Research Article

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Green Economy: Development of Sustainable Dairy Cow Manure Utilization Processes for Farmers in the Northeastern Region of Thailand

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Abstract

The research aimed to develop and assess the satisfaction of a sustainable utilization process for dairy cow manure for farmers in the Northeast region of Thailand. The population comprised 162 dairy farmers in Pak Chong District, Nakhon Ratchasima Province, Thailand and the group sampling consisted of 150 dairy farmers in Pak Chong District by using a simple random sampling method to analyze the mean and exploratory factor analysis (EFA). Additionally, dairy cow's dung that was used to be processed into organic fertilizer could reduce methane emission by using a newly developed dairy cow's dung converter, which the organic fertilizer yield was qualified as follows: 1) Organic matter = 14.5% by weight, 2) C/N ratio = 11.24:1, 3) electrical conductivity = 4.23 decimals per meter. and 4) the valuable pH = 8.35. Then, the results of the test for the amount of the primary nutrients from the primary macronutrient analysis were total organic carbon = 9.1%, nitrogen = 0.8%, phosphorus = 0.6%, and potassium = 0.84% when using the new converter. Furthermore, it was piloted with a group of farmers in the aforementioned area. From the results, it was found that there were three factors affecting the satisfaction of dairy cow farmers toward the new dairy manure conversion process; namely, the features of the machine, the efficiency of the machine, and the appearance of the machine. Simultaneously, when taking all three factors to evaluate the satisfaction, the following results were found: 1) The features of the machine that is very important (mean = 4.283; SD = 0.661), 2) the efficiency of the machine that is very appropriate (mean = 4.280; SD = 0.528), and 3) the appearance of the machine that is very appropriate (mean = 4.013; SD = 0.632). Then, these three factors were considered as the highlights of the machine for converting dairy cow dung into ready-made organic fertilizer for cultivating plants in organic agriculture that could be seen as being environmentally friendly.

Keywords: *Green product, Milk cow manure processing machine, Dairy farmer, Dairy cow manure product*

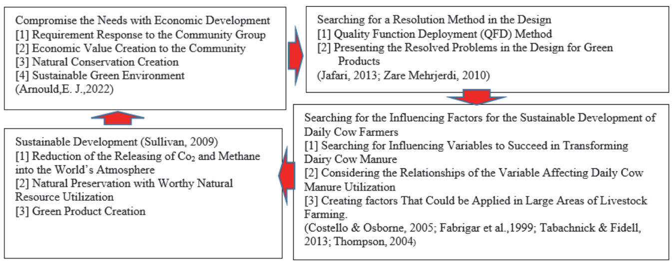
1. Introduction

The raising of dairy cows to produce milk for domestic consumption in Thailand has appeared since 60 years ago, where farming was often done freely in open fields and without any systematic care. However, this was different from the culture in modern times where the raising method was improved to a higher standard from the initiative of His Majesty King Bhumibol Adulyadej the Great, who set up the Thai-Danish Dairy Farming Training Center in Muak Lek District, Saraburi Province with King Frederick IX of Denmark in 1962. This center was then developed into the Dairy Farming Promotion Organization of Thailand that became a state enterprise under the jurisdiction of the Ministry of Agriculture and Cooperatives. Similarly, His Majesty the King experimented with dairy farming in the Chitralada Palace area to initiate the raising of dairy cows in a standardized system for the first time in Thailand. This knowledge has been disseminated for more than 60 years to farmers throughout Thailand with the positive efforts for the farming of dairy cows to generate income for farmers in the Northeast region of Thailand. Thus, in 2021, there were 202,253 cows in the country, which has seen an increasing number of dairy cows at a rate of 3.4% every year. As a result, Nakhon Ratchasima Province, now has 148,540 cows, which is the highest number of dairy cows in Thailand (Angthong et al., 2022; Moungsree et al., 2022). Hence, dairy farmers want to produce cow's milk that has passed the raw milk standard for consumption, which is an important factor in caring for dairy cows to be able to produce milk with quality that meets the required standard. Moreover, farmers must take care of the health of all dairy cows to prevent disease from occurring. Otherwise, this would cause the value of the raw milk to be lower than the standard, so the farmers would prevent any occurrence of disease by keeping the stalls clean and free from germs and bacteria. Therefore, every day, the farmers clean the stalls by scooping the cow dung out so to prevent germs and bacteria that would have the opportunity to arise from cow dung and urine. After that, the dairy cow dung of the farmers would be used as fertilizer for plants or put in the sun to dry before selling to generate income. In addition, the method of converting dairy cow dung into ready-to-sell organic fertilizer has become popular among farmers who grow many crops in nearby areas. On the other hand, there is the problem of the length of time in the sun to allow the cow dung to dry completely and have an appropriate moisture level, including the prevention of mold from dried dairy cow dung. In this case, the drying of dairy cow dung by natural methods is always faced with problems during the rainy season of Thailand that lasts longer than six months. Consequently, the farmers who produce organic fertilizer from dairy cow dung are unable to produce organic fertilizer in time, and the complete drying process for the dairy cow dung would take a long time and take up a large area to dry. Therefore, this would affect the environment in the drying area that would cause an accumulation of manure in the dairy farm area. Furthermore, this could result in becoming a breeding ground for the larvae of vector insects that would bring contagious diseases to the dairy cows. Simultaneously, this would also cause the release of carbon dioxide and methane into the atmosphere and add to global warming (Trenberth et al., 2014). According to a report by the World Meteorological Organization (WMO), the levels of greenhouse gases were found in three categories: methane, carbon dioxide, and nitrous oxide concentrations that have steadily increased during 2021 to 2022 (Zhang et al., 2022), thus indicating that the problem of global warming has not improved. Moreover, there is a tendency for the world to face natural disasters from climate change, which would escalate global temperatures (Mella, 2022; Neumann et al., 2022), as well as the continued drastic increase in methane, considered a gas produced by ruminants, such as pigs, dairy cattle and buffaloes, in many large-scale farms around the world. Therefore, this involves the expansion of arable areas to meet the food needs of humans until a large amount of methane would be formed from the fermentation of waste and excretion of cattle herds (Zandalinas et al., 2021). In addition, in 2022, there was a 262% increase in methane in the Earth's atmosphere than in pre-industrial times that is a major problem affecting the world (Gills & Morgan, 2020). As such, one way to reduce methane emissions from the cow manure excretion and fermentation processes is the necessarily to develop processes and agricultural machinery that could shorten the drying time of dairy cow manure. In this case, this could effectively control the temperature and humidity of the produced dairy cow manure until the cow dung stopped the fermentation process that would cause methane gas to emerge in the farming area. Then, this would be considered as developing another approach to create products that would reduce potential environmental impacts in the future by developing the process of transforming dairy cow dung at this time. Additionally, this would show the responsibility to nature, including promoting the standardization of ready-to-use organic fertilizer products that would have standards and be convenient for production, distribution, storage, transportation, and use.

2. Objectives

1. To study and develop the utilization of dairy cow manure in Thailand.
2. To assess the community's satisfaction with the newly developed dairy cow dung converter.

3. Research of the Conceptual Framework



4. Literature Review

The integration of modern science and technology into industrial product design is the direction of innovation development in the future world; new products could reduce the destruction of nature and help alleviate environmental problems. As a result, according to the concept of circulation, this must use new resources as much as possible and make the most of old resources to create sustainable development to coexist with nature as well as help to solve pollution problems that may have an impact on nature. Therefore, innovation development would be a necessary obligation to show effective development guidelines with a procedure for being a sustainable green environment (Deci & Ryan,1985; Dhir et al., 2021; Shahrudin et al., 2017).

In this case, utilizing the dung of daily cows often causes pollution problems that has a toxic smell and is a breeding ground for pathogens. Therefore, preventing the potential source of pathogens would be necessary to wash the stall frequently, including preventing the fermentation until the formation of parasite eggs or pathogens from the manure. During this period, piles of manure often emit carbon dioxide and methane into the atmosphere until becoming the root of the greenhouse effect (Hu et al., 2021). Hence, this would be another way to reduce the problem of greenhouse gas emissions according to the European Union's environmental policy that shows measures to combat global warming. Likewise, this has had an impact on business in Thailand. The EU Environment Policy Conference 2009 on July 16, 2009, reported that Thailand was the twenty-fifth largest emitter of greenhouse gases in the world with 344 million tons per year of carbon dioxide (Chamnarn, 2012). In this case, energy production for domestic use is the number one greenhouse gas generator, followed by agriculture and livestock, respectively.

As a consequence, the results from climate change in Thailand are becoming more severe from the seasonal variations that are different from the past, and the average temperature of Thailand is increasing and has a longer dry season. As such, these changes are the result of climate change that has negatively impacted the people of Thailand since the beginning of the twenty-first century and is tending to appear to be more severe. This is also affecting the health of people in Thailand from the increasing rate of epidemics in the summer that have continued to rise.

From the impact on the environment and people's health in Thailand, the development of environmentally friendly technologies would help promote sustainability in living and help bring development in line with the current world dynamic innovations. Consequently, attention should be paid to the innovation process that would be consistent with the technology, including the way of life, the environment and other related factors. With this in mind, this could encourage the creation of technological products that would be suitable for the era and the needs of consumers (David, 2021), in which the process of developing new innovations would be considered as a new product development strategy (Elverum et al., 2016; Schuh et al., 2018; Yun et al., 2019). Furthermore, this could innovate products to suit the demand and supply at the time by helping to produce according to the needs of consumers by creating new innovations. Thus, there would be a novelty in the nature of the process that would be unique. This would be as follows: 1) Creating benefits for users, and 2) creating an increase in the economic value for producers (Egwutvongsa, 2021), which would be determined as the direction of the development of the dung processing machine for dairy cows in three approaches as follows:

- Development of a new production process that would be more efficient and help increase productivity or reduce production costs by offering solutions to problems that would be currently encountered.
- Development that would meet the needs of consumers: 1)User desirability, 2) business viability, 3) technical feasibility, and 4) collaboration.
- Developments that would create added economic value until becoming a new business or expanding their own consumer group.

Hence, the agricultural machinery industry in 2021 had a growth rate of 11.5% with the highest production and distribution countries being Japan, China, India, and the United States. Moreover, these were considered an industrial product with high export value, and the products sold would take a lot of research and development time. This also required high investment in production on the market, so these products would always suffer from imitation or comparison with existing products (Kotler et al., 2006; Weng et al., 2021). Therefore, this would be the primary goal of helping developers understand the real needs of consumers, and they could also develop products that would appropriately meet the needs of farmers and their behavior.

5. Research Scope

According to the scope of research during the study and development of the utilization of dairy cow dung in Thailand, this was a study of the physical characteristics of dairy cow dung and proposed methods for converting dairy cow manure raised on farms in Thailand.

- Population: A group of 369 dairy farmers in the area of Nakhon Ratchasima Province, Thailand.
- Sample Group: A total of 150 dairy farmers in Pak Chong District Nakhon Ratchasima Province according to the prefabricated random tables of Krejcie and Morgan (Krejcie& Morgan,1970) with the sample discrepancy of 0.05 by using a simple random sampling method.
- Research tools: A structured questionnaire was made to inquire about the characteristics of dairy cow dung and the need for dairy cow dung processing machines by the farmers by evaluating the estimation scale with a five-point Likert scale and confidence with the Cronbach's alpha coefficient = 0.809, which was considered to be an appropriate level.
- Data analysis: Was conducted by using the mean, standard deviation (SD) and quality function deployment (QFD) to present solutions to problems from the old process that farmers currently used.

The scope of the research during the assessment of the satisfaction of the community group on the dairy cow dung processing machine.

- Population: One hundred and sixty-two dairy farmers in Pak Chong District Nakhon Ratchasima Province (the farmers registered as entrepreneurs in 2020).
- Sample group: One hundred and fifty dairy farmers in Pak Chong District to implement the ready-made random tables of Krejcie and Morgan (Krejcie& Morgan,1970) with a sample discrepancy of 0.05 that used a simple random sampling method.

- Research tool:A structured questionnaire was used to inquire about the farmers' needs for dairy cow manure processing machines by using an estimation scale with a five-point Likert scale, which the confidence of the questionnaire appeared to be an appropriate level with the Cronbach's alpha coefficient = 0.813.
- Data analysis:An exploratory factor analysis (EFA) was used to find the factors by converting the dairy cow dung into organic fertilizer for using in agricultural areas in Thailand.

6. Results

Study results and development of the utilization of dairy cow dung in Thailand.

6.1 Community needs (dairy farmers)

The dairy farmers wanted to use a dairy cow dung processing machine with waste separation technology Then, they could require a good standard of cow's milk production by take caring of the health of every dairy cow to be safe from disease that cause raw milk values to be below the standard. raw milk nutrition. As such, the stall was cleaned to prevent germs and bacteria, which every day the farmers would clean this location by scooping up the dairy cow dung to prevent pathogens. Therefore, the dairy cow 's manure would be used to make fertilizer for plants or be dried before using. Similarly, the method of converting dairy cow dung into ready-made organic fertilizer for sale was popular among many farmers who grew crops in the vicinity. However, there was the problem of the period of sun drying by allowing the cow dung to dry completely and to have an appropriate moisture level to prevent mold. In addition, drying by sunlight often encountered problems in production. As a result, farmers who produced organic fertilizers from dairy cow dung were unable to increase the yield of organic fertilizers to meet the demand for use.

Problem Conditions of Manure in the Dairy Cattle Area
1) Waste from excretion.
2) Naturally drying for storing caused the release of large amounts of methane.
3) It took time to eliminate from the system with more than one week for fermentation and microorganism growth with the dairy cow manure.

Figure 1: The process of drying cow dung for dairy farmers of medium-sized farms.
Source: Author

Moreover, the dairy farming area in Thailand tended to increase steadily every year until causing a large amount of waste, such as waste water from washing and food scraps left over from raising dairy cows. As such, this has now become a large area that has released large quantities of carbon dioxide and methane gas into the atmosphere of the world because this area is a large livestock farming area in Thailand. Therefore, it would be considered as a cause that would affect the environment resulting in the global warming phenomenon conforming with the rapid increase in the global average temperature of 1.14°C throughout the twentieth and twenty-first centuries. Thus, this represented a highly variable rate of change in the global environment. Hence, the research aimed to create a process for utilizing dairy cow dung in Nakhon Ratchasima Province by bringing dairy cow dung to be converted into organic fertilizer for using in growing crops in nearby areas. Furthermore, this would be considered as helping to reduce the accumulation of dairy cow dung and the fermentation of dairy manure by more than 10 tons/day before converting it into organic fertilizer that would help generate income for dairy farmers in another way. As a result, this would include reducing the activities on the farm that would cause greenhouse gas emissions and reduced greenhouse gases in the atmosphere (Jeffry et al., 2021).

According to the research, a report from Carbon Majors (Paul Griffin,2017) indicated that more than 70% of greenhouse gas emissions came from the agricultural sector where animals were raised for meat or milk. Moreover, this was considered an activity with a rate of greenhouse gas emissions similar to the transport sector (Tuckett, 2019). and these two sectors were considered as the main factors affecting the global environment in the long run. Additionally, from the problem of global warming that is affecting human life today, there is more variation of the seasons; these problems affect Thailand, which would suffer severe natural disasters in 2022: 1) More severe storms, 2) major floods in the country, 3) more severe and frequent forest fires, and 4) rising summer temperatures with prolonged droughts. These situations have prompted the Thai government to support the policies that set national goals to reduce greenhouse gas emissions by 25% by encouraging large-scale livestock farming to reduce waste and fermentation of dairy cow dung, including promoting the use of large amounts of dairy cow dung in a variety of ways that would demonstrate the utilization of natural resources and the increased sustainability of the environment before 2030.

The process of studying the data on the use of dairy cow dung as an ingredient in organic fertilizer production and agricultural utilization was based on a literature review of 75 internationally published research articles (Scopus). Then, we summarized the issues leading to the development of a dairy cow manure converter. As such, it was necessary to realize the needs of the farmers, which were as follows: 1) Transformation system, 2) transformation process, 3) development goals, and 4) reducing wastage of the transformation process. All of them could increase the value of the new dairy cow manure process.

In summary, the development of a new type of dairy cow dung processing machine was based on the following product development concepts:1)Considering the potential loss from the new system to the environment, 2) considering the loss from the transportation system, 3) realizing the loss from each transformation stage, 4) realizing the resource loss in each transformation stage, 5) realizing the loss from the defects of new products, 6) taking into account the loss from excessive movement, and 7) realizing the losses incurred from each step of the production process (Atkinson, 1999; The Innovation Research Interchange, 2019). All of them were considered as quality and cost analysis steps for the development of a new type of dairy cow manure processing machine. Additionally, they wanted to show innovation that had green environment coordination in a closed-loop supply chain with price-dependent returns (Giovanni, 2020).

For the analysis of the existing nutrients in dairy cow dung cultured in the Northeastern region of Thailand, it was collected from medium and large farms in Nakhon Ratchasima Province to study the physical characteristics of the dairy cow dung, which was collected from dairy cows aged two to eight years old.

Table 1: Mean nutrient content for plants contained in dried manure.

Manure	Total Nutrient Content (%)		
	Nitrogen	Phosphorus	Potassium
[1] Beef Dung	1.364	0.511	1.712
[2] Dairy Cow Dung	1.272	0.481	1.421

Source: Author

Table 2: NPK nutrient analysis from the sample farm with dairy cow manure for the total nutrient content (%).

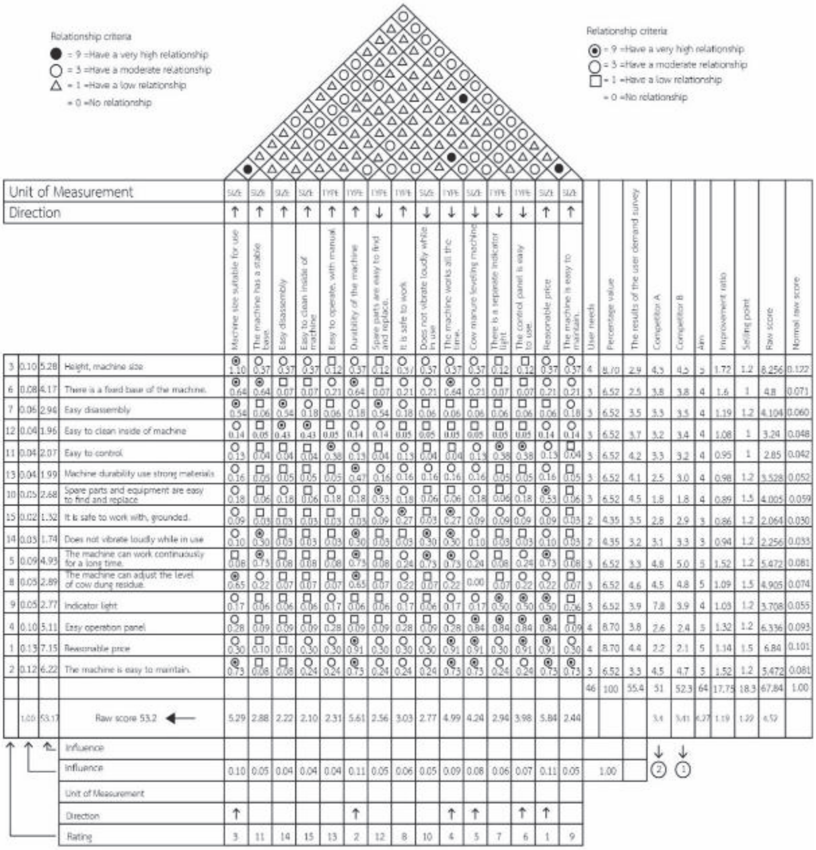
Dairy Cow Manure	Total Nutrient Content (%)		
	Nitrogen	Phosphorus	Potassium
[1] Dairy cow manure 1	2.072	0.847	1.981
[2] Dairy cow manure 2	1.646	0.372	0.678
[3] Dairy cow manure 3	1.872	1.227	1.645
Average	1.863	0.815	1.434

Source: Author

According to the nutrient value of dry manure produced from dairy cow dung from the three large breeding sites, it showed that each farm had different nutrient values of nitrogen, phosphorus, and potassium because the nature of rearing and the feed for dairy cows was different according to the formula used in each farm. The average amount of the nutrients was nitrogen = 1.863%, phosphorus = 0.815%, and potassium = 1.434%. In addition, the nitrogen value found in dairy cow dung was the highest, followed by potassium and phosphorus, respectively which was considered as the right amount of nutrients to help plants grow well. This was conducted as follows:

1. Use the guidelines for the development of a dairy cow dung processing machine with waste separation technology for dairy cow farmers to learn how to solve the problem of converting dairy cow manure into organic fertilizer.
2. Use the analysis of the material properties to produce parts of dairy cow dung processing machinery and production machinery and control systems by considering the raw materials available in Thailand to be mainly applied in the production process.
3. Develop a technique for separating the water and residue from dairy cow dung to determine the machine's mechanism to be efficient with strength, durability, and ease of maintenance.
4. Specify the system and structure of the machine for converting dairy cow manure into organic fertilizer by comparing the properties of the newly developed dairy cow manure processor with the old products in the market.
5. Evaluate the properties of the newly developed machine in terms of processing time with the convenience of use, safety, strength, durability, and beauty.

Table 3: Solutions to the problems from the dairy cow dung utilization process by the QFD technique.



Thus, it could be concluded that a group of dairy farmers in Nakhon Ratchasima Province wanted to develop a dairy cow dung conversion process. Moreover, there were five very important requirements: 1) appropriate price level (influence = 0.11), 2) durability of the converter (influence = 0.11), 3) the converter would be suitable for use (influence = 0.10), 4) the converter could be operated at any time (influence = 0.09), and 5) the processing machine could adjust the level of fineness and dryness of dairy cow dung (influence = 0.08). Then the sorting order of the solutions received from Nos.1-15 were sorted in descending order into the process of designing a machine that would convert dairy manure into organic fertilizer for the crops by bringing the results into the development stage of the new product.

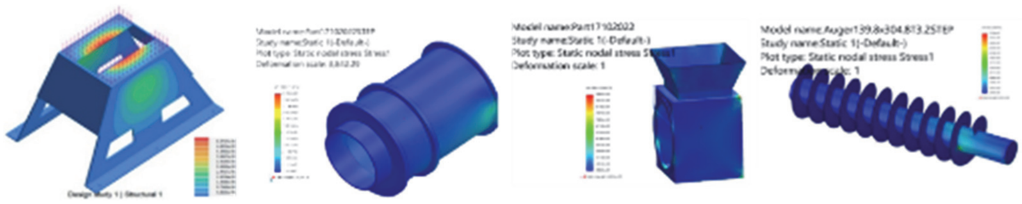


Figure 2: The prototype development process for converting dairy cow dung into organic fertilizer by a simulation test using finite element analysis (FEA).
Source: Author

Furthermore, a dairy cow manure processing system was set up that was physically wet and soggy. As such, the solution obtained from the QFD analysis was used as a solution for 15 solutions by giving importance to the solutions in order of the weight of each solution, which would appear as different importance values. Therefore, the mechanism and overall characteristics of the machine for converting dairy cow dung into organic fertilizer for cultivation were then designed in a highly environmentally friendly way.

Table 4: Comparison of the three newly developed dung processing machines for dairy cows.

	**Development Pattern 1**			**Development Pattern 2**			**Development Pattern 3**		
									
Assessment List	**Mean**	**SD**	**Level**	**Mean**	**SD**	**Level**	**Mean**	**SD**	**Level**
1] Usage Characteristics	4.17	0.75	Excellent	2.83	1.17	Moderate	4.00	0.63	Excellent
2] Ease of Use	4.17	0.75	Excellent	3.17	0.75	Moderate	4.00	0.89	Excellent
3] Movement or Transportation	3.67	1.03	Excellent	2.67	0.82	Moderate	3.33	0.82	Moderate
4] User-friendly Features	4.00	0.63	Excellent	3.00	0.63	Moderate	3.83	0.41	Excellent
5] Convenient to Maintain	4.17	0.75	Excellent	2.67	0.82	Moderate	3.50	1.22	Moderate
6] Uniqueness	3.00	0.63	Moderate	2.33	0.52	Less	2.83	0.75	Moderate
7] Modern Style	3.00	0.63	Moderate	2.17	0.75	Less	2.67	0.52	Moderate
8] Suitable Materials	4.17	0.41	Excellent	3.33	0.82	Moderate	3.67	0.82	Excellent
9] Proper Production Process	3.67	0.82	Excellent	3.00	0.89	Moderate	3.17	0.75	Moderate
10] High Strength	4.50	0.84	Excellent	3.17	1.33	Moderate	3.33	1.21	Moderate
Overall	**3.88**	**0.40**	**Excellent**	**2.82**	**0.62**	**Moderate**	**3.45**	**0.58**	**Moderate**

Source: Author

In this case, the results of the evaluation of the prototype of the product of converting dairy cow dung into ready-made organic fertilizer for organic crops could be concluded that the first concept was suitable for production as a real model for trial use with a group of farmers based on 10 evaluation criteria with a high level of satisfaction (mean = 3.88; SD = 0.40). The farmer group gave priority to the first place or the new high-strength machine followed by the second place or the usage characteristics that included the ease of use, suitable materials, and convenient to maintain, and easy-to-use characteristics, and the third place or user-friendly features. From the three new product forms, farmers would have higher demands for using the machine to transform dairy cow dung into ready-made organic fertilizer for organic crops as Form 1 in the higher level than Form 2 and Form 3.

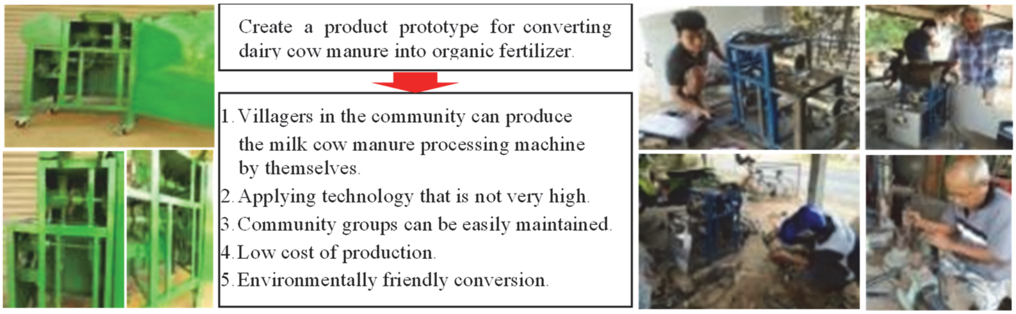


Figure 3: A prototype that leads to an experimental process with a group of dairy farmers.
Source: Author

In addition, this involved the experimental use of a prototype machine for converting dairy cow manure into organic fertilizer for planting by a group of dairy farmers. Moreover, the conversion of dairy cow manure that was wet as an organic fertilizer with high nutrients for planting had the following: 1) Compaction to extract water from dairy cow dung, 2) drying, 3) grinding to obtain a high resolution of dairy cow dung, 4) mixing essential nutrients for plants into dried dairy cow dung, 5) mixing and spraying microorganisms, and 6) pelletizing. All six steps were performed in a newly developed dairy cow dung processing machine.
Thus, the test results of ready-made organic fertilizers from dairy cow dung obtained from the new processing machine were as follows:

1. The amount of organic matter had an average weight of 14.5%.
2. The carbon to nitrogen ratio (C/N ratio) had an average of 11.24:1.
3. Electrical conductivity was 4.23 decimeters per meter.
4. The fertilizer moisture content before and after had a mean of 72.8% and weight of 9.7%, respectively.
5. The pH value (pH) was 8.35. The test results for the amount of primary nutrients (primary macronutrient analysis) consisted of the total organic carbon (TOC), nitrogen (N), phosphorus (P) and potassium (K) values with the average weight of 9.1%, 0.8%, 0.6%, and 0.84%, respectively. Likewise, the sodium (Na) content had an average weight of 0.15%, which included the satisfaction of the farmers with the prototype to determine the design factors of the next generation of processors to be more responsive to farmers.

Table 5: Satisfaction of the dairy farmers toward the new generation of dairy manure converting machines.

No.	Farmers' Satisfaction Assessment	Mean	S.D.	Level of Satisfaction
1	The size of the machine is suitable for use.	3.980	.714	Very Satisfied
2	The weight of the machine is suitable for use.	4.000	.670	Very Satisfied
3	The shape of the machine is convenient to use.	4.060	.712	Very Satisfied

No.	Farmers' Satisfaction Assessment	Mean	S.D.	Level of Satisfaction
4	The base of the machine is stable.	4.060	.767	Very Satisfied
5	It is easy to assemble and install.	4.060	.767	Very Satisfied
6	It is easy to assemble the parts.	4.200	.700	Very Satisfied
7	The material is strong.	4.320	.621	Very Satisfied
8	The materials used to manufacture the machine have a long service life.	4.120	.594	Very Satisfied
9	The chassis does not contain sharp components that are harmful to the user.	4.000	.728	Very Satisfied
10	The chassis cover can be easy disassembled.	4.260	.803	Very Satisfied
11	It is easy to clean outside.	4.140	.904	Very Satisfied
12	It is easy to clean inside.	4.100	.678	Very Satisfied
13	It is easy to move and save transportation space.	4.000	.857	Very Satisfied
14	It can use water to wash the inside and is easy to compress the cow dung.	4.140	.990	Very Satisfied
15	The power system is easy to install.	4.140	.926	Very Satisfied
16	There is a ground wire to prevent a short circuit at the base of the machine.	4.140	.926	Very Satisfied
17	Every electrical device has a watertight seal.	4.060	.620	Very Satisfied
18	All electrical devices have TIS standards.	4.320	.768	Very Satisfied
19	The replacement equipment can be easily found.	4.180	.691	Very Satisfied
20	The control panel is in Thai and English.	4.220	.737	Very Satisfied
21	The control panel is easy to use.	4.320	.621	Very Satisfied
22	The control panel is categorized for ease of use.	4.220	.616	Very Satisfied
23	The color of the control buttons is designed according to the TIS standards.	4.420	.731	Very Satisfied
24	The green indicator light is designed according to the TIS standards.	4.400	.728	Very Satisfied
25	The red abnormal indicator light is designed according to the TIS standards.	4.480	.762	Very Satisfied
26	The stop indicator is white according to the TIS standards.	4.440	.760	Very Satisfied
27	The indicator light bulb is an LED light according to the TIS standards.	4.440	.787	Very Satisfied
28	The machine does not vibrate while operating.	4.100	.678	Very Satisfied
29	It can be used with a battery power source from a solar cell charge.	4.300	.544	Very Satisfied
30	It can be used with wind turbine power sources that store the battery charge.	4.320	.587	Very Satisfied
31	The moisture content of dairy cow manure from compression can be adjusted.	4.420	.728	Very Satisfied
32	It can set the compressive strength of the compression screw to determine the dryness of the dairy cow dung.	4.120	.918	Very Satisfied
33	It can separate the urine from dairy cow dung.	4.100	.886	Very Satisfied
34	The painted part of the device has a baking coating with the durability in use.	4.220	.737	Very Satisfied
35	The body spray paint is resistant to acid and corrosion.	4.160	.738	Very Satisfied
36	Reasonable price.	4.200	.728	Very Satisfied
37	It can work at any time without resting the machine.	4.240	.744	Very Satisfied
38	Automatic shutdown time can be set.	4.320	.794	Very Satisfied

Source: Author

According to the results of the satisfaction evaluation of the dairy farmers in Nakhon Ratchasima Province, it was found that the top three most items of satisfaction were: 1. The abnormal red indicator light to be designed according to the TIS standards that had a high level of satisfaction (mean = 4.480; SD = 0.762), 2 the stop indicator that is white according to the TIS standards and the indicator light bulb is an LED light according to the TIS standards (mean = 4.440; SD = 0.787; 0.760), and 3. the moisture content of dairy cow manure from compression can be adjusted and the color of the control buttons is designed according to the TIS standards (mean = 4.420; SD = 0.728; 0.731). All the data were taken into consideration to determine the factors by using EFA.

Table 6: Values of the KMO and Bartlett 's Test of the samples who were satisfied with the prototype of the dairy cow dung processing machine.

KMO and Bartlett's Test of Sphericity	
Approx. Chi-Square	1832.906
Df	703
Sig.	.000
Kaiser-Meyer-Olkin Measure of Sampling Adequacy	.771

*Significance = .05.

Source: Author

According to the analysis of the KMO and Bartlett 's Test, it showed the Kaiser-Meyer-Olkin = .771, which was greater than 0.50. Moreover, it appeared that the collected data showed the satisfaction with the new dairy manure processing machine to be appropriate, and it was analyzed with the exploratory components (Chi-square = 1832.906; significance = 0.000). Therefore, it could be concluded that there were 38 related variables.

Table 7: Clustering of the variables with the varimax method.

Variable as the Machine Property		F/1	F/2	F/3
First Factor: Machine Property				
W24	Green indicator light according to the TIS standards.	.891	-	-
W25	Red fault indicator light according to the TIS standards.	.868	-	-
W23	The color of the control buttons is designed according to the TIS standards.	.851	-	-
W26	The stop indicator is white according to the TIS standards.	.796	-	-
W27	The indicator light bulb is an LED lamp according to the TIS standards.	.750	-	-
W38	Automatic shutdown time can be set.	.742	-	-
W32	It can be set for the compressive strength of the compression screw to determine the dryness of dairy cow dung.	.709	-	-
W16	There is a ground wire to the base of the machine.	.680	-	-
W37	It can work at any time without resting the machine.	.642	-	-
W33	It is able to separate the urine from dairy cow dung.	.641	-	-
W31	The moisture content of dairy cow manure from the compression can be adjusted.	.631	-	-
W6	It is easily disassembled.	.628	-	-
W18	All electrical devices have TIS standards.	.609	-	-
W15	Easy wiring system	.601	-	-
Factor 2 : Machine performance				
W29	It can be used in conjunction with a battery power source from a solar cell charge.	-	.842	-
W30	It can be used with wind turbine power sources that store the battery charge.	-	.830	-
W34	The paint used to spray the body is acid and corrosion resistant.	-	.646	-
Factor 3 : The image of the machine				
W2	The weight of the machine is suitable for use.	-	-	.865
W1	The size of the machine is suitable for use.	-	-	.807
W3	The shape of the machine is convenient to use.	-	-	.782

Source: Author

According to the factors obtained by rotating the axis to predict the relative effect (rotate and interpret factors), it was found that there were three binding factors and the researchers eliminated the factors at 4, 5, 7, 8, 9, 10, 11, 12, 13, 14, 17, 19, 20, 21, 22, 28, 35, and 36 because all 18 factors could not be matched to each other according to the criteria set at 0.06 (coefficients).Hence, it could be concluded that all 38 variables could be divided into three factors appearing by weight of importance as follows: The first factor was the machine features as the most important, which described the variance of the data at the level of 17.939%. The second factor was the efficiency of the machine at the level of 2.733%, and the third factor was the image of the machine at the level of 2.055%. Then, the scree plot was analyzed to show the Eigen value with the 38 variables, which appeared that all three were suitable, and the 38 variables could be sampled with a relatively good correlation by showing a graph with a slope from the first factor to the third factor, in which all three factors were matched with the variables as a relatively good correlation.

Table 8: Analysis of the anti-image matrices (measures of sampling adequacy: MSA).

V	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14	W15	W16	W17	W18	W19
W1	1.00																		
W2	.31	1.00																	
W3	.65	.73	1.00																
W4	.34	.52	.55	1.00															
W5	.30	.30	.20	.58	1.00														
W6	.06	.17	.30	.55	.70	1.00													
W7	.25	.44	.33	.39	.43	.30	1.00												
W8	.34	.31	.47	.25	.34	.38	.50	1.00											
W9	.36	.38	.39	.51	.59	.40	.36	.43	1.00										
W10	.22	.34	.40	.44	.44	.60	.40	.40	.52	1.00									
W11	.11	.26	.41	.44	.41	.31	.26	.25	.38	.73	1.00								
W12	.23	.34	.43	.40	.49	.34	.32	.42	.43	.65	.77	1.00							
W13	.13	.32	.28	.34	.34	.34	.31	.22	.33	.40	.48	.65	1.00						
W14	.37	.43	.50	.47	.44	.44	.27	.44	.36	.36	.59	.71	.60	1.00					
W15	.26	.31	.36	.53	.61	.35	.32	.25	.70	.31	.63	.75	.59	.73	1.00				
W16	.25	.30	.42	.56	.62	.35	.26	.34	.45	.33	.62	.65	.47	.73	.86	1.00			
W17	.28	.30	.36	.29	.29	.30	.21	.26	.36	.38	.42	.28	.37	.31	.22	.34	1.00		
W18	.38	.44	.52	.52	.56	.56	.47	.41	.56	.62	.62	.61	.55	.53	.66	.79	.60	1.00	
W19	.21	.22	.23	.29	.36	.30	.20	.34	.32	.39	.37	.45	.31	.43	.41	.30	.55	.58	1.00
W20	.20	.33	.36	.48	.45	.43	.29	.22	.50	.63	.54	.54	.45	.58	.62	.64	.33	.67	.60
W21	.29	.29	.23	.26	.35	.32	.21	.34	.41	.44	.36	.45	.36	.50	.49	.32	.16	.47	.53
W22	.20	.25	.20	.27	.36	.37	.45	.37	.46	.30	.40	.53	.48	.35	.52	.45	.07	.50	.24
W23	.25	.25	.50	.57	.61	.59	.33	.45	.56	.51	.55	.62	.41	.62	.66	.76	.26	.70	.45
W24	.13	.13	.35	.47	.54	.52	.30	.41	.46	.41	.45	.53	.37	.46	.57	.61	.17	.61	.38
W25	.21	.24	.40	.51	.47	.54	.32	.50	.44	.46	.47	.56	.46	.59	.61	.68	.53	.67	.45
W26	.21	.20	.29	.48	.51	.45	.30	.33	.44	.34	.39	.49	.47	.50	.57	.61	.33	.56	.47
W27	.23	.23	.32	.53	.53	.30	.33	.37	.50	.36	.44	.43	.41	.39	.47	.36	.26	.57	.42
W28	.21	.18	.20	.26	.19	.13	.17	.27	.25	.18	.30	.24	.29	.39	.25	.30	.13	.33	.27
W29	.36	.34	.27	.35	.30	.21	.50	.20	.21	.19	.28	.29	.25	.35	.41	.32	.07	.30	.34
W30	.21	.26	.15	.23	.25	.24	.04	.12	.14	.21	.29	.34	.33	.37	.45	.40	.11	.31	.46
W31	.09	.13	.21	.45	.49	.48	.44	.32	.42	.40	.49	.45	.33	.46	.56	.65	.15	.53	.45
W32	.10	.17	.30	.45	.51	.57	.40	.42	.46	.48	.57	.64	.47	.63	.66	.70	.31	.58	.48
W33	.16	.24	.35	.50	.50	.53	.42	.36	.44	.39	.54	.57	.46	.54	.61	.63	.25	.52	.47
W34	.09	.12	.23	.52	.48	.51	.33	.31	.30	.38	.54	.51	.41	.46	.62	.64	.33	.63	.56
W35	.20	.21	.33	.42	.34	.37	.24	.33	.46	.30	.42	.45	.29	.42	.56	.39	.20	.59	.46
W36	.32	.42	.45	.50	.42	.40	.26	.32	.46	.47	.45	.53	.41	.52	.61	.36	.29	.61	.45
W37	.06	.21	.24	.58	.51	.53	.36	.30	.49	.41	.53	.50	.35	.48	.62	.63	.19	.54	.39
W38	.12	.23	.40	.54	.61	.38	.37	.39	.49	.34	.60	.56	.45	.57	.67	.77	.29	.70	.36

V	W20	W21	W22	W23	W24	W25	W26	W27	W28	W29	W30	W31	W32	W33	W34	W35	W36	W37	W38
W20	1.00																		
W21	.60	1.00																	
W22	.34	.56	1.00																
W23	.51	.51	.56	1.00															
W24	.33	.39	.53	.91	1.00														
W25	.39	.45	.51	.88	.90	1.00													
W26	.33	.43	.53	.76	.82	.86	1.00												
W27	.39	.46	.51	.70	.76	.73	.83	1.00											
W28	.26	.31	.24	.41	.41	.46	.51	.61	1.00										
W29	.39	.31	.29	.24	.16	.14	.22	.31	.25	1.00									
W30	.40	.44	.31	.30	.22	.29	.35	.31	.28	.78	1.00								
W31	.49	.35	.36	.60	.66	.60	.54	.63	.41	.46	.47	1.00							
W32	.47	.47	.36	.71	.80	.75	.63	.55	.37	.38	.50	.73	1.00						
W33	.40	.39	.48	.63	.56	.65	.65	.67	.43	.44	.53	.70	.84	1.00					
W34	.53	.36	.30	.58	.53	.54	.48	.50	.41	.09	.53	.72	.59	.69	1.00				
W35	.53	.67	.37	.52	.52	.55	.49	.58	.46	.04	.35	.70	.50	.66	.52	1.00			
W36	.49	.40	.90	.33	.46	.56	.50	.55	.37	.01	.37	.06	.50	.63	.54	.66	1.00		
W37	.50	.09	.36	.61	.57	.58	.53	.56	.48	.42	.38	.66	.73	.74	.76	.71	.70	1.00	
W38	.61	.53	.54	.75	.39	.69	.64	.69	.47	.39	.39	.77	.70	.74	.35	.71	.70	.84	1.00

Bartlett's Test = 1832.906; Sig = .000; KMO = .771; MSA = .553 - .885.

Source: Author

According to the results of checking the correlation between the variables, it has been studied with the Bartlett's Test to show that all variables were correlated with statistical significance at .05 when testing the appropriateness of the variables. Moreover, it is used for confirmatory factor analysis with the Kaiser-Meyer-Olkin method showed an MSA of .771 and a variable between .553 and .885, which is greater than .50 (Hair et al., 2006). Therefore, it can be concluded that the variables are suitable for confirmatory factor analysis by checking the factor measurement model based on the observed variables in the future. Then, all three factors were used to evaluate the satisfaction of dairy farmers. The effects of the conversion of dairy cow dung into the new organic fertilizer can be summarized in Table 9.

Table 9: Efficiency evaluation of dairy cow manure converting machine to organic fertilizer (n=50).

Performance aspects that affect usability	Mean	S.D.	Priority
Factor 1 : Features of the Machine	4.283	0.661	High Level of Importance
Factor 2 : Machine Performance	4.280	0.528	High Level of Importance
Factor 3 : Image of the Machine	4.013	0.632	High Level of Importance

Source: Author

This showed the mechanical performance with evaluation approaches for the saving of human labor (Egwutvongsa et al., 2021) by using the three factors to evaluate the results from the use. Moreover, this appeared to be effective in each aspect that affected the usability with the first factor being the features of the machine is very important (mean = 4.283; SD = 0.661), the second factor being the efficiency of the machine to be very appropriate (mean = 4.280; SD = 0.528), and the third factor being the image of the machine to be very appropriate (mean = 4.013; SD = 0.632).Then, all three factors were regarded as the highlight of the newly developed dairy cow manure conversion machine for organic crop cultivation. that could show environmental friendliness as follows:

1. It could encourage farmers to use cow dung in large amounts on the farm to convert into organic fertilizer with high nutrient value for plants.
2. Dairy cow manure could be converted to 10 kg each time, and it took 20 minutes to produce dry organic fertilizer pellets with a weight of 3.56 kg.
3. It could help to reduce the accumulation of dairy cow manure that could cause fermentation and the release of methane gas.
4. It could generate income for farmers from selling organic fertilizer tablets.
5. There was a cycle of reusing natural resources according to the sustainable development guidelines.

7. Conclusion

According to the physical characterization of daily cow dung, it was processed into granulated organic fertilizer, which was considered to have high nutrient value for plants by promoting the use of organic fertilizers from dairy cow dung to grow crops in an organic way. Moreover, this was highly environmentally friendly by bringing manure produced from three large farms to inspect with manure produced from dairy cow dung, which each farm had a nutrient value. Then, the plants contained different amounts of nitrogen, phosphorus, and potassium, and this was because of the upbringing and feed that the dairy cows ate would vary according to the feed formula used for the dairy cows of each farm. Thus, it was found that the nitrogen value was the highest, the second was potassium, and the last was phosphorus. In addition, these were considered to be important nutrients that helped plants grow well in accordance with the building pattern with organic farming or natural farming (Lertchamchongkul et al., 2022). As a result, the practice of organic farming is a method of farming based on the balance of nature to create biodiversity by reducing dependence on foreign substances, synthetic chemicals. chemical fertilizers, and growth promoters (Akinremiet al., 2000; Landrot et al., 2021). Therefore, this would help Thailand become the world's leader in producing sustainable organic agriculture (Terlingen et al., 2014). However, when farmers bring dairy manure to be processed, this would help to produce organic fertilizer that would be environmentally friendly as follows: 1) Releasing the nutrients slowly, 2) releasing the nutrients that exceeded the needs of the plants into the environment, 3) helping to adjust the pH of the soil for being suitable, 4) helping to retain moisture, and 5) adding with organic matter to the soil (Chen et al., 2018; Egwutvongsa, 2021).

Consequently, the cow manure processing machine developed a process of transformation to separate the water and dairy cow dung from each other by adding the following steps: 1) Crushing, 2) fermentation and addition of nutrient value, 3) pelletizing, and 4) drying. Additionally, the production of the newly developed machine would use raw materials that would be available in the country and rely on labor within their own communities with the sustainable development concept (Egwutvongsa, 2008).This could create sustainable development that would help to foster the development of the community's potential with local self-sufficiency, and learn how to apply a large amount of unused resources in their own community to generate income as an economic return.Therefore, this could solve the problems encountered in the community area with the processing of dairy cow dung by using the QFD technique, Furthermore, it appeared that there were needed problems to be solved as follows: 1) Reasonable price, 2) durability, 3) suitable size for use, 4) the machine can be operated all the time, 5) the machine can adjust the fineness of the dung, 6) the panel is easy to use the control, 7) separate light to show the status, 8) safety, 9) easy to maintain, 10) no vibration; loud noise while in use, 11) the machine that has a stable base, 12) easiness to find accessories, 13) easiness to operate, 14) easiness to disassemble parts, and 15) easiness to clean inside the machine for the dairy cows that were more efficient.

Hence, according to the satisfaction of the community group toward the cow dung processing machine, it showed that the dairy cow dung could become organic fertilizer. Moreover, it appeared that the new development could meet the needs of users as the outstanding issue in terms of reasonable prices, which the users had the demand for low prices, and it was also appropriate to produce with the technology that existed within the community itself. Additionally, this relied on skilled craftsmanship that was not high to help in production until being able to generate income in the production of the dairy cow dung processing machines to sell to farmers within the community. Significantly, with the development of the local potential cooperating together to develop a new type of dairy manure processing machine, there was an opportunity to produce the results that would encourage society and communities to have opportunities for sustainable economic development and social and environmental aspects, which would be consistent with the concept of sustainable development (Duarah et al., 2022). Moreover, when examining the properties and plant nutrients found in the treated cow dung, it appeared that this was an organic fertilizer suitable for growing crops, especially to be an organic fertilizer that would be environmentally friendly to the world, which could create the fertility of the crops in the local agricultural area. Therefore, this was consistent with the concept of creating a fertile arable soil that would contain sufficient nutrients for plants. Likewise, there must be food that would promote the growth of soil organisms, such as earthworms that were soil organisms that helped confirm the fertility of the soil in the agricultural area. For example, the dairy cow manure would be a fertilizer for stimulating the creation of a good food source for nematodes in the soil, while the nematodes would help increase the oxygen and soil fertility. Thus, it would be considered that the conversion of dairy cow dung to organic fertilizer would be another method that would help to conserve the environment and enrich the soil in the farmland as well (Garg & Gupta, 2011; Joglekar et al., 2019).

For the application of the factors in the development of the utilization process of dairy cow dung for dairy farmers in the Northeastern region of Thailand, this showed that a newly developed process could be applied to convert dairy cow dung into useful organic fertilizer for local farmers' crops. Additionally, this could demonstrate their contribution to the sustainability of the global environment in the future with the strategy used to respond to the supply chain of green products, including the process of converting dairy cow dung, so to acquire a dairy cow dung processing machine that would have the efficiency in separating water from dairy cow dung. This would also increase the nutrient value for plants by spraying beneficial microorganisms on the plants while mixing in the dregs of dairy cow dung for producing to cultivate local crops or sell to farmers who grew crops. Then, this development would be in the conjunction with the concept of an environmentally friendly design by relying on the potential of the community to drive sustainable development with the indicators (Li et al., 2016): 1) Utilization of dairy cow dung, 2) reduction of the fermentation of dairy cow dung that would produce methane gas, 3) development of a machine for converting dairy cow dung into organic fertilizer, 4) environmental security, 5) generating income from dairy cow dung to be an income for dairy farmers, and 6) creating sustainable development in the future. These six indicators were in conjunction with the concept of cooperation among the people in the community that created development opportunities that were environmentally friendly (Hong & Guo, 2019).

From the results of the experimental process of converting dairy cow dung with a machine into organic fertilizer, this showed that when piloting, it was found to be consistent with the results of the technical analysis. In addition, the QFD was summarized according to the order of priority in solving the 15 problems found in the articles until being able to design a new type of dairy cow dung processing machine that effectively met the needs of the dairy farmers in the Nakhon Ratchasima area of Thailand. Thus, this was related to the satisfaction of the farmers who tried using the new dairy cow dung processing machine (Fadavi et al., 2022). Simultaneously, the long-term impact of large-scale livestock farming on the planet has changed the methods and developed the appropriate technology to solve the problem of methane emissions from large dairy farming areas in Thailand, including showing a responsibility for the global environment now and in the future, (Christopher, 2000; Zhu et al., 2020).

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