Manure management and pollution levels between contract and non-contract livestock farming in Vietnam

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ABSTRACT

In analyzing contract farming in livestock production, many studies have focused on the economic aspect. This paper offers environmental issue by comparing the manure management and pollution levels between contract farming (CF) and non-contract farming (NCF) livestock producers. By surveying 270 pig farms and analyzing the wastewater samples collected from 29 contract farms and 30 non-contract farms, we found that CF producers show less severe pollution levels than NCF producers do. The pollution levels are distinguished by land area for manure treatment plants (MTPs), knowledge of handling manure, types of MTPs, and amount of water use for cleaning piggeries. The study results suggest that the government should regulate the minimum required land area for installation of MTPs that combine biogas plants and stabilization ponds. Additionally, to recycle and utilize pig manure, advanced technologies for reducing water use pig production are necessary for CF producers.

Keywords: manure treatment; waste recycling; contract farming; pig production; manure treatment plant

1. Introduction

Although animal manure is a valuable source of nutrients for crop production, without proper manure treatment practices, it is a large source of pollution. In Vietnam, it is estimated that around 40% of animal waste is dumped into the environment (Dinh, 2017), resulting in soil, water, and air pollution, and causing a public health hazard.

To meet the increasing demand for meat, the patterns of livestock production in Vietnam have changed to intensive farming. Over the last ten years, CF - a type of large-scale farms - has been the new trend in Vietnam. In 2018, Vietnam had 3,010 pig CF producers, accounting for 30.8% of total large-scale farms and 15.2% of total pig population (Quynh, 2018).

Numerous studies have investigated the manure treatment practices in Vietnam and proposed solutions for small-scale farms (Hai, Schnitzer, van Thanh, Thao, & Braunegg, 2016; Huong, Madsen, Anh, Ngoc, & Dalsgaard, 2014; Roubík, Mazancová, Banout, & Verner, 2016; Thien Thu et al., 2012;

Q. D. Vu et al., 2012; T. K. V. Vu, Jensen, Sommer, & Bruun, 2015). Regarding CF issues in Vietnam, many previous studies have focused only on economic analysis. Saenger, Qaim, Torero, and Viceisza (2013) analyzed the effectiveness of contracts between a processor and smallholder farmers in terms of the quality of milk. Costales, Son, Lapar, and Tiongco (2006) and Costales, Son, Lapar, and Tiongco (2008) summarized typologies of CF and determinants of CF participation in pig production in Northern Vietnam.

Although previous studies have provided valuable information on either environment or CF, some research gaps still exist. First, studies on manure management in Vietnam focused on only small-scale farms that are gradually decreasing because of the intensification trend in the livestock sector, but did not investigate CF producers. Second, these studies paid much attention to the aspects of environmental engineering, but almost ignored socioeconomic facets in manure treatment.

To fill the aforementioned research gaps, this paper sets the following objectives. First, it analyzes manure management in CF and NCF pig producers in Vietnam, indicating the limitations of manure management and the need for governmental support for the producers. Second, it compares between CF and NCF producers in terms of pollution levels.

2. Method

2.1. The study site

From June to August 2018, we conducted a survey in Hanoi, which produces the largest number of pigs 1,635.9 thousand pig heads, accounting for 5.8% of the pig population in Vietnam (GSO, 2017). According to the statistics of the Hanoi Veterinary Department, in May 2018, there were about 205 CF producers out of 101,813 pig owners, accounting for 20% of the total pig population in the area. We carried out the survey 270 producers in the following districts: Ba Vi, Phuc Tho, Thach That, Dan Phuong, Chuong My, and Thanh Oai (Fig1).

2.2. Data collection and analysis

The randomly selected farms were initially surveyed using questionnaires. After surveying 270 farms using questionnaires, we obtained data from 46 CF and 224 NCF producers. We collected wastewater samples at 29 CF producers and 30 NCF producers to compare the pollution levels. Before the analysis, the data were rechecked to ensure accuracy. If information was inconsistent, the interviewer contacted the farm and surveyed the farmer again. In addition, if reliable data could not be obtained, they were omitted from the data analysis. Then, the information from the questionnaires and wastewater analysis were input into computer and analyzed using the statistical software package STATA 14.

3. Results and Discussion

3.1. Descriptive characteristics of pig farms

CF producers have lower average age and experience than NCF producers because CF started about only ten years ago in Vietnam's livestock sector, while traditional farming existed for a long time (Table 1). However, educational level and knowledge of manure treatment of CF producers is higher than that of NCF producers. We asked farm heads to list the technologies of manure treatment

available in Vietnam. There were six technologies being listed (i.e., biogas plants, compost, vermicompost, bio-bedding, separator machines, and constructed wetland systems), in which the first two are the most common with the farm heads. In addition, there are large differences in total land area between CF and NCF producers. On average, the total land area of the CF producers is about three times that of the NCF producers. According to the Vietnamese government policy on promoting large-scale farms since 2014, CF producers must be located in the fields that are far from residential zones and have large land area for installation of MTPs. Whereas, due to lack of capital, most NCF producers are still in residential zones. As a result, CF producers have more land for waste treatment than NCF do.

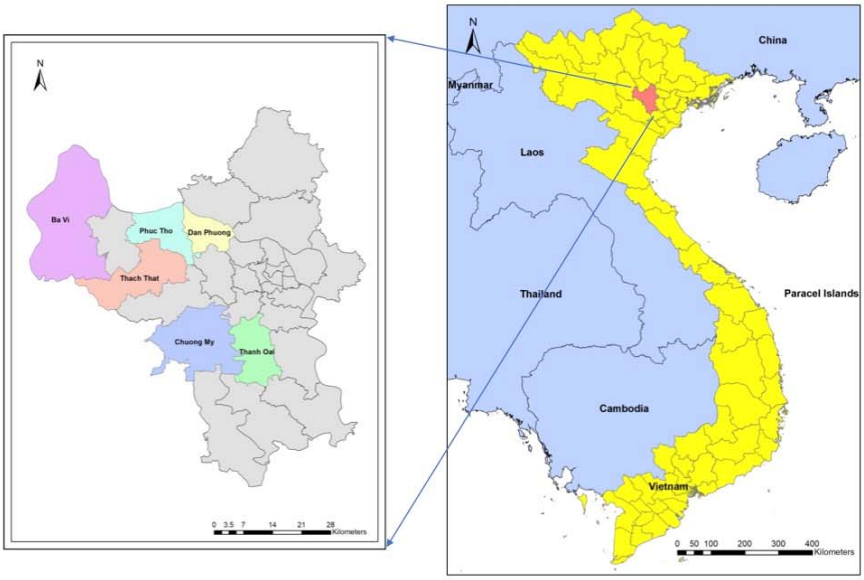

Fig.1. Maps of the study site

The average number of pigs raised by CF producers (1,208 heads) is much higher than that of NCF producers (69 heads). Most CF producers rear farrow-to-finish pigs, with the number of pigs confined in a standard CF piggery being about 500 heads. Piglets provided by the agribusiness firms are transported to the farms, with the average weight of the piglet being about 7 kg, whereas the weight of a slaughter pig is about 100 kg. It takes about 5.5 months to finish the circle from a piglet to a slaughter pig. At the end of the circle, the slaughter pigs are collected and transported to the firms. The firms pay for the farms the allowance that calculated by the total liveweight of the slaughter pigs multiplying the wage by kilograms. The CF producers reported to us that they earn a wage from $0.11 to $0.15 per kg, depending on the quality of piggeries, productivity, and feed conversion ratio (FCR), which is estimated by feed intake divided by weight gain.

CF producers could cut down the volume of water for washing and cooling piggeries, especially in summer, because of using artificial ventilation. Therefore, the daily water use per pig of CF producers was lower than that of NCF producers. With a huge volume of manure emitted, CF

producers invest a large capital in the construction of MTPs; however, their MTPs construction costs per pig are much lower than that of NCF producers. Nevertheless, there is no statistically significant difference in maintenance costs between them.

Table 1: Socioeconomic characteristics of pig farms

	Unit	NCF producer (N=224)	CF producer (N=46)	t-value [a]
Age of farm head	year	50.9 (10.3)	46.6 (8.3)	3.0***
Experience in pig production	year	20.5 (11.0)	7.8 (9.1)	8.2***
Education	year	8.0 (3.2)	9.5 (3.6)	2.4***
Knowledge of manure treatment	item	1.8 (1.0)	3.3 (1.3)	6.6***
Total land of farm including breeding and crop land areas	m^2	3,188.5 (9,782.8)	10,802.2 (13,149.5)	3.7***
Land for installation of MTPs	m^2	118.3 (1,271.5)	1,003.3 (936.5)	5.4***
Total number of pigs	head	69.6 (136.4)	1,208.9 (605.6)	12.6 ***
Daily water use per pig	liter	282.2 (250.1)	63.6 (27.4)	12.7***
Construction cost of MTPs per pig	$	25.4 (31.4)	8.1 (6.0)	7.5***
Annual maintenance cost of MTPs per pig	$	0.006 (0.016)	0.004 (0.011)	NS
Annual crop income	$	638.3 (3,079.1)	385.3 (1,211.9)	NS
Annual livestock income excluding pig production	$	985.3 (4,179.8)	3,117.5 (12,501.9)	NS
Annual off-farm income	$	2,568.9 (5,709.5)	1,250.0 (2,636.2)	2.4***
Annual pig production income	$	452.8 (2,278.2)	15,243.9 (13,040.5)	7.6***

[a]: t-values of two sample t-tests with unequal variances were conducted. *** and ** are statistically significant at the 1% and 5% levels, respectively. NS means not significant. Standard deviations are in parentheses.

We estimate the income from pig rearing for CF producers as the total received allowance subtracting depreciation, labor, and water and electricity costs. The income of CF producers is more stable and higher than that of NCF producers because NCF pig production is significantly affected by the market. Contrary to CF producers who are engaged in monoculture farming that produces only pigs, NCF producers also do off-farm jobs. Therefore, the average annual off-farm income of NCF producers is higher than that of CF producers. However, there is no significant difference in other income sources between CF and NCF producers.

3.2. Manure treatment plants

Slurry is discharged into one of three MTPs. In MTP 1, the raw slurry is released into lagoons or cesspits, then discharged into public water ways when exceeding the storage. In MTP 2, the slurry is pushed into biogas plants, with liquid digestate from the plants being stored in tanks or directly discharged into public water ways. In MTP 3, the slurry is pushed into biogas plants, with liquid digestate from the biogas plants flowing to stabilization ponds and being finally discharged into the environment. This MTP combines anaerobic and aerobic processes, which helps to remove organic (BOD and COD) and nutrient matters (nitrogen and phosphorus) (Tilley, 2014).

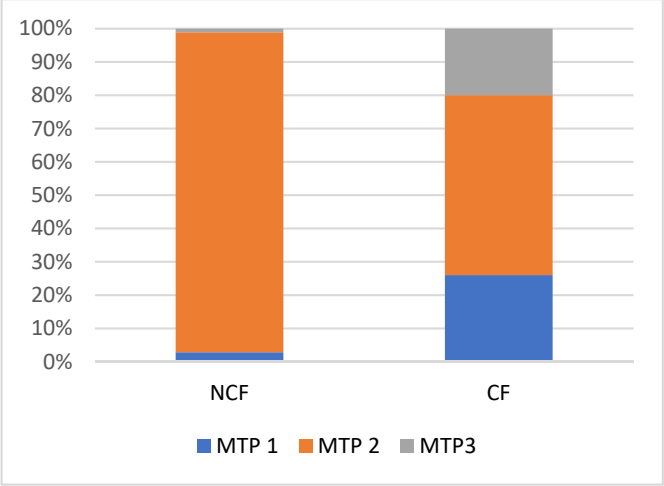

Fig.2. Distribution of manure treatment plants

More than 80% of producers in the study area use MTP 2, with the share of other MTPs accounting for approximately 20%. Half of CF producers use MTP 1 and MTP 3 (Fig.2) since they have large land available for installing slurry lagoons or stabilization ponds. Contrary to CF producers, NCF producers prefer installing MTP 2 because they are located in residential zones, thus having small land for installing the lagoons or ponds. For MTP 2, biogas plants do not occupy large land area because biogas digesters are installed underground. The average land area of MTP 2 is 116 m^2, while it is 1,151 m^2 for MTP 3 and 2,033 m^2 for MTP1 (Table 2). Second, the average construction costs of MTP 2 are lower than that of the other MTPs. However, the number of pigs served by MTP 2 is much lower than by other MTPs. MTP 2 and MTP 3 incur annual maintenance costs because sludges in biogas plants need to be removed regularly. In addition, biogas digesters, which are made

from plastic material, can be easily pierced, thus needing minor repairs regularly. The most common problem of small-scale biogas digesters is the leakages from digesters leading to undesired methane (CH4) emissions, which sometimes stops the biogas plants from functioning (Roubík et al., 2016).

Table 2: Summary of wastewater treatment plants

	Unit	MTP 1 (N=18)	MTP 2 (N=200)	MTP 3 (N=11)
Number of pig	head	1,204.7[a] (1,011.0)	191.2[b] (361.1)	947.8[a] (478.4)
Land occupation	m^2	2,033.9[a] (4,419.8)	116.9[b] (334.5)	1,151.8[a] (574.4)
Construction cost	$	4,058.0[a] (3,242.6)	1,833.8[b] (3,240.5)	11,747.90[c] (9,206.6)
Annual maintenance cost	$	0.0[a] -	9.1[b] (29.5)	83.6[c] (153.9)

Pairwise comparison of means with unequal variances were conducted. In each row, the different superscripts represent statistically significant difference in the pair.

3.3. Pollution levels of pig farms

To compare the pollution levels of the farms, we use five parameters as total suspended solid (TSS), chemical oxygen demand (COD), biological oxygen demand (BOD), total nitrogen (TN) and total phosphorus (TP). In general, effluent quality of both CF and NCF producers are far to meet the livestock effluent standards of Vietnam, warning the serious environmental pollution in the country. Pollutants' concentrations of the of CF producers are lower than that of NCF producers, especially in the concentrations of TN and TP. In fact, CF producers installed more advanced MTPs than that of NCF, resulting better removal efficiency of the nutrient matter.

Table 3: Pollution levels of pig farms

Parameters (mg/l)	NCF	CF	t value
TSS	3,203.3	2,106.3	1.5*
COD	1,447.2	1,272.4	NS
BOD	1,094.4	898.4	1.3*
TN	819.0	400.7	3.2***
TP	150.1	80.3	2.7***

Pairwise comparison of means with unequal variances were conducted. *** and ** are statistically significant at the 1% and 5% levels, respectively. NS means not significant.

To compare the pollutant removal efficiency of MTPs, we analyze wastewater samples discharged from them. In general, pollutant concentrations of MTP 3 are lowest, followed by MTP 2 and that of MTP 1 are highest (Table 4). The main functions of MTP 1 are to remove BOD and settle

the undigested material and non-degradable solids as bottom sludge. With the large surface area, it can remove total nitrogen. MTP 2 helps to remove most of the BOD and COD and small amounts of nitrogen (Van Duy & Vu Dinh, 2010). MTP 3 combines anaerobic and aerobic processes, which helps to remove organic (BOD and COD) and nutrient matters (nitrogen and phosphorus) (Tilley, 2014). Compared to the others, MTP 3 is the best one to reduce pollutant concentrations, so it should be developed. However, because this MTP requires substantial land area, it is more suitable for CF producers than for NCF producers.

Table 4: Pollution levels of manure treatment plants

Parameters (mg/l)	MTP 1	MTP 2	MTP 3
TSS	3,162.7[a]	2,807.5[a]	1,142.1[b]
COD	2,075.8[a]	1,297.5[b]	834.5[c]
BOD	1,478.6[a]	958.0[b]	626.2[c]
TN	372.5[a]	722.3[b]	254.4[c]
TP	64.7[a]	134.1[b]	69.0[a]

Pairwise comparison of means with unequal variances were conducted. In each row, the different superscripts represent statistically significant difference in the pair.

4. Conclusions

Previous studies in Vietnam hardly addressed the influence of production patterns on livestock waste management and pollution levels. Therefore, this study compares two important production patterns, namely, CF and NCF, in Vietnamese pig production. CF producers have less severe pollution levels than NCF producers do because they have more knowledge of manure treatment, utilize a larger land area for manure treatment plants (MTPs), and use less water for washing piggeries. With this result confirming the importance of environmental and economic aspects for supporting the development of CF pig producers in Vietnam.

This study points out that, compared with other MTP types, MTPs combining biogas plants and stabilization ponds show the least pollution level. However, this combination requires a large land area; therefore, it is only suitable for CF producers or large-scale farms that own sizable land. Until more advanced technologies are developed, this cost-effective combination still offers an acceptable pollution level. Regarding the MTPs of NCF producers located in residential zones, future research should study technologies suitable for undersized land area.

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