered groups under contact.
	2	Measures taken for the control of the incoming poultry. E.g. traders' questionnaire, take records in each cycle etc.
	1	Find sources of chicken and measures for disease control in poultry farm.
	0	No measure taken.
5. Measures for visitors	3	Visitor Cannot enter the building or there is a fully developed disinfection system (taking a shower; changing clothes).
	2	Taking some measures for the visitors, protection under functional equipment. Setting a sign in front of the farm. Fencing around the farm. Footwear and disinfection are required at the entrance.
	1	Measures taken but not so effective or under poor arrangement.
	0	Visitor can enter the poultry house directly.
6. Measures for traders	3	Traders don't need to enter the farm
	2	Traders enter the farm without entering the poultry house.
	1	Traders stay inside the house after getting disinfection.
	0	No measures for the traders at all.
7. Measures for equipments and vehicles	3	No vehicle in the farm.
	2	Disinfect the vehicles upon entry.
	1	Measures taken but not so effective or under poor arrangement.
	0	No control to the vehicles.
8. Source and treatment of water	3	Healthy cool water from underground
	2	Water from healthy source (rain, recycle), no pollution
	1	High quality surface water and under protection during transfer
	0	Surface water without treatment
9. Source of feed	3	Feed provided by the company, no process is needed.
	2	Feed mixed by machine indoor.
	1	Feed mixed by human indoor.
	0	Feed mixed outdoor.
10. Local environment: Distance from the road and other farm	3	Fully protection of the farm, far from a public road more than 300m.
	2	Either other farm or public road located within 200m.
	1	Either other farm or public road located within 100m.
	0	Both other farm and public road located within 50m.
11. Types of poultry in the farm	3	Only one type of poultry in the farm.
	2	A few types of poultry in the farm, reared in separated housings.
	1	A few types of poultry in the farm, free range.
	0	Many types of poultry in the farm, free range
12. Capacity to clean and disinfect the farm	3	Clean and disinfect the whole area regularly (more than once a week).
	2	Clean and disinfect the whole area or only several parts of the farm regularly (more than a month per time).
	1	Clean and disinfect only several parts of the farm irregularly. (Usually upon the outbreaks)
	0	No disinfection or cleaning at all.
13. Measures taken at the entrance to poultry sheds	3	Fully developed system of disinfection (Usually under the guidance of a company).
	2	-Some measures of disinfection, including scored 2. -Changing boots or other footwear for the poultry house. -Taking a shower and changing clothes. -Passing a disinfectant tank before entering the poultry house and wear gloves
	1	Measures taken but not so effective.
	0	No disinfection or cleaning at all
14. Biosecurity plans	3	Design a coherently suitable plan under sustainable development.
	2	Farmers have separate plans e.g., updating equipments for a better biosecurity level, studying about the biosecurity
	1	Just obey any guidance or regulation of the local area. No individual plan.
	0	No plan or guidance to follow

- The score of measures for visitors of the PPC in Mahasarakham was significantly higher than the PPC in Nakhon Phanom and Nong Khai ( $p < 0.05$ ). The score of measures for visitors of the PPC in Nakhon Phanom was significantly higher than the PPC in Nong Khai ( $p < 0.05$ )
- The score of measures for traders of the PPC in Mahasarakham was significantly higher than the PPC in Nakhon Phanom and Nong Khai ( $p < 0.05$ ). The score of Measures for traders of the PPC in Nakhon Phanom was significantly higher than the PPC in Nong Khai ( $p < 0.05$ )
- The score of measures for equipments and vehicles of the PPC in Mahasarakham was significantly higher than the PPC in Nakhon Phanom and Nong Khai ( $p < 0.05$ ). The score of measures for equipments and vehicles of the PPC in Nakhon Phanom was significantly higher than the PPC in Nong Khai ( $p < 0.05$ )
- The scores of source and treatment of water among Mahasarakham, Nakhon Phanom and Nong Khai were not significantly different ( $p > 0.05$ )
- The scores of source of feed of the PPC in Mahasarakham and Nong Khai were significantly higher than the PPC in Nakhon Phanom ( $p < 0.05$ )
- The score of local environment: distance from road to farm of the controlled group in Mahasarakham was significantly higher than others group ( $p < 0.05$ ) The score of local environment of the poultry cluster in Nakhon Phanom was significantly higher than the poultry cluster in Mahasarakham, the controlled group in Nakhon Phanom and the PPC in Nong Khai ( $p < 0.05$ )
- The scores of different types of poultry in farm among Mahasarakham, Nakhon Phanom and Nong Khai were not significantly different ( $p > 0.05$ )
- The score of capacity to clean and disinfect the farm of the PPC in Mahasarakham was significantly higher than the PPC in Nakhon Phanom and Nong Khai ( $p < 0.05$ ). The score of capacity to clean and disinfect the farm of the PPC in Nakhon Phanom was significantly higher than the PPC in Nong Khai ( $p < 0.05$ )
- The score of measure taken at the entrance to poultry sheds of the PPC in Mahasarakham was significantly higher than the PPC in Nakhon Phanom and Nong Khai ( $p < 0.05$ ). The score of measure at taken at entrance to poultry sheds of the controlled group in Nakhon Phanom was significantly higher than the poultry cluster and the PPC in Nong Khai ( $p < 0.05$ )
- The score of biosecurity plans of the controlled group in Mahasarakham was significantly higher than the poultry cluster, the controlled group in Nakhon Phanom and the PPC in Nong Khai ( $p < 0.05$ ). The scores of biosecurity plans of the poultry cluster in

Mahasarakham and the controlled group in Nakhon Phanom were significantly higher than the poultry production cluster in Nong Khai ( $p < 0.05$ ). The score of biosecurity plans of the poultry cluster in Nakhon Phanom was significantly higher than the PPC in Nong Khai ( $p < 0.05$ ) (Table 2)

A field study was conducted for biosecurity evaluation, comparing between farms in 1. Poultry Production Cluster (PPC) in Mahasarakham which conducted contract farming system with private companies (this farming pattern is categorized as the second sector) (Tiensin *et al.*, 2007), 2. poultry production cluster in Nakhon Phanom which were cooperative layers farms and 3. layers farmers groups that raised layers upon fish ponds in Nong Khai. The result was that the biosecurity score of the poultry farmers in Mahasarakham was higher than those in Nakhon Phanom and Nong Khai consecutively. This might be because, after the outbreaks of the Avian Influenza, Department of Livestock Development had issued measures for disease control which required poultry farms to undergo Farm Inspection and Certification (Heft-Neal *et al.*, 2008; Kasemsuwan *et al.*, 2009) before commencing the operation. Furthermore, one condition of the contract farming was that the farms that could make a contract with the company needed to pass the Farm Inspection and Certification. Thus such poultry production farmers obtained higher biosecurity scores than the poultry production cluster in Nakhon Phanom and Nong Khai. When the biosecurity scores of the poultry production cluster in Nakhon Phanom and Nong Khai were compared, it is found that the score of Nakhon Phanom province was higher than that of Nong Khai even comparing the entire province of both Nakhon Phanom (Heft-Neal *et al.*, 2009b) and Nong Khai (Chantong and Kaneene, 2011). This was due to the budget promoted the grouping of chicken farming and continuous disease control in farms. The continuous support policy of poultry production contributed to the higher biosecurity scores of the poultry farms. Anyhow, even though the biosecurity scores of the poultry production cluster was higher than that of the poultry production cluster in Nong Khai, when comparing with the poultry farms in Mahasarakham it was found that the indicators of farms in poultry production cluster in Nakhon Phanom which had lower scores than the poultry farms in Mahasarakham were measures for visitors, measures for traders, measures for equipments and vehicles, source of feed, capacity to clean and disinfect the farm and measures taken at the entrance to poultry sheds. Whereas the indicators of farms in poultry production cluster of Nong Khai that were lower than those of the clusters in Mahasarakham and Nakhon Phanom were attractiveness to wild birds, wild-bird protection, measures related to staffs in the farm, measures for visitors, measures for traders,

Table 2: Comparison of indicators for biosecurity evaluation in poultry farm of the PPCs in Thailand

Indicators	Mahasarakham		Nakhon Phanom		Nong Khai	
	Control	Cluster	Control	Cluster	Control	Cluster
Attractiveness to wild birds	2.23±0.73 <sup>ab</sup>	2.23±0.83 <sup>ab</sup>	2.50±0.63 <sup>a</sup>	1.87±0.40 <sup>b</sup>	0.00±0.00 <sup>c</sup>	0.00±0.00 <sup>c</sup>
Wild-bird protection	3.00±0.00 <sup>c</sup>	3.00±0.00 <sup>c</sup>	1.07±0.53 <sup>c</sup>	1.50±0.27 <sup>a</sup>	1.50±0.68 <sup>b</sup>	1.13±0.44 <sup>c</sup>
Measures related to staffs in the farm	2.58±0.49 <sup>ab</sup>	2.46±0.52 <sup>b</sup>	2.93±0.26 <sup>a</sup>	2.67±0.41 <sup>ab</sup>	1.93±0.18 <sup>c</sup>	2.07±0.75 <sup>c</sup>
Measures for incoming poultry (incl. fighting cocks)	3.00±0.00 <sup>c</sup>	2.92±0.28 <sup>b</sup>	2.83±0.24 <sup>a</sup>	2.57±0.70 <sup>b</sup>	3.00±0.00 <sup>c</sup>	3.00±0.00 <sup>c</sup>
Measures for visitors	2.23±0.95 <sup>a</sup>	2.46±1.03 <sup>a</sup>	1.13±0.81 <sup>b</sup>	0.60±0.21 <sup>c</sup>	0.13±0.23 <sup>cd</sup>	0.07±0.18 <sup>d</sup>
Measures for traders	2.31±0.75 <sup>a</sup>	2.31±0.78 <sup>a</sup>	1.17±0.65 <sup>b</sup>	0.77±0.42 <sup>c</sup>	0.10±0.21 <sup>c</sup>	0.07±0.18 <sup>d</sup>
Measures for equipments and vehicles	2.35±0.75 <sup>a</sup>	1.92±1.04 <sup>a</sup>	1.2±0.82 <sup>b</sup>	0.87±0.48 <sup>b</sup>	0.10±0.21 <sup>c</sup>	0.07±0.26 <sup>c</sup>
Source and treatment of water	3.00±0.00	2.92±0.28	3.00±0.00	3.00±0.00	3.00±0.00	3.00±0.00
Source of feed	3.00±0.00 <sup>c</sup>	3.00±0.00 <sup>c</sup>	2.00±0.00 <sup>b</sup>	2.00±0.00 <sup>b</sup>	3.00±0.00 <sup>c</sup>	3.00±0.00 <sup>c</sup>
Local environment: distance from road to farm	2.77±0.33 <sup>a</sup>	1.27±0.60 <sup>b</sup>	1.23±0.75 <sup>b</sup>	1.70±0.37 <sup>b</sup>	1.07±0.32 <sup>c</sup>	1.13±0.40 <sup>c</sup>
Different types of poultry in farm	2.92±0.28	3.00±0.00	3.00±0.00	3.00±0.00	2.80±0.65	2.70±0.65
Capacity to clean and disinfect the farm	2.77±0.44 <sup>a</sup>	2.77±0.44 <sup>a</sup>	1.53±0.55 <sup>b</sup>	1.70±0.32 <sup>b</sup>	0.00±0.00 <sup>c</sup>	0.00±0.00 <sup>c</sup>
Measures taken at the entrance to poultry sheds	2.42±0.91 <sup>a</sup>	2.58±0.88 <sup>a</sup>	0.97±1.03 <sup>b</sup>	0.40±0.66 <sup>c</sup>	0.07±0.18 <sup>c</sup>	0.03±0.13 <sup>c</sup>
Biosecurity plans	2.58±0.49 <sup>a</sup>	2.12±0.42 <sup>b</sup>	1.90±0.60 <sup>b</sup>	1.47±0.69 <sup>b</sup>	1.00±0.00 <sup>c</sup>	1.00±0.00 <sup>c</sup>

measures for equipments and vehicles, capacity to clean and disinfect the farm, measures taken at the entrance to poultry sheds and biosecurity plans. The differences of the farms in poultry production cluster of the three provinces were due to several factors e.g. farming pattern, different ecology of farms, compliance to governmental measures and policies and capacity to invest in biosecurity system. Such factors substantially contributed to the different biosecurity scores of the three poultry production clusters.

From the evaluation of biosecurity levels comparing between farms in controlled groups and those in poultry production clusters, it was found that for the poultry production clusters in Mahasarakham that conducted contract farming with private companies, the controlled group had higher scores for Local environment and biosecurity plans than the cluster. The crucial reasons were because most farms in the controlled group were established afterward and expanded from farms in the cluster. So the farms were more away from the road than those in the cluster. Furthermore most farmers of the controlled group were new farmers that emphasized the disease control policies more than the former farmers in the cluster and that the governmental control were more strict. Evaluating the difference of the controlled group to the cluster in Nakhon Phanom, it was found that the higher indicators were attractiveness to wild birds, measures for incoming poultry, measures for visitors, measures taken at the entrance to poultry sheds and biosecurity plans. As well as the poultry production cluster in Mahasarakham, the farms in the controlled group was established after those in the cluster and most farmers were new farmers who emphasized the disease control policies more than those in the cluster. The lower indicators of biosecurity scores of farms in Nakhon Phanom from the controlled group comparing to those of the cluster were wild-bird protection and Local environment. This was because ponds were excavated around communities for the soil to be used in the road construction, farms were located along the new road

outside the cluster. Ponds and the proximity to the road of the farms resulted in the lower indicators of wild-bird protection and Local environment of the controlled group comparing to the cluster. In Nong Khai, the indicators for wild bird protection of the controlled group were higher than the cluster with the same reason as in Mahasarakham and Nakhon Phanom. Anyhow, observing the indicators of biosecurity levels of Nong Khai, most biosecurity scores were not much different. This might be because of limited area for farming. Also the main characteristic of farms in Nong Khai with chicken barns over the ponds which required that farms located near water resource allowed only little new farms. So the biosecurity scores of farms in the controlled group and in the cluster were not different. FAO (2008) defined the term "Biosecurity" that "Biosecurity is 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 behaviours by people to reduce risk in all activities involving domestic, captive exotic and wild birds and their products". This comprised of 3 steps: segregation, cleaning and disinfection respectively. For the indicators of this study as classified by the concept of FAO, they both differed from and matched the FAO concept. But all in all, there was no difference. The difference occurred was due to the fact that the indicators of this study had been modified to suit with the ecology of poultry production in Thailand which details shared some similarity with the indicators of the biosecurity level study in Belgium (Steenwinkel *et al.*, 2011) and Indonesia (Lestari *et al.*, 2011). Thus the indicators used in the evaluation of the biosecurity system in the poultry farms needed to be improved to suit with the area and the application's objectives.

**Conclusion:** After the avian influenza outbreaks in 2003, the government promoted the disease control policies. A measure was that the poultry farmers were grouped together in an area called Poultry Production Cluster

(PPC). An evaluation of the biosecurity system of poultry production clusters in three provinces of Thailand, one group in each province, with different farming patterns was conducted. The farming patterns were 1) contract farming with private companies in Mahasarakham, 2) cooperative farming in Nakhon Phanom and 3) chicken barns over fish ponds in Nong Khai. The result had it that the biosecurity levels of the three poultry production clusters were different. Moreover, the biosecurity levels between the controlled group and the cluster were also different. The farming pattern, farm's ecology, compliance to the governmental measures and policies and the capacity to invest in biosecurity system resulted in different levels of biosecurity scores of the farms in each group.

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