การจัดการเรียนรู้ของเกษตรกรผู้เลี้ยงสุกรขนาดเล็กต่อการยอมรับการผลิตก๊าซชีวภาพร่วม: กรณีศึกษาจังหวัดราชบุรี

Learning Management of Small-Scale Pig Farmers to Adopt Biogas Coproduction: A Case Study of Ratchaburi Province

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บทคัดย่อ

งานวิจัยนี้มีวัตถุประสงค์เพื่อ 1) ระบุคุณลักษณะของฟาร์มและเกษตรกรผู้เลี้ยงสุกรขนาดเล็ก ที่ส่งผลต่อการจัดการเรียนรู้ในการยอมรับการผลิตก๊าซชีวภาพร่วม (BcP) 2) หาคุณลักษณะของ BcP ที่มีอิทธิพลต่อการจัดการเรียนรู้ของเกษตรกรผู้เลี้ยงสุกรขนาดเล็กต่อการยอมรับ BcP และ 3) ประเมินความคิดเห็นของเกษตรกรผู้เลี้ยงสุกรขนาดเล็ก เจ้าหน้าที่ภาครัฐ และผู้เชี่ยวชาญ เกี่ยวกับการยอมรับ BcP การวิจัยครั้งนี้ใช้วิธีการวิจัยแบบผสมผสาน โดยรวบรวมทั้งข้อมูลเชิงปริมาณและข้อมูลเชิงคุณภาพ เครื่องมือที่ใช้ในการศึกษาประกอบด้วย 1) แบบสอบถาม และ 2) การสัมภาษณ์แบบกึ่งโครงสร้าง กลุ่มตัวอย่างคือ 1) เกษตรกรผู้เลี้ยงสุกรขนาดเล็กในจังหวัดราชบุรี จำนวน 90 คน 2) เจ้าหน้าที่ภาครัฐ จำนวน 3 คน และ 3) ผู้เชี่ยวชาญด้านวิชาการและอุตสาหกรรม จำนวน 3 คน โดยการเลือกตัวอย่างแบบเจาะจง สถิติที่ใช้ในการวิเคราะห์ข้อมูลเชิงปริมาณ ได้แก่ ร้อยละ ค่าเฉลี่ย ส่วนเบี่ยงเบนมาตรฐาน สถิติทดสอบที (T-test) การวิเคราะห์ความแปรปรวน (ANOVA) และการวิเคราะห์การถดถอยพหุคูณ ในส่วนการวิเคราะห์ข้อมูลเชิงคุณภาพใช้การวิเคราะห์เนื้อหา ผลการศึกษาพบว่า 1) ระดับการศึกษา รายได้ของฟาร์มต่อเดือน จำนวนสุกรในฟาร์ม ประสบการณ์การยอมรับเทคโนโลยี และประสบการณ์ด้านเครือข่ายหรือการทำงานร่วมกัน ส่งผลต่อการจัดการเรียนรู้ในการยอมรับ BcP ของเกษตรกรผู้เลี้ยงสุกรขนาดเล็ก อย่างมีนัยสำคัญทางสถิติที่ระดับ 0.05 2) คุณลักษณะของ BcP ได้แก่ ความเข้ากันได้ (β = 0.670) ประโยชน์เชิงเปรียบเทียบ (β = 0.279) ความยุ่งยากซับซ้อน (β = 0.124) และสามารถทดลองใช้ (β = 0.113) ส่งผลต่อการจัดการเรียนรู้ของเกษตรกรผู้เลี้ยงสุกรขนาดเล็กต่อการยอมรับ BcP ร้อยละ 70.2 ในเชิงบวกอย่างมีนัยสำคัญทางสถิติที่ระดับ 0.05 3) เกษตรกรผู้เลี้ยงสุกรขนาดเล็กมีการยอมรับ BcP ในอัตราที่สูงขึ้นเมื่อมีการสนับสนุนทางการเงิน ความรู้และความเชี่ยวชาญ การแนะนำความปลอดภัยทางชีวภาพ การเยี่ยมชมกรณีจริงและการสังเกต และการมีส่วนร่วมของหน่วยงานภาครัฐ

คำสำคัญ : การยอมรับ, ก๊าซชีวภาพ, เกษตรกรผู้เลี้ยงสุกรขนาดเล็ก

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Abstract

The objectives of this research were 1) to identify farm and small-scale pig farmers' characteristics that affected their learning management to adopt biogas coproduction (BcP) 2) to determine the attributes of BcP that predicted small-scale pig farmers' learning management to adopt BcP, and 3) to evaluate small-scale pig farmers', ministry officials', and experts' perspectives on adoption of BcP. The research employed mixed methods using quantitative and qualitative data. The research instrument used in the study consisted of 1) a questionnaire and 2) a semi-structured interview. A sample was selected using purposive sampling, including 1) 90 small-scale pig farmers in Ratchaburi province, 2) 3 ministry officials, and 3) 3 academic and industry experts. Statistics used in quantitative data analysis included percentage, mean, standard deviation, T-test, ANOVA, and multiple regression analysis. Analyses of qualitative data used content analysis. The results of the study revealed that 1) education level, monthly farm income, number of pigs on farm, technology adoption experience, and networking or collaboration experience affected learning management to adopt BcP of small-scale pig farmers statistically significant at the 0.05 level., 2) Compatibility (β = 0.670), relative advantage (β = 0.279), complexity (β= 0.124), and trialability (β = 0.113) were predictors of small-scale pig farmers' learning management to adopt BcP at the 70.2 percentage, with positive and statistical significance at the 0.05 level., and 3) Small-scale pig farmers were more likely to adopt BcP at a higher rate when it had financial support, knowledge and expertise, an introduction to biosecurity, actual case visits and observations, and involvement by state agencies.

Keyword : Adoption, Biogas, Small-scale pig farmers

Introduction

The pig industry plays a crucial role in the global and national economies, food supply chains, and food security. The Food and Agriculture Organization of the United Nations [FAO] has revealed that there was pig meat in more than one-third of global meat supplies in 2020 (Food and Agriculture Organization of the United Nations, 2022). Thailand is one of the top ten major pig producers in Asia, accounting for 894 thousand tonnes of pig meat production (Food and Agriculture Organization of the United Nations, 2022) and with more than 15.8 million pigs raised in 2022 by 149,575 pig farms (Office of Agricultural Economics, 2022). However, pig farming has caused significant environmental issues through the improper disposal of pig manure and wastewater, including emissions of greenhouse gases, pollution of the water and soil, the spread of zoonotic pathogens, and the release of extreme odors that disturb their neighbors, degrade the quality of life in nearby communities, and negatively affect human health. As a result, enhanced pig manure and wastewater management resource utilization solutions are required to develop sustainable pig farming (Chen et al., 2021). Biogas production is the most appropriate and sustainable method for managing pig manure and wastewater using the waste-to-energy concept. Biogas is produced through an anaerobic digestion process whereby bacteria act on bio-digestible materials (animal manure and wastewater), referred to as feedstock. Biogas is a clean, renewable form of energy that can be used as a fuel for electricity generation. Organic fertilizer, which is a solid by-product of biogas production, enables the recycling of nutrients. Moreover, biogas production can help solve the

environmental problems of pig farming as aforementioned effectively as well as meet the sustainable development goals (SDGs) of economic, social, and environmental pillars (Obaideen et al., 2022).

The Thai government recognized the advantages of biogas. As a result, there is a national policy known as the alternative energy development plan, which aims to increase the proportion of electricity generation from renewable energy to 30 percent of total energy consumption by 2037, accounting for 1,183 MW from biogas (Department of Alternative Energy Development and Efficiency, 2020). To meet this goal, the Thai government encourages pig farmers to produce biogas on their farms by providing financial subsidies of 50 percent of the investment in building systems. However, the adoption of biogas production on farms among small-scale pig farmers is still very low due to a lack of financial capital, skilled labor, and information, a deficiency of knowledge, and an inadequate feedstock supply (Obaideen et al., 2022). This low rate of adoption is a critical issue since small-scale pig farmers constitute over two-thirds of commercial pig producers in Thailand (Department of Livestock Development, 2022). In addition, small-scale pig farmers dispose of livestock waste improperly by depositing it in a pond and then discharging it into surface water as well as using low biosecurity and management practices. These result in a high risk of disease transmission and environmental damage that cause significant economic losses throughout the entire pig industry and serious social problems (Chan et al., 2022). To relieve the problems, biogas coproduction (BcP) is a suitable option for small-scale pig farmers. BcP is defined as a group of local individuals taking collective action to produce biogas at the local level, which is considered community renewable energy (Mukherjee, 2020). The approach requires small-scale pig farmers to come together to form a cooperative and to manage the collection of manure and wastewater from different farms for transportation to a centralized location, a biogas power plant, that would treat the waste and turn it into biogas for electricity generation and then sale to the national electrical grid. Fertilizer, as a by-product from biogas production, can be sold to farmers growing crops (Worawimut et al. 2020).

The learning management to adopt community energy projects is regarded as one of the essential policy-relevant social science elements as the decision-making stage leads to the implementation stage (Mancini & Raggi, 2022). In order to succeed in the sustainable environmental solution in pig farming, understanding the circumstances and factors that influence small-scale pig farmers' BcP adoption is vital for designing and developing targeted policies or initiatives to support adoption. However, there is a lack of research on BcP adoption by small-scale pig farmers, especially in Thailand. Therefore, this research was to investigate small-scale pig farmers' learning management to adopt BcP in a cooperative form using the theory of diffusion of innovation in order to identify the factors influencing BcP adoption. The findings of this research may aid policymakers in proposing policies and actions to effectively promote BcP adoption among small-scale pig farmers and lead to sustainable pig farming.

Objectives

This study aimed to:

1. identify farm and small-scale pig farmers' characteristics that affected their learning management to adopt BcP.
2. determine the attributes of BcP that predicted small-scale pig farmers' learning management to adopt.
3. evaluate small-scale pig farmers', ministry officials', and experts' perspectives on the adoption of BcP.

Literature Reviews

1. Characteristics of Farmers and Farms

Characteristics of farmers as significant determinants of the innovation adoption decision. The farmer typically serves as both the owner and manager, as well as the main decisions-maker of the farm. The farmer's characteristics are important in defining an innovative attitude. This is because the characteristics of the farmers influence the farm's overall management style (Sishodia et al., 2020). Moreover, the demographic characteristics of farmers influence perception, understanding, decision-making, and interpretation, causing individual differences (Kerdngern et al., 2021).

For example, gender is an important variable. Females and males are different not only in the physical aspect, mental state, thoughts, aptitudes, emotions, and feelings but also in psychology, including values and attitudes. Age is the one factor affecting human communication behavior since age determines and indicates the person's experiences in various matters, which is an indicator or expression of a person's thoughts, beliefs, and reactions to various events that occur. Education level is a significant characteristic that influences the thoughts, attitudes, expertise, and interests of an individual. People receive different education levels in different eras and educational systems; there will also be different feelings, thoughts, ideologies, needs, thoughts, and attitudes. Income is an individual economic opportunity, which is an indicator of what will determine behavior and lifestyle for adopting or choosing to buy various products and services (Kerdngern et al., 2021).

Characteristics of farms play a major role in influencing the decision to adopt an innovation. The size of farms and the quantity of livestock owned affect the adoption of new technology by accounting for economies of scale. Larger farms have more infrastructure and resources to support innovation uptake, while small farms suffer from a unique circumstance known as resource poverty. Resource poverty is caused by a variety of problems specific to small farms, including functioning in a highly competitive economy, budgetary limits, a lack of professional experience, and vulnerability to external pressures (Sishodia et al., 2020).

2. Diffusion of Innovation (DOI) Theory

The DOI theory is used to explain the decision to adopt innovation by considering the perceived innovation characteristics. The attributes have been widely relied on in research contexts where there is inquiry into the adoption of new practices in farming. (Rogers, 2003) proposed a focus on five attributes required for an innovation to be adopted and spread. The first of these is relative advantage, which refers to farmers' perceptions of the advantage of the innovation compared to their existing practices. Compatibility refers to how well the innovation meshes or merges with their practices. Complexity relates to the difficulty or ease of use of the innovation by farmers. Trialability involves the ability to test or try the innovation before adoption. Observability relates to whether farmers can observe tangible effects of the innovation prior to adoption (Rogers, 2003).

Based on a review of literature on the characteristics of farmers and farms as well as the perceived innovation characteristics of DOI theory, these influence innovation adoption. Figure 1 shows the research framework used to investigate the characteristics that influence small-scale pig farmers' learning management to adopt BcP.

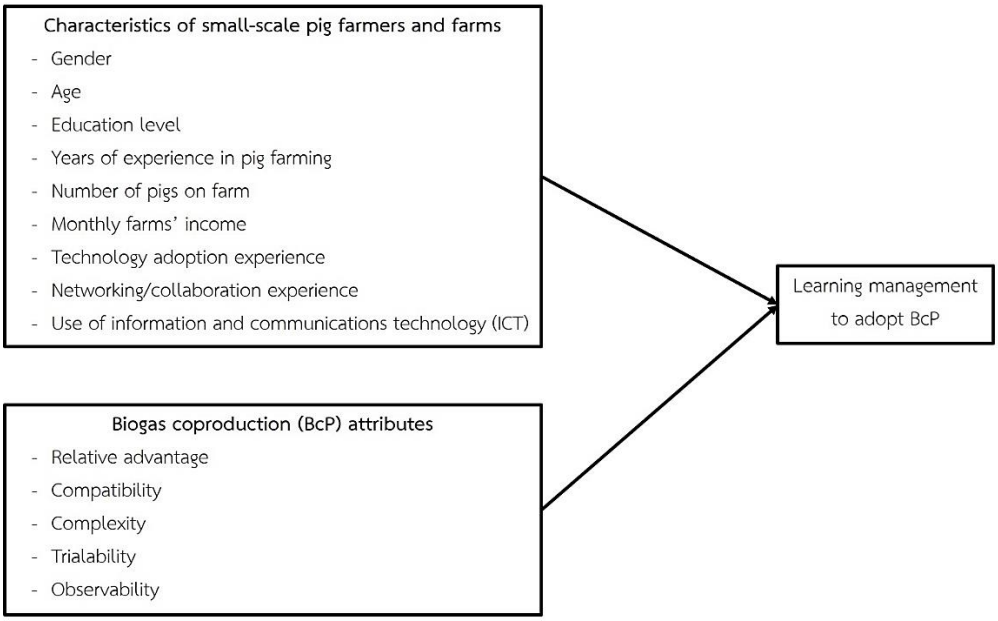

Figure 1 Research framework.

Methodology

This study employed mixed methods. The quantitative and qualitative data were employed concurrently and analyzed the study's results.

1. Instruments

Collecting the quantitative data used a structured questionnaire regarding the learning management of small-scale pig farmers to adopt biogas coproduction. The questionnaire was constructed by consisting of two parts, as follows:

The first part related to small-scale pig farmers' and farms' information, including gender, age, education level, years of experience in pig farming, number of pigs on farm, monthly farms' income, technology adoption experience, networking/collaboration experience, and use of information and communications technology (ICT). This part of the questionnaire consisted of nine close-ended items. The information in this part regarding the characteristics of farmers and farms that influence the decision to adopt an innovation is related to perception, understanding, decision-making, and interpretation of adopters, causing individual differences.

The second part related to the learning management of small-scale pig farmers to adopt biogas coproduction. This part of the questionnaire consisted of five attributes of DOI, including the attributes of relative advantage, compatibility, complexity, trialability, and observability. The questions in each attribute were constructed by relating to the definition of each attribute as follows

a. Relative advantage refers to small-scale pig farmers' perceptions of the advantage of the BcP compared to their existing practices.
b. Compatibility refers to how well the BcP meshes or merges with small-scale pig farmers' practices.
c. Complexity refers to the difficulty or ease of use of the BcP by small-scale pig farmers.

d. Trialability refers to the ability to test or try the BcP before adoption by small-scale pig farmers.
e. Observability refers to whether small-scale pig farmers can observe tangible effects of the BcP prior to adoption.

The multiple questions in each attribute in this part were developed from (Sishodia et al., 2020) questionnaire, which validated the instrument, due to a similar study focused on finding the factors influencing agricultural technology adoption by farmers based on the DOI theory. A 5-point Likert scale (i.e., strongly disagree, disagree, neutral, agree, and strongly agree) was used in this part of the questionnaire. The questions were divided into five attributes, as follows: 1) Relative advantage consisted of 4 items; 2) Compatibility consisted of 7 items; 3) Complexity consisted of 3 items; and 4) Trialability consisted of 2 items. 5) Observability consisted of 5 items.

Collecting the qualitative data used a semi-structured interview regarding small-scale pig farmers' officials' and experts' perspectives to find the reasons for BcP adoption and factors that support small-scale pig farmers to increase BcP adoption levels. The questions consisted of all 21 items.

2. Participants

All 90 small-scale pig farmers (50-500 pigs), who have been farming in the Ratchaburi province for at least five years and were not producing biogas, were selected using purposive sampling for collecting the quantitative data. Qualitative data were collected from a total of 96 individuals selected using purposive sampling, including 90 farmers, 3 agricultural ministry officials, and 3 academic and industry experts in biogas production.

3. Process and Data Collection

Step 1: Several documents, concepts, theories, and research work related to the adoption of agricultural practices and biogas technology had been studied.

Step 2: Research instrument was constructed and submitted to three experts to assess content validity using the method of the index of Item Objective Congruence (IOC). The results of the IOC were 0.87, which was over 0.5, suggesting that the questions were consistent and accurate. Then, the instrument was tried out 30 samples with similar characteristics to the actual sample. The reliability of the instrument using Cronbach's Alpha Coefficient (α) was 0.828.

Step 3: The research instrument was used to collect data. The data were collected through face-to-face interviews.

4. Data Analysis

Analysis of quantitative data employed both descriptive and inferential statistics using statistical analysis programs. The percentage, mean, and standard deviation were all used in descriptive statistical analysis. T-test, ANOVA, and multiple regression analysis were used for inferential statistical analysis.

Analysis of qualitative data employed content analysis to extract recurring themes and suggestions, which were then grouped into the categories of attributes.

Hypotheses of the Research

1. Different characteristics of small-scale pig farmers and farms will affect small-scale pig farmers' learning management to adopt BCP in different.
2. There is a positive influence of BcP attributes (relative advantage, compatibility, complexity, trialability, and observability) on the perceived BcP adoption of small-scale pig farmers.

Results

1. Small-Scale Pig Farmers' and Farms' Characteristics and Adoption of BcP

Small-scale pig farmers were 58 percent male and 42 percent female. The majority (42%) were between the ages of 50 and 59. Forty-five percent had some form of post-secondary education, ranging from a diploma (13%) to a bachelor's degree (32%). The majority (61%) had more than 15 years of experience in pig farming. Most farms (48%) had from 301 to 500 pigs. Most farmers (32%) had an average monthly farm income of 20,000–50,000 Baht. Eighty-one percent of farmers had ever adopted a new innovative technology for use on their farms. Seventy-four percent had ever experienced networking with or collaborating with other pig farmers. In terms of information and communications technology (ICT) use, 90 percent relied on mobile phones.

Table 1 and Table 2 present the results of the analysis of the effect of small-scale pig farmers' and farms' characteristics on learning management to adopt BcP. Education level (p = 0.000), number of pigs on the farm (p = 0.000), monthly farms' income (p = 0.000), technology adoption experience (p = 0.000), and networking or collaboration experience (p = 0.000) did affect the learning management to adopt BcP of small-scale pig farmers statistically significant at the 0.05 level. This means that the different education levels, number of pigs on the farm, monthly farms' income, technology adoption experience, and networking or collaboration experience of small-scale pig farmers had different effects on their learning management to adopt BcP. However, small-scale pig farmers' gender, age, years of experience, and use of ICT did not significantly affect their learning management to adopt BcP.

Table 1 Results of F-test of the effect of farmers' and farms' characteristics on learning management to adopt BcP.

Variables	$\bar{x}$	S.D.	F	Sig
Education level			12.499	0.000*
Primary	3.38	0.74		
Secondary	3.50	0.58		
Higher secondary or equivalent	4.40	0.55		
Diploma or equivalent	4.50	0.59		
Bachelor's degree	4.55	0.67		
Number of pigs on farm			36.907	0.000*
Less than 100	4.05	0.96		
100-300	4.50	0.67		
301-500	4.57	0.70		
Monthly farms' income			9.673	0.000*
Less than 20,000 Baht	4.00	0.49		
20,000-50,000 Baht	4.13	0.64		
50,001-80,000 Baht	4.22	0.67		
More than 80,000 Baht	4.71	0.69		

*$p < .05$

Table 2 Results of t-test of the effect of farmers' and farms' characteristics on learning management to adopt BcP.

Variables	$\bar{x}$	S.D.	t	Sig
Technology adoption experience			4.640	0.000*
Yes	4.67	0.52		
No	4.16	0.75		
Networking/collaboration experience			3.814	0.000*
Yes	4.50	0.82		
No	4.17	0.85		

*$p < .05$

Table 3 presents the results of the difference between means of pairwise comparisons for education level using the least significant difference (LSD) method. It found that small-scale pig farmers with higher education levels than primary had better learning management to adopt BcP than those with primary, and small-scale pig farmers with higher education levels than secondary also had better learning management to adopt BcP than those with secondary.

Table 3 Results of difference between means of pairwise comparisons for education level.

Education level		Primary	Secondary	Higher secondary or equivalent	Diploma or equivalent	Bachelor's degree
	$\bar{x}$	3.38	3.50	4.40	4.50	4.55
Primary	3.38	0.00	0.12	1.02	1.12	1.17
Secondary	3.50	-0.12 (0.00)*	0.00	0.90	1.00	1.05
Higher secondary or equivalent	4.40	-1.02 (0.00)*	-0.90 (0.02)*	0.00	0.10	0.15
Diploma or equivalent	4.50	-1.12 (0.00)*	-1.00 (0.00)*	-0.10	0.00	0.05
Bachelor's degree	4.55	-1.17 (0.00)*	-1.05 (0.00)*	-0.15	-0.05	0.00

*$p < .05$

Table 4 presents the results of the difference between means of pairwise comparisons for number of pigs on farm using the least significant difference (LSD) method. It found that small-scale pig farmers with 100 to 500 pigs had better learning management to adopt BcP than those with less than 100 pigs, and small-scale pig farmers with 301 to 500 pigs also had better learning management to adopt BcP than those with 100-300 pigs.

Table 4 Results of difference between means of pairwise comparisons for number of pigs on farm.

Number of pigs on farm		Less than 100	100-300	301-500
	$\bar{x}$	4.05	4.50	4.57
Less than 100	4.05	0.00	0.45	0.52
100-300	4.50	-0.45 (0.00)*	0.00	0.07
301-500	4.57	-0.52 (0.00)*	-0.07 (0.00)*	0.00

*$p < .05$

Table 5 presents the results of the difference between means of pairwise comparisons for monthly farms' income using the least significant difference (LSD) method. It found that small-scale pig farmers with an average monthly farm income of 20,000 to more than 80,000 Baht had better learning management to adopt BcP than those with less than 20,000 Baht, and small-scale pig farmers with an average monthly farm income of more than 80,000 Baht also had better learning management to adopt BcP than those with 20,000-50,000 Baht.

Table 5 Results of difference between means of pairwise comparisons for monthly farms' income.

Monthly farms' income		Less than 20,000 Baht	20,000-50,000 Baht	50,001-80,000 Baht	More than 80,000 Baht
	$\bar{x}$	4.00	4.13	4.22	4.71
Less than 20,000 Baht	4.00	0.00	0.13	0.22	0.71
20,000-50,000 Baht	4.13	-0.13 (0.00)*	0.00	0.09	0.58
50,001-80,000 Baht	4.22	-0.22 (0.00)*	-0.09	0.00	0.49
More than 80,000 Baht	4.71	-0.71 (0.00)*	-0.58 (0.02)*	-0.49	0.00

*$p < .05$

2. Small-Scale Pig Farmers' Adoption of BcP Analyzed by Attributes

As shown in Table 6, the results of the multiple regression analysis indicated that the R-square (R^2) of a regression model for this relationship is 0.702, suggesting that the model is goodness-of-fit to the data. Compatibility (p = 0.000, Beta (β) = 0.670), relative advantage (p = 0.004, β = 0.279), complexity (p = 0.045, β = 0.124), and trialability (p = 0.047, β = 0.113) were positive and significant predictors of the small-scale pig farmers' learning management to adopt, while observability (p = 0.450) was not. The standardized equation of predicting small-scale pig farmers' learning management to adopt BcP (Y) is shown in Equation (1).

Y= 0.670 (Compatibility) + 0.279 (Relative advantage) + 0.124 (Complexity) + 0.113 (Trialability) (1)

Table 6 Results of multiple regression analysis.

Attributes	Unstandardized coefficients		Standardized coefficients	t	Sig
	B	Std. Error	Beta		
(Constant)	-0.057	0.761		-0.075	0.941
Relative advantage	0.572	0.189	0.279	3.028	0.004*
Compatibility	0.624	0.072	0.670	8.641	0.000*
Complexity	0.229	0.099	0.124	2.307	0.045*
Trialability	0.218	0.147	0.113	1.478	0.047*
Observability	-0.152	0.200	-0.061	-0.759	0.450
F=29.191, R=0.838, R^2= 0.702, Sig. = 0.00					

*$p < .05$

3. Small-Scale Pig Farmers' Officials' and Experts' Perspectives on the Adoption of BcP

As the results in Table 6, the relative advantage, compatibility, complexity, and trialability all had positive and significant effect on the small-scale pig farmers' learning management to adopt BcP. The results of the reasons for BcP adoption are organized according to each attribute as presented below.

a. Relative Advantage

According to the qualitative data, BcP relative advantage positively and significantly affected the small-scale pig farmers' learning management to adopt BcP. This is because the small-scale pig farmers substantially perceived BcP benefits as superior to their current practice in aspects of social harmony and cohesion, financial advantage, social status, and workload reduction. All of these aspects contributed to BcP adoption

In relation to social harmony and cohesion, the farmers were very motivated to join BcP to solve the problems of environmental pollution caused by their pig farming in a sustainable way. This is because their pig farming has negative effects on the community and causes social problems. Participation of the farmers in BcP could help change the neighbors' and officials' attitudes regarding their pig farming from negative to positive since BcP helps create a better environment and decreases the incidence and spread of disease in pigs.

In terms of financial advantage, the farmers could earn increased income by selling electricity as well as manure and residual treated wastewater from the BcP process as fertilizer.

Regarding social status, the cooperative's formation would give the small-scale pig farmers more power in expressing their opinions, making decisions, and negotiating with the government or non-governmental organizations (NGOs), as well as all the associated rights, responsibilities, and privileges that come with the status of energy producers and owners.

In terms of workload reduction, manure and wastewater would be removed from their farms by a fecal suction truck every day for use in BcP, reducing the farmers' practice steps in manure and wastewater management on their farms.

b. Compatibility

According to the qualitative data, BcP compatibility had significantly the strongest effect on the farmers' learning management to adopt BcP. This is because the small-scale pig farmers perceived BcP as compatible and suitable with their current practices, operations, and farm location, as well as meeting government policy requirements for waste management, environmental protection, and renewable energy production to increase energy security. These factors contributed to the adoption of BcP and resulted in the farmers being more likely to cooperate and work together within a cooperative, which is one of the most important attributes that BcP compatibility needs to have. Because of their participation in BcP, the farmers would operate within a cooperative with other farmers who share the same goal and would need to come together in a cooperative to overcome their limited capacity and coordinate with the government sector.

However, 52% of small-scale pig farmers had insufficient knowledge to use BcP, and 60% of these farmers were from the category of farmers with lower education levels in higher secondary, or equivalent. Forty-four percent of small-scale pig farmers had insufficient funds to carry out BcP, and 70% of these farmers belonged to the group of farmers whose monthly farm income was less than 50,001 Baht, and/or 58% were from the group whose number of pigs was less than 301 pigs.

c. Complexity

According to the qualitative data, the small-scale pig farmers' learning management to adopt BcP was affected positively and significantly by the BcP complexity. Although BcP would require changes in farms' operations along with the adoption of more complex tools, the majority (93%) of small-scale pig farmers perceived BcP as not too difficult to perform, understand, and skill. This is because the formation of the cooperative can help reduce the complexity through the provision of human and social capital that can compensate for a lack of knowledge and skill, especially if those with higher levels of education support the participation of those with lower levels. Moreover, the cooperative would be a hub of learner-centered community learning that encompasses the learning processes farmers need to increase their knowledge and skills.

d. Trialability

According to the qualitative data, the trialability of the BcP influenced small-scale pig farmers' learning management to adopt it positively and significantly. The majority (91%) of the small-scale pig farmers thought that they could be able to trial BcP, and 76% of the farmers would permit its use for a certain period of time to see the possibilities and benefits. However, some farmers (24%) refused to use it long enough to see its possibilities and benefits, and these farmers, who made up 68% of the group, earned less than 50,001 Baht of monthly farm income.

e. Factors that Support Increasing BcP Adoption Levels for Small-Scale Pig Farmers

i. Finances

Historically, small-scale pig farmers have had difficulty accessing financial incentives. The farmers need financial support from government agencies and NGOs to cover 50-100 percent of the start-up costs for BcP. The financial support would help increase the level of BcP adoption in attributes of relative advantage and compatibility.

ii. Knowledge and Expertise

Since the farmers don't have enough knowledge, expertise, and experience with biogas production to generate electricity and cooperatives, they need knowledge, information, training, and advice from

experts to be able to perform more easily and improve their capacity to increase technical, social, and economic knowledge and skills. From a technical perspective, the farmers need knowledge, training, and advice regarding setting up farms' layouts to have the systematic collection of pig manure in an efficient and secure way to implement it and the operational processes of the biogas power plant. From a financial and social perspective, the farmers need to know about the steps of the cooperative and their participation as cooperative members. Support in knowledge and expertise would enhance the BcP adoption level in attributes of complexity, compatibility, and relative advantage.

iii. Biosecurity

In the manure and wastewater collection procedure from different farms for use in BcP, a fecal suction truck would travel from farm to farm for collection. This may lead to the spread of pig diseases. To reduce disturbances and enhance biosecurity, experts and livestock officials need to introduce the farmers to measures to avoid and prevent disease transmission between farms from the fecal suction truck. The farmers have to comply with and conform their practices to the standardized procedures and operations. For example, to allow the truck to enter the farm as little as possible, the farmer would need to have a covered cement lagoon to collect manure and wastewater near where the truck enters, as well as a wash bay with disinfectant at the truck's entrance. With biosecurity support, the level of BcP adoption would rise in attributes of compatibility and relative advantage.

iv. Actual case visit and observation

The farmers should visit and observe medium- or large-scale pig farms that produce biogas for electricity generation to learn how to do each step and see how it works, as well as the Nongpho Ratchaburi Dairy Cooperative to learn about the workings and benefits of being a part of the cooperative. After visiting other farms and a cooperative, the farmers would recognize the benefits and possibilities. The actual case visit and observation would help increase the level of BcP adoption in attributes of trialability.

v. Involvement by state agencies

To participate in BcP, the farmers need to have a connection with and cooperate with the related agencies, including the local Energy Office, Livestock Office, Cooperative Promotion Office, and Electricity Authority, in order to receive advice, knowledge, information, support, and assistance. For example, visits to other farms and the Nongpho Ratchaburi Dairy Cooperative by the farmers must be organized by the livestock officials, who are procurement and coordinators, to regulate biosecurity issues and pig disease and limit entry. Having the involvement of state agencies would aid in increasing the level of BcP adoption across the attributes.

Conclusion and Discussion

This study was to determine the factors influencing small-scale pig farmers' learning management to adopt BcP in a cooperative form in Ratchaburi province, Thailand. The findings revealed that 1) the affecting factors of small-scale pig farmer and farm characteristics are education level, monthly farms' income, number of pigs on the farm, and experience of technology adoption and networking or collaboration. This is consistent with (Janthong et al., 2023) finding that education level and income from banana planting positively affected adoption. Higher farmers' levels of education and income were more likely to adopt the technology of banana production based on good agricultural practices (GAP) because they were more aware of its benefits, which led to faster technology adoption. (Tamirat & Abafita, 2021) found that the number of livestock possessions, education level, and farm income were positively and significantly correlated with farmers' adoption decisions

of row planting technology in wheat cropping. The average adoption probability was higher for those with a higher number of livestock possessions, a higher education level, and a higher farm income (23.5%, 26.5%, and 14%, respectively). (Putra et al., 2019) investigated the affecting factors of adoption of biogas technology with small-scale farmers in Indonesia. They discovered that farmers had positive experiences with technology adoption, resulting in easier adoption of new technology for use on their farms. (Mukeshimana et al., 2021) found that farmers had good collaboration experiences with partners and organizations affecting the adoption of biogas with success.

2) The factors of BcP characteristics, based on DOI theory, found that the attributes of relative advantage, compatibility, complexity, and trialability of BcP were positively affecting the small-scale pig farmers' adoption decisions, while observability was not. This is consistent with the findings of (Zheng et al., 2019), who found out the factors that affected farmers' decisions to adopt agricultural technology for use in farm operations in China and revealed that relative advantage and complexity had a positive influence on adoption. (Putra et al., 2019) studied the factors that influenced the adoption of biogas technology in Indonesia and found that the relative advantage and trialability influenced adoption for small-scale livestock and mixed-crop farmers. (Mannan et al., 2017) investigated the technological adoption of green fertilizer in Malaysia and found that compatibility had a positive effect on the adoption of green fertilizer technology by local farmers for paddy farming. (Shang et al., 2021) synthesized 54 cases to study the factors that influenced agricultural technology adoption decisions by farmers and discovered that the observability attribute of technology was not significant.

3) The perspectives on the BcP adoption of small-scale pig farmers, ministry officials, and experts revealed that in the BcP relative advantage attribute, the small-scale pig farmers strongly perceived the BcP benefits, especially in aspects of social harmony and cohesion, financial advantage, social status, and workload reduction, that would be better than their current practice. The benefits of the BcP relative advantage attribute in this context are consistent with what (Luangchosiri et al., 2021) discovered in Thailand in relation to community renewable energy. Socioeconomic benefits, poverty reduction, a higher standard of living and income, social cohesion, and increased human capacity were among the positives.

In the BcP compatibility attribute, the small-scale pig farmers perceived BcP as meeting the requirements of government policy for sustainable development goals as well as being compatible and suitable with their current practices, operations, and farm location. This compatibility is consistent with (Mottaleb, 2018) findings that new technology must be compatible with demand, existing practices, and the local environment that influenced its adoption.

In the BcP complexity attribute, the small-scale pig farmers perceived BcP that the formation of the cooperative could help reduce the BcP complexity, making it not too difficult to perform, understand, and related skills. This fits with what (Yasmin & Grundmann, 2019) found about the farmers' perceptions of the ease of use, access to support, resources, and skills of biogas in Pakistan that significantly impacted their adoption. In terms of working together, (Luangchosiri et al., 2021) found that Thai society was characterized by a collectivist culture and long-term relationships, making group formation for a community renewable energy project easy.

In the BcP trialability attribute, the small-scale pig farmers viewed BcP as something they could trial and wait to see its possibilities and benefits. Similarly, (Putra et al., 2019) explained that the trialability had a significant effect on farmers' adoption by familiarizing them with the technology.

To encourage the small-scale pig farmers to adopt BcP at a higher rate, the provision of financial support, knowledge and expertise, an introduction to biosecurity, actual case visits and observations, and participation by state agencies are needed. This is consistent with (Mahaarcha, 2019) finding that financial support and access to funding from external sources have resulted in faster and higher Thai farmers' adoption of adaptive strategies in their farming operations. According to (Larnlua et al., 2022) analysis of evolving agricultural products, farmers' success as agricultural producers needed to improve their knowledge and skills because farmers typically lack knowledge and experience. Moreover, in the western part of Saudi Arabia, (Makki & Mosly, 2020) investigated the factors influencing the learning management to adopt regarding technologies of renewable energy and found that addressing the risk of technologies was a key factor influencing the faster learning management to adopt. In actual case visits and observations, (Selvakkumaran & Ahlgren, 2019) found that engaging with current adopters or peer effects could also help compensate for trialability and observability barriers. (Sitthiwong et al., 2021) identified collaboration between various stakeholders, notably state agencies, as an important factor in initiating farmers' adoption of using microbes to manage pests.

Recommendation for applying the research results

Using the results of research on the learning management of small-scale pig farmers to adopt biogas coproduction for use with other innovations, those who use it must consider the differences between farmer and farm characteristics as well as innovation and technology characteristics to make the learning management of farmers to adopt innovation effectively.

Recommendation for future research

Future research should expand the scope, especially population, in other provinces to compare the data of each locality or region to create differences in opinions and obtain more diverse research results.

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