JEL: O30, Q10, Q13

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BUSINESS MODEL DEVELOPMENT FOR INSTALLATION OF RUBBER FLOOR MATS TO SUPPORT PRODUCTIVITY IN DAIRY FARMING

Purpose. *Ribbed smoked sheet (RSS) rubber gradually loses its quality as it is stored after production. Rubber floor mats are recommended as a marketable upstream production in the Thailand rubber industry to help add economic value to low-graded RSS. However, limited attention in research has been paid to business development, particularly on practical models focusing on the demand perspectives. This study helped fill the knowledge gap by analysing factors influencing labour production in dairy farming and proposing a business model based on productivity analysis. The aim of the project was to create a practical business model for cattle rubber floor mats made of low-graded RSS rubber used for nourishing and housing management to promote labour productivity in dairy farming.*

Methodology / approach. *The study used mixed-methods research. A theoretical framework was developed concerning rubber floor mats used in dairy farming, which helped improve the nourishing and housing management of dairy cattle and promote labour productivity. This research adopted Osterwalder's business model canvas to examine the demand and supply elements of dairy cattle floor mats made of low-graded rubber. It also used the knowledge-based entrepreneurship concept to scrutinise knowledge-based business development. A questionnaire survey was used to collect data required for multiple regression analysis of labour productivity using the Ordinary Least Square (OLS) method. It also used semi-structured interviews to scrutinise the subjective experiences of farmers. A focus group discussion was conducted to investigate academics and rubber promotional authorities concerning potential technology and the possibility of transfer of production technology to promote knowledge-based business development.*

Results. *The empirical evidence presented in this paper confirmed that rubber floor mats could help enhance cattle nourishment, dairy housing management and labour productivity. Regional knowledge transfer network was revealed as a driver of knowledge-based development for assisting local upstream rubber farmers in pursuing eco-innovation in rubber production, aligning with the national initiatives of Industry 4.0 and Bio-Circular-Green economy (BCG) concepts.*

Originality / scientific novelty. *The originality of this paper is that it presents the results of an empirical study using mixed methods for the first time aiming at clarifying practical elements of the supply and demand sides' components of the Osterwalder's Business Model Canvas for developing a business model delivered as a knowledge-based business model for the production of dairy cattle floor mats made of low-graded RSS rubber to help guide practical downstream rubber business development. The qualitative results, together with the quantitative analysis of labour productivity, are based on the perceptions of local farmers in Thailand regarding the use of rubber floor mats on the farm; previous studies scientifically prove its positive relation to an increase in dairy cattle nourishing, hence the daily productivity.*

Practical value / implications. *The novel business model canvas could promote the practical cattle floor mats business development. University engagement and public support were included as the critical drivers in this knowledge-based business model. The model implementation could help*

encourage rubber farmers and smallholders in upstream rubber production to move towards downstream business development and become knowledge-based entrepreneurs in value-added rubber floor mats production. It could also guide the agricultural policymakers to benchmark and evaluate their policy targeting innovative knowledge-based business development for rubber extension.

Key words: *agricultural economics, business development, innovation, knowledge-based economy, labour productivity.*

1. INTRODUCTION

Thailand's domestic rubber price fluctuates depending on influencing factors and demand conditions (Doner & Abonyi, 2013). Thai rubber farmers in the upstream sector often suffer when prices are low. Fresh and concentrated rubber, the two types of upstream rubber products, have short storage life and are forced to sell even when the prices are low, resulting in a business loss. Farmers can choose to transform their product into ribbed smoked sheet (RSS) rubber and wait for altered market circumstances to help drive up market prices. However, the key challenge is that the stored rubber loses its quality over time and becomes a low-graded product with worsened market value and loses competitiveness compared to the newer rubber supplied to the market. Low-graded RSS rubber often becomes a burden; farmers are desperately forced to choose whether to keep storing them and accept declining quality, lessening competitiveness and possibly increasing storage costs. Alternatively, they must dispose of them properly at additional costs, which can ultimately result in a loss to the business.

This study is relevant due to growing concern about wasted rubber becoming an environmental threat (Li et al., 2020) and various recent economic development policies focusing on circular economy and waste management (Gorokhova et al., 2023; Kucher et al., 2022). It also accounts for Thailand's national economic development initiative, which recently promoted the Bio-Circular-Green economy, also known as the BCG economy (National Science and Technology Development Agency of Thailand, 2023). For the rubber industry, Thailand has encouraged local farmers to move downstream to increase their production value. Various product developments, such as vehicle tiles, auto parts, construction materials, and belt products (Weerathamrongsak & Wongsurawat, 2013), are recommended to guide innovative rubber business development.

Various products recently developed to improve cattle nourishment include animal scratching posts, and floor mats. Among various possible marketable products, livestock rubber mat is often recommended at the policymaking level as a potential commercial product to benefit livestock productivity, given international studies confirming its anti-fatigue benefit for animals (Sadharakiya et al., 2019; Schütz et al., 2018) and helping to improve productivity in livestock industries such as dairy farming and cattle breeding (National Science and Technology Development Agency of Thailand, 2023b; Weerasinghe et al., 2021). According to the National Science and Technology Development Agency of Thailand (2023), technology and national innovation policies are available to promote rubber mat production. This study was

conducted in Mahasarakham, Thailand, and focused on empirically studying the use of rubber mats in dairy cattle. This province is home to 164 dairy farms membered to two local dairy cooperatives. Its results could lead to further implications that could help improve the businesses of these local farms.

However, most previous studies in Thailand have focused on product innovation on the supply side at the policymaking levels, especially on scientific techniques for processing upstream rubber into value-added downstream products (National Science and Technology Development Agency of Thailand, 2023b; Sirisinha et al., 2020); limited attention in research has been paid to business development, particularly on practical model focusing on the demand perspectives.

This study helped fill the knowledge gap by analysing factors influencing labour production in dairy farming and proposing a business model based on productivity analysis. It aimed to present a practical business model for cattle rubber floor mats made of low-graded RSS rubber used for nourishing and housing management to promote labour productivity in dairy farming. This paper, therefore, presents the research results to help fill the knowledge gap by providing empirical evidence on demand-side analysis to promote the development of the business model. Its results are expected to help reduce the rubber waste of the upstream industry by delivering novel practical knowledge on the understanding of the demand required for rubber floor mats business development. This downstream rubber business promotion is expected to help promote sustainable agriculture in Thailand's rubber industry and reduce the environmental threat caused by defunct upstream low-graded rubber.

2. LITERATURE REVIEW

Thailand exports a third of the world's natural rubber supply (Trade Policy and Strategy Office of Thailand, 2023). Raw rubber production, which is considered the world's leading exporter, is usually carried out by smallholders, mainly local farmers (Delarue, 2011). Given that rubber is always among the top ten most exported agricultural products of the country, domestic rubber prices, especially in the exploration sector, inevitably depend on the world market and are influenced by both external and internal factors and demand conditions, which leads to fluctuations and instability of market prices (Weerathamrongsak & Wongsurawat, 2013).

Marketable rubber products have been recommended to help move Thailand's rubber industry in the downstream direction. Recent scientific research and development (R&D) studies indicate available techniques for processing rubber into usable mats to serve various purposes, such as absorption mats for the elderly (Atthawuttikul & Chavalkul, 2018) and livestock floor mats to enhance the animals' loafing area condition and to ease the pain from leg and feet injuries (National Science and Technology Development Agency of Thailand, 2023b). However, these studies are often conducted at the theoretical level to promote rubber innovation to serve the national policymaking aiming at the technology transfer for advancing the rubber industry; none has explored the demand analysis, especially to help the business development.

This study focused on rubber floor mats targeting dairy farming use and the potential implementation of results for promoting the rubber flooring business to reach dairy smallholders throughout the country. Suárez-Usbeck et al. (2023) examine studies and literature on various types of bedding for dairy cattle welfare and find that rubber mats, also known as rubber bedding, have internationally been increasingly introduced for use in cattle farms of importance to the economies. Studies in Australia (Herzog et al., 2020), Canada (Tucker et al., 2003), and the UK (Vanegas et al., 2006) have scientifically confirmed that floor mats installation benefits dairy cattle's health, resulting in increased milk production. These studies suggest that rubber flooring helps improve the cows' living conditions and lessen their health problems in the breeding area, allowing the farm workers to increase their productivity.

Since dairy farming is the target customer of this study of rubber business development, the study focused on using rubber in cattle nourishing to help promote the labour productivity of dairy farming. Labour productivity is among common partial productivity analysis techniques; it measures the ratio of outputs to inputs (Salehi et al., 2013). Dairy production is commonly expressed in the gross milk output per cow (Kimura & Sauer, 2015). This research, therefore, analysed labour productivity, referring to the milk output produced per labour on the farm. Then, there was further investigation on how the demand for rubber floor mats should be characterised concerning such flooring was proven to enhance dairy nourishment, hence promoting milk production (Tucker et al., 2003; Vanegas et al., 2006). Ultimately, these findings can be used to formulate the demand analysis and production on the supply side for business model development.

The authors reviewed previous studies focusing on the relationship between farming flooring improvement and labour productivity in dairy farms. Various previous studies suggested a positive relationship between labour productivity and rubber floor mats used in dairy farms. Haskell et al. (2006) found that farms invest in materials other than hard concrete flooring to provide a comfortable surface for standing and lying down, which helps reduce lameness and leg lesions in dairy cows. Less labour hours were required for cow nourishment and lameness and leg lesions treatment. For this reason, better nourishment conditions help increase milk production as the cows stay productive in the farms, increasing milk output. This study guides the authors in including factors related to investment, namely capital-labour ratio (CAP) and total input cost (COST). Ramos (2021) studies family labour organisation of dairy farming businesses and finds that the number of family members working for the farm, the farm size and comfortable flooring conditions in the loafing area positively create good breeding conditions and environment. Therefore, similar to Haskell et al. (2006), comfortable flooring positively supports labour productivity as it helps reduce the duty hours for treating unwell dairy cows with lameness and leg lesions. This study suggests that the researchers select household size (HOU), experience (EXP), and total farming area (AREA) as variables to be studied in this research. Kumarasekara & Edirisinghe (2009) point out that education level positively affects labour productivity in dairy smallholders. Another factor to include in this research focusing on the labour

productivity analysis was the labourers' education level (EDU).

The purpose of the article is a new study that will help to develop a practical business model for rubber floor mats concerning its benefits for the labour productivity of dairy farms. The research was based on Osterwalder's business model, which has been used in studies of business development in various industries (Osterwalder & Pigneur, 2010). It also adopted the concept of knowledge-based entrepreneurship development to examine a practical business model canvas for farmers at the upstream rubber businesses to produce rubber floor mats, considering the possibility of product development made from a low-grade type of RSS rubber.

3. METHODOLOGY

This research conducted an empirical study of dairy farming smallholders in Mahasarakham, a province in the North-East region of Thailand. It is home to 164 dairy farms membered to two local dairy cooperatives (Cooperative Promotion Department, 2023). It aimed to examine the demand for rubber floor mat to help increase the business performance of dairy farming – the unit of analysis as individual smallholders. The study used Osterwalder's business model canvas (Osterwalder & Pigneur, 2010) to analyse the demand from studied farmers whose labour productivity could benefit from rubber floor mats installation.

The authors used mixed-methods research with a convergent design, known as interactive mixed-method research (Greene et al., 1989) and equal-status mixed-methods research (Johnson et al., 2007). For this study, the quantitative and qualitative components had equal value and importance in helping the researcher achieve the research objectives. As Chanthes (2023) points out, the convergent design is chosen when the researcher needs to construct a holistic understanding of the studied phenomenon by comparing statistical results with the qualitative elements.

On the one hand, the quantitative analysis allowed the researcher to statistically examine the factors influencing the labour productivity of dairy farming, as guided by the literature in the field (Akzar et al., 2023; Boyer et al., 2023), to understand the labour productivity of relevance to its dairy nourishing and housing management. This quantitative research phase was designed based on a set of variables suggested by previous studies on the labour productivity (LP) of dairy farms (Kimura & Sauer, 2015; Ramos, 2021; Schroeder et al., 1986; Van der Meulen et al., 2014). These variables included capital-labour ratio (CAP), total input costs (COST), experience (EXP), education (EDU), household size (HOU) and total farming area (AREA).

On the other hand, the qualitative analysis helped to scrutinise further and explain subjective perspectives embedded in the studied subjects' experiences. As a result, the quantitative and qualitative analysis led this study to understand how the demand for rubber floor mats should be characterised as the business development targeting to help enhance the labour productivity of dairy farming. This research adopted Osterwalder's business model canvas to guide its investigation (Table 1).

The canvas has widely been used for studying business development in diverse agricultural industries (Barel-Shaked, 2023; Engelen et al., 2023), including rubber

products (Andren & Hedin, 2018). However, such a model has not been used for natural rubber mats targeting dairy farming use in Thailand. Results from this paper will, therefore, fill this knowledge gap.

Table 1

Elements of the supply and demand sides of the business model canvas

<table>
<tr><td colspan="3">The Supply Side</td><td colspan="3">The Demand Side</td></tr>
<tr><td rowspan="2">Key partners</td><td>Key activities</td><td rowspan="2">Value propositions</td><td>Customer relationships</td><td rowspan="2">Customer segments</td></tr>
<tr><td>Key resources</td><td>Channels</td></tr>
<tr><td colspan="3">Cost structure</td><td colspan="2">Revenue streams</td></tr>
</table>

Source: based on Osterwalder's business model canvas (Osterwalder & Pigneur, 2010).

Following the ethical approval of the research instruments granted by the internal review board (IRB) of Mahasarakham University. This study used a questionnaire survey to collect data to calculate the average product of the labour input, or the labour productivity, using multiple regression modeling, a powerful statistical method for studying the relationships between variables (Salehi et al., 2013). The first fieldwork, conducted in February 2023, was the questionnaire survey. According to Krejcie and Morgan's formula, the minimum sample size of the population of dairy farms, N = 164, in the studied province was determined to be 115 (Krejcie & Morgan, 1970). The data collection was assisted by the two managers of the local dairy cooperatives and two trained research assistants handing out the questionnaire in person to members randomly showing up to deliver their milk in the morning. The study received 51 returned questionnaires or a 44.35 % response rate. Since all the responses were from members delivering the milk on site, all of the collected data was assured from those currently active in their dairy businesses while answering the questions.

The second fieldwork, carried out in March 2023, was qualitative data collection. The authors interviewed 34 questionnaire respondents who agreed to provide further information and the two cooperatives' managers of the sites where the questionnaires were distributed. Semi-structured interview questions were designed bounded within the five elements of Osterwalder's business model canvas, guiding the investigative aspects to include customer segments, customer relationships, channels, value propositions, and revenue streams (Osterwalder & Pigneur, 2010). The authors also included questions relating to the initial statistical results of the variables studied to examine subjective interpretations of both statistically significant and insignificant variables of the regression analysis of labour productivity.

The elements required for the demand characterisation to fill the canvas include customer segments, customer relationships, channels, value propositions, and revenue streams (Osterwalder & Pigneur, 2010).

As a result, the review of relevant literature and previous studies, cited above, led the authors to construct the conceptual framework for investigating the demand, which is outlined in Figure 1.

In the final data collection phase, the authors conducted a focus group discussion to collect further data to analyse the production possibilities for the supply side from

business and production technology aspects. Given the knowledge-based economy (KBE) development, which suggested the importance of knowledge networks and technology transfer for innovation development, academics and public rubber promotional personnel were invited as participants. Six academics from a regional university were invited to participate in this research: two from mechanical engineering, one from chemical engineering, one from business economics, one from management, and one from marketing. An expert from the rubber promotional authority, the Regional Rubber Authority of Thailand (Northeast Office), was also invited to participate in the discussion.

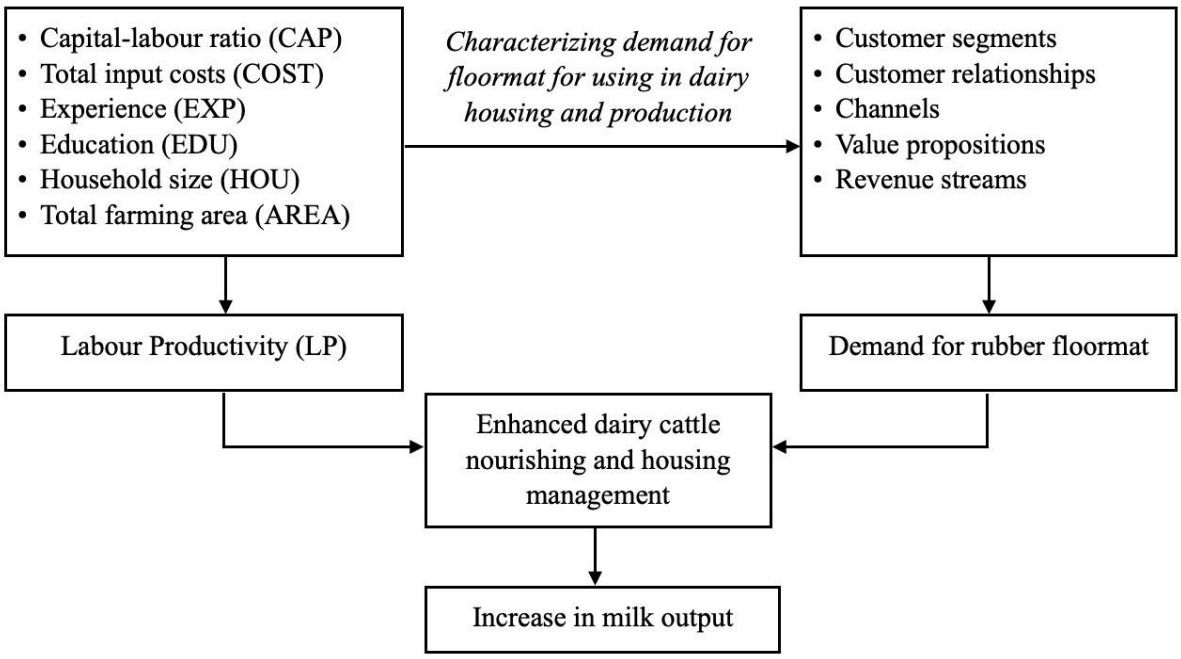

Figure 1. The conceptual framework for analysing the demand for dairy cattle floor mats

Source: created by the authors based on selected variables guided by Haskell et al. (2006), Ramos (2021), Van der Meulen et al. (2014) and demand elements of Osterwalder's business model canvas (Osterwalder & Pigneur, 2010).

Throughout the data analysis, the authors also examined the secondary data source using a documentary analysis approach (Yin, 2017). They analysed public documents and reports provided by government authorities of Thailand at the regional and national levels. The selected authorities were those responsible for rubber production development and cattle breeding promotion. The authors used a generic interpretive approach to analyse the research data. They constructed codes and categories based on the underpinning conceptions to provide the scope of the data analysis and interpretation of the results (Merriam & Tisdell, 2015). They also used a coding of conceptual interest technique (Creswell & Creswell, 2018) to conceptualise the empirical evidence discovered from the studied sites. This analysis technique allowed the researchers to adopt the underlying concepts of the business model canvas (Osterwalder & Pigneur, 2010) and the knowledge-based entrepreneurship development by Akuhwa et al. (2015) to lay the analysis foundation for cattle floor mats business development in a sustainable rubber ecosystem. Coding at this eventual

step was guided by elements of Osterwalder's business model canvas's supply and demand sides analysis (Osterwalder & Pigneur, 2010).

4. RESULTS

Based on the farmers' responses to questions in the survey and interviews, the socio-economic characteristics of the respondents are given in Table 2, and the background of the studied farmers' experience and perceptions of rubber floor mats installed in dairy farms are summarised in Table 3. The Table summarises the farmers' experience and perceptions of rubber floor mats on dairy farms based on the questions asked in the survey and interviews. These experiences were the empirical evidence laying a foundation for presenting research results and discussions in this section.

Table 2

Socio-economic profile of the respondents

Indicators		Household	Percentage
Gender	Male	23	45.10
	Female	28	54.90
	Total	51	100.00
Age, years	20–30	5	9.80
	31–40	9	17.65
	41–50	15	29.41
	51–60	15	29.41
	61–70	5	9.80
	71–80	2	3.92
	Total	51	100.00
Farm size	Small farm with no more than 20 dairy cows	3	5.88
	Medium-sized dairy farm, 21–100 cows	47	92.16
	Large dairy farms, 100 cows or more	1	1.96
	Total	51	100.00
Total area for dairy farming, acres	0–5	35	80.40
	6–10	6	17.60
	11–15	7	2.00
	Total	51	100.00
Dairy farming experience, years	1–5	20	39.22
	6–10	18	35.29
	11–15	8	15.69
	16–20	4	7.84
	20 years and more	1	1.96
	Total	51	100.00
Educational level	No compulsory education (0 years)	1	1.96
	Primary school (6 years)	16	31.37
	Secondary school (9 years)	7	13.73
	High school (12 years)	9	17.65
	Vocational college (12 years)	3	5.88
	Higher vocational college (14 years)	2	3.92
	Bachelor degrees (13 years and more)	13	25.49
	Total	51	100.00

Source: created by the authors based on the collected survey and interview data.

Table 3

Experiences and perceptions of studied farmers relating to rubber floor mats

Questions	Number of farms	% of total observations
Have you ever considered using rubber floor mats for livestock?		
Yes	35	68.60
No	16	31.40
Do you perceive rubber flooring to benefit dairy output?*		
Yes	18	35.30
No	33	64.70
Expected specifications of rubber floor mats		
None (rubber flooring is not necessary on the farm)	10	4.80
Stability	20	9.50
Durability	10	4.80
Suitable thickness	15	7.10
Non-slip	32	15.20
Shock-resistance	38	18.10
Easy care for cleaning routine	26	12.40
Waterproof	17	8.10
Anti-mould	19	9.00
Strength and thickness for tractor trucks passing	22	10.50
Other (good design)	1	0.50
Acceptable price ranges		
None (rubber flooring is not necessary on the farm)	15	29.40
100–150 Baht**/square metres	30	58.80
151–200 Baht/square metres	2	3.90
201–250 Baht/square metres	1	2.00
> 250 Baht/square metres	3	5.90
Are you willing to try installing rubber floor mats for free?		
No (suspect negative effects)	12	19.05
Yes (know the benefits without prior trial)	14	22.22
Yes (know the benefits and wanting to learn more from trying the product)	12	19.05
Yes (have previous experience using the product and already knowing the benefits)	12	19.05
Yes (with other positive perceptions)	13	20.63

Notes. *The participants answered based on their perceptions rather than their direct experience using rubber mats on their farms. Most previous experiences comes from trial installations for research or demonstration purposes. Although 64.70 % of the respondents answered "No" to the question "Do you perceive rubber flooring to benefit dairy output?" (see Table 3) due to the limited direct experience, both Yes and No respondents agreed to continue answering all the following questions relating to their expectations regarding installing rubber mats in their farms.

**As of 2023, the exchange rate of Thailand Baht/US Dollar (THB/USD) ranged between (34–35 THB/USD).

Source: created by the authors based on the collected survey and interview data.

Labour productivity analysis in dairy cattle farming. The authors used the Ordinary Least Squares (OLS) method to compute the multivariable regression model, using the data collected in the first fieldwork, the survey. The production function

estimated was:

$$LP_i = \beta_0 + \beta_1 CAP_i + \beta_2 EXP_i + \beta_3 EDU_i + \beta_4 HOU_i + \beta_5 COST_i + \beta_6 AREA_i, \quad (1)$$

where LP_i – the value of milk output in Baht/person per year for the i^{th} farm (household);

CAP_i – capital-labour ratio in Baht/person of the i^{th} household;

EXP_i – average number of years of all labourers working in the dairy farm of the i^{th} household;

EDU_i – average number of years of all labourers attending schools in the Thailand's educational system in the dairy farm of the i^{th} household;

HOU_i – total number of family labourers in the i^{th} household;

$COST_i$ – total input costs in Baht/year of the i^{th} household;

$AREA_i$ – total farming areas in square metres (sq. m) of the i^{th} household;

β – values of the coefficients to be estimated.

Descriptive statistics of the variables used in the labour productivity function are given in Table 4, showing the mean, median, maximum, minimum and standard deviation values of each variable used to analyse the 51 observations.

Table 4

Descriptive statistics of the variables

Indicators	LP, Baht/person	CAP, Baht/person	EXP, years	EDU, years	HOU, person	COST, Baht	AREA, sq. m
Mean	394,846.80	238,762.40	8.52	9.86	3.15	720,065.30	17,874.51
Median	327,456.80	169,000.00	7.00	9.33	3.00	646,512.80	12,800.00
Maximum	1,160,928.00	1,281,667.00	29.00	22.00	7.00	1,771,681.00	64,000.00
Minimum	56,590.46	26,250.00	2.00	2.00	2.00	128,706.00	3,200.00
Std. Dev.	243,506.80	230,288.60	5.48	3.95	1.12	365,620.60	13,266.62
Observations	51	51	51	51	51	51	51

Note. All values in the Table on a year basis.

Source: created by the authors based on the collected survey data.

The authors used SPSS as the statistical software for analysing the data. They verified the regression model by controlling the multi-collinearity and heteroscedasticity using simple correlation coefficient testing variables and the Heteroskedasticity test: ARCH (Salehi et al., 2013). As presented in Table 5 and Table 6, the model does not contain multi-collinearity ($-0.8 < r_{xy} < 0.8$) and heteroscedasticity for significance at the 0.1 level ($\alpha = 0.01$), Prob. > α.

Table 5

Testing for multi-collinearity of variables influencing dairy output per labour

Correlation	CAP	EXP	EDU	HOU	COST	AREA
CAP	1.000000	-	-	-	-	-
EXP	-0.214920	1.000000	-	-	-	-
EDU	0.227089	0.129977	1.000000	-	-	-
HOU	-0.174796	0.079340	-0.010005	1.000000	-	-
COST	0.151336	0.208861	0.275281	0.109345	1.000000	-
AREA	0.371697	0.164461	0.131587	0.114932	0.173080	1.000000

Source: created by the authors based on the collected survey data.

Table 6

Heteroskedasticity test: ARCH

Heteroskedasticity test: ARCH			
F-statistic	1.757888	Prob. F(1.48)	0.1912
Obs·R-squared	1.766442	Prob. Chi-Square(1)	0.1838

Source: created by the authors based on the collected survey data.

Finally, given the production function, the estimation of parameters through OLS was calculated as presented in Table 7.

Table 7

Estimated parameters of the production function model through OLS

Variable	Coefficient	Std. error	t-Statistic	Prob.
CAP	0.088647	0.069802	1.269973	0.21
EXP	-1,993.314	2,754.249	-0.723723	0.47
EDU	-1,070.526	4,245.243	-0.252171	0.80
HOU	-103,957.9	15,581.20	-6.672008	0.00*
COST	0.560213	0.038568	14.52547	0.00*
AREA	-0.053690	1.421267	-0.037776	0.97
Constant	328,874.7	86,075.38	3.820775	0.00

Notes. R^2 = 0.843, Adj R^2 = 0.813, P-value = 0.000, F-stat = 28.301, Obs = 51.

*Presents the significance level at 1 %.

Source: created by the authors based on the collected survey data.

Table 7 shows that two factors used in the production function are significant at a 99 % confidence level ($p < 0.01$). Total input costs (COST) positively influenced the average productivity of milk output in the sampled observations, meaning higher input costs in the business led to more milk output. Conversely, household size (HOU) significantly has a negative influence on the labour productivity of milk output, indicating that larger household sizes showed less labour productivity. Four variables showed statically insignificance in labour productivity of milk output ($p > 0.05$) despite being selected for the estimated production function following related previous studies in the field (Kimura & Sauer, 2015; Ramos, 2021; Van der Meulen et al., 2014). Creswell & Creswell (2018) suggested that insignificant quantitative results could be caused by the differences in demographics, different socio-economic, or different sample sizes of different studied fieldwork, resulting in insignificant hypothetical variables.

Accordingly, an additional qualitative investigation was designed to scrutinise further explanations concerning the specific settings of this research's empirical site. The qualitative analysis was based on all significant and non-significant variables. It examined the positive influences of capital-labour ratio (CAP) and total input costs (COST) and the negative influences of experience (EXP), education (EDU), household size (HOU) and total farming area (AREA). The following is an explanation of the research findings organized by elements of the demand analysis for canvas business model, including customer segments, customer relationships, channels, value propositions, and revenue streams. The presentation of results and corresponding discussions combine both quantitative and qualitative analysis of the empirical evidence from the research data.

There are three common types of housing management in local smallholder dairy farming in Thailand: straw-yard, free-stall, and mixed-type. This study's survey respondents were 11.30 % straw-yard, 43.40 free-stall and 45.30 % mixed-type farms (Table 8). These numbers were consistent with the Cooperative Promotion Department (2023), indicating that most local dairy farms in Thailand have been promoted through the cooperative networks to manage the farm using free-stall or cubicle housing areas to raise higher productivity. Thus, only the minority work entirely on conventional straw-yard farms. Results from the interview data helped explain that the traditional type of farming family preferred traditional straw-yard farming; they only managed to have a small area for concrete as a milking parlour and feeding the cows in the family's grazing land area. They bred the cows and grazed them in the family pasture.

Table 8

Dairy farm housing

Housing management type	Number of farms	% of total observations
Straw-yard	6	11.30
Free-stall	22	43.40
Mixed-type	23	45.30
Total	51	100.00

Source: created by the authors based on the collected survey data.

The qualitative examination revealed that family labourers with longer experience were mostly experienced in conventional straw-yard farms. Although statistically insignificant, this result was consistent with the variable experience (EXP) for having a negative relation to labour productivity (LP). Additional evidence collected through interviews helped explain that the traditional housing technique was based on the farmers' indigenous knowledge; this finding was consistent with scientific studies (Haskell et al., 2006; Langford et al., 2021) confirming that soil and grazing surfaced yards provide cushioning effects helping to reduce cow foot and hoof problems caused by concrete. Therefore, rubber flooring was unnecessary for conventional straw-yard farming (Figure 2, Appendix A). This type of traditional farming used a larger land area (AREA) while delivering relatively less productivity, as seen earlier in Table 4, showing a negative influence of AREA on LP, significant at a 99 % confidence level ($p < 0.01$).

Considering the three types of dairy housing management, traditional straw yards, modern free stalls, and mixed-type, this paper suggests modern free stalls farms using cubicle housing design as the target market segment (Figure 3, Appendix A). Interviews with the farmers confirmed the positive relation between total input costs (COST) and labour productivity (LP), with statistical significance ($p < 0.01$), indicating that farms with higher costs resulted in higher labour productivity. The results also helped explain the positive effects of the capital-labour ratio (CAP) on labour productivity (LP), revealing that free-stall farms invested more in construction design and housing facilities, such as permanent sheds and concrete flooring. Agreeing with the study of Haskell et al. (2006), a good free-stall design helps reduce lameness and leg lesions in dairy cows. These results implied that farmers could increase their

investment in enhancing the sheds and flooring materials to promote the breeding environment where the labourers nurtured the cows to increase productivity.

The survey findings showed that 68.60 % of the respondents had experience using the mats, and 64.70 % found rubber flooring useful for promoting the cows' well-being. Most past experiences has come from a trial installation for research or demonstration purposes. Therefore, the farmers only try using the mats in a partial housing area. Despite the benefits, the movable mats led to multiple hygienic and routine care problems caused by debris, cow drops, and water trapped underneath the mats. Considering the difficulties, these removable large and heavy mats eventually became a burden to remove. Accordingly, the finding suggested that rubber floor mats should be placed on a concrete floor instead of a removable construction, which most in the market recently offered.

Suitable mat installation requires high personnel involvement and the provision of extended training in customer relations. This result suggested that training is based on the research findings revealing the average year of education of labourers on the surveyed farms. The mean value of education (EDU) was only 9.86 years, meaning that most labourers achieved only the national compulsory secondary school education with no specific expertise in livestock sciences. Furthermore, higher-educated family labourers obtained their degrees from other areas not specific to livestock sciences or dairy farm business; these labourers often had another job and only worked for family farms, providing little productivity. Although statistically insignificant, these data helped explain the negative relation between education (EDU) and labour productivity (LP).

This paper, therefore, suggests that floor mat business development should include an on-site fitting service to help enhance the farm design for better productivity. Additional training for housing management and using rubber flooring to promote productivity should also be offered as part of the business model for customer relationships. Kumarasekara & Edirisinghe (2009) point out that education level of the farmers and training extension positively affects dairy smallholders' labour productivity. Recommended activities for farm improvement, based on Andren & Hedin (2018) and Vanegas et al. (2006), may include on-site service, technical training for product installation and maintenance and custom free-stall flooring design for individual customers.

The finding showed that no respondents who worked for local family farms ever purchased rubber floor mats at their own cost; even those who had previous experience using rubber floor mats were offered a trial use for either demonstration or research purposes through various channels: from the cooperatives they membered for commercial demonstration; from regional universities offering a trial product for research purposes; and from local agricultural promotional authorities for technology and knowledge transfer purposes. This result suggested an extension of training about the contributary benefit of farming facilities, such as rubber mats, to positively benefit productivity. This paper, therefore, recommends a rubber floor mat business model that includes networking promotional schemes to encourage demand. It perceives existing

connections among farmers and the established networks engaged by public and educational sectors as essential for business development. As a result, the paper suggests basic channels for connecting with the target customers based on personal references among local farmers, their cooperatives, local agricultural authorities, and regional universities.

As discussed earlier, 64.70 % of the respondents, having tried rubber mats on their farm, confirmed acknowledging the benefits of rubber flooring. Langford et al. (2021) also insist that the concrete floor with its unyielding nature adversely affected the health of the legs and feet of the cows. Accordingly, the perceived benefits led these respondents to identify their expectations for product development, including permanent installation with a minimum of fifteen years of durability (based on the expected lifetime of all investing capital of the housing construction (Table 9).

Table 9

Dairy farm investing capital

Investment category	Average investment value, Baht	Current usage, years	Expected remaining usage, years
Housing construction (including loafing area and milking parlour)	452,291.04	7.14	9.47
Milking machines	67,391.11	6.45	6.61
Farming machinery (including tractor truck)	211,411.76	3.08	5.96
Milking equipment	17,039.22	3.24	2.94
Miscellaneous	4,147.06	0.45	0.59

Source: created by the authors based on the collected survey data.

The value propositions of rubber mats also concerned various reported hygienic problems and impractical installation caused by the removable construction of most available mats, either those recently supplied in the market or those resulting from rubber research and development (R&D) projects. This finding helped change the direction of livestock mat design regarding how rubber mats should be developed to address many of the perceived defects that hinder the desire to purchase. It suggested that rubber flooring should be permanently installed and designed in such a way that they do not cause hygiene problems and complicate routine maintenance during long-term use. Also, the promotion of mat value should focus on the following qualities, as summarised based on the farmers' perspectives presented in Table 3: durability, non-slip, shock-resistance, anti-mould, waterproof, easy-care for cleaning routine, strength and thickness for tractor trucks passing.

According to the interview data and multiple site visits to the farms during the second fieldwork, the recommended installation for the loafing area was 10 square metres per cow. These data suggest that more cows require more fenced area to install mats, leading to an increase in the farm's capital-labour ratio (CAP) and input costs (COST) to influence an increase in LP positively. Table 10 illustrates the calculated housing area of the research site, given that most observed farms (> 85 % of the total surveyed area) operated cubical farming, regarded as the target market segment.

Table 10

Farm sizes and recommended housing areas for healthy loafing activity

Farm size (classified by numbers of cows*)	Number of farms	% of total observations	Total surveyed housing area, sq. m
Small (1–20)	8	15.69	195.03
Medium (21–100)	42	82.35	500.38
Large (101 and more)	1	1.96	1,264.74
Total			653.38

Note. *As guided by the interview with the managers of dairy cooperatives at the research sites.
Source: created by the authors based on the collected survey data.

Although no respondents had ever purchased rubber mats, those who expressed a positive perception of the benefits of rubber flooring predicted an acceptable price range, provided the installation met their expectations. The following price ranges were given as part of the descriptive statistics of the survey results (see also Table 3): 58.80 % for 100–150 Baht/sq. m, 3.90 % for 151–200 Baht/sq. m, 2.00 % for 151–200 Baht/sq. m, while 5.90 % would agree to pay above 251 Baht/sq. m. Only 29.40 % asserted rubber floor mats were unnecessary for their farms, hence no intention to pay for the product. Given the anticipated price ranges, these findings suggested that private demand for rubber installation could be created.

In circumstances where farmers do not pay their own costs, such as the mat being offered for demonstration, public support or research purposes, 81.95% of respondents said they would agree to try installation. This finding suggested that in addition to private demand, there was another source for demand creation involving public sources of funds, including public authorities, regional universities, and research institutions. These public and educational sectors could purchase rubber floor mats to provide to local dairy smallholders, offering the installation for agricultural research or promotional policy implementation.

The analysis conducted by the authors on the supply side was informed by the insights of rubber innovation specialists and academics. Additionally, the authors supplemented their findings using a secondary data analysis of government reports and public records. This study showed that the studied regional university possesses the necessary innovative rubber technology for processing low-grade rubber for the production of cattle floor mats. One of the participants in the focus group, who possessed expertise in mechanical engineering and had a research interest in rubber science and production, verified the existence of production technology that enables the customisation of low-quality RSS rubber. This customisation involves the use of various chemical substances to facilitate the processing of the rubber, resulting in desired qualities such as thickness, hardness, durability, or water resistance. The author presented instances of compounds incorporated into untreated RSS rubber by diverse formulas in order to convert the rubber into distinct specifications suitable for further forming into new rubber products. Examples are shown in Figure 4 (Appendix A).

Furthermore, it has been recommended by other scholars in the field of engineering to pursue the establishment of a sustainable rubber production ecosystem in alignment with the contemporary national economic development framework known

as the Bio-Circular-Green economy model (National Science and Technology Development Agency of Thailand, 2023). The research findings, therefore, revealed biofuel production technology that can be utilised to convert RSS rubber and obsolete products, including raw low-graded RSS rubber, waste generated during rubber sheet manufacture, and aged RSS products, into biofuel; see also Figure 5 (Appendix A).

Given the diverse range of raw and discarded RSS rubber, which holds the potential for conversion into rubber biofuel that has been scientifically demonstrated to be comparably effective to diesel fuel, this new rubber product might be afterwards marketed as downstream rubber products within the framework of the BCG model. From an academic viewpoint, engineering academics confirmed that there was a viable potential for the transfer of production technology as a means of university outreach to facilitate the advancement of rubber innovation. This result was consistent with prior research examining the development of a KBE in small agricultural commodities in Thailand (Chanthes & Sriboonlue, 2021; Puangpronpitag, 2019). It states that small-scale local farmers face constraints on research and development opportunities, which hinder their ability to collaborate with local higher education institutions and benefit from university outreach programs and technology transfer initiatives.

The data sources were conceptualised in accordance with the five parts of the canvas supply side, namely key partners, key activities, key resources, cost structure, and value propositions. This conceptualisation was complemented by the analysis conducted from the demand side, as proposed by Osterwalder & Pigneur (2010). Consequently, the findings were organised within the framework of the canvas, encompassing both the supply and demand aspects. The shared value propositions for the rubber cow floor mat products are presented in Table 11, which provides a formation of the knowledge-based business model canvas for RSS rubber cattle floor mats.

The business model canvas outlined in Table 11 led to a practical implementation this research offered as a contribution to knowledge in the field. The components filled in each of all the nine modules could lead to developing a business for transforming low-graded RSS rubber into a value-added product of cattle rubbers to encourage its use in dairy farming to promote productivity, based on the analysis of the supply and demand sides this empirical research has delivered. All the elements listed in the nine modules, namely key partners, key activities, key resources, cost structure, customer relationships, customer segments, channels, revenue streams, and value propositions, could be essential guidelines for establishing a high-potential success business.

5. DISCUSSION

Considering the research results about encouraging demand for using rubber floor mats to promote a nourishing environment for dairy cattle and hence increase dairy productivity, agricultural promotional policies should be implemented through public and private connections between local authorities and local farmers. The results of this study support previous studies by Chanthes (2022) and Puangpronpitag (2019); public and private connections in agribusiness development through personal references can

promote knowledge transfer among the involved parties. According to the findings of these previous studies, Chanthes (2022) studies the public-private connection in the organic rice production business, and Puangpronpitag (2019) considers various local farming businesses, including dairy farms in the UK. They similarly discover the positive effect of the relationship on promoting demand for using agricultural supplies and equipment following public agricultural promotional policies.

Table 11

Knowledge-based business model canvas for RSS rubber cattle floor mats

<table>
<tr>
<td rowspan="2">Key partners:
- RSS rubber farmers
- Knowledge and technology transfer partners, i.e., regional universities and local public authorities for cattle promotion
- Local distributing partners
- Local sales and marketing partners</td>
<td>Key activities:
- Raw RSS rubber transformation by adding active agents
- Moulding processed RSS rubber sheet into designed cattle floor mats shapes production
- Machinery design assisted by the production technology transfer through university outreach and regional engagement</td>
<td rowspan="2">Value propositions:
- Rubber flooring has been scientifically proven to reduce the health problems concerning the cow’s legs and feet caused by unyielding concrete floors
- Permanent superimposed installation on concrete is required
- Customer’s product expectations: non-slip, shock-resistance, anti-mould, waterproof, easy-care for cleaning routine, strength and thickness for tractor trucks passing</td>
<td>Customer relationships:
- Highly personal
- On-site service for product installation
- Technical training for product installation and maintenance is provided
- Custom free-stall flooring design for individual customers</td>
<td rowspan="2">Customer segments:
- Free-stall farms
- Cubicle housing areas in mixed-type farms
- Farms with concrete-surfaced loafing areas
- Prioritising farms with relatively high capital-labour ratio and higher investment costs, e.g. larger farms with more cows, more housing construction area or higher business investment value</td>
</tr>
<tr>
<td>Key resources:
- Raw RSS rubbers
- Skilled workforce
- Cost of chemical substances
- Financial support (public initiatives / private investment)
- Technical support from regional universities and rubber promotional authorities</td>
<td>Channels:
- Direct contact through personal references and networks
- Through dairy cooperatives, they membered for commercial demonstration
- Through regional universities for research purposes
- Through local agricultural authorities, responsible for promoting technology and knowledge transfer policies</td>
</tr>
<tr>
<td colspan="3">Cost structure:
- Material costs: raw RSS rubber supplies (Fluctuating prices based on the world rubber markets)
- Costs for investment and maintenance of forming equipment
- Labor costs
- Marketing costs
- Customer relations costs
- Product distribution costs</td>
<td colspan="3">Revenue streams:
- The expected price range is 100–150 Baht/sq. m for general customers’ expectations
- The expected price range is above 250 Baht/sq. m for premium products
- Government subsidies or public funding schemes are used to initiate wider public recognition of rubber flooring benefits
- Recommended installation for the loafing area is 10 sq. m per 1 cow; more cows, more areas, more installation area</td>
</tr>
</table>

Source: created by the authors based on Osterwalder’s business model canvas (Osterwalder & Pigneur, 2010).

Similar results to the previous study by Puangpronpitag (2019) were discovered in this study because the respondents were members of the local dairy cooperatives, where public authorities for dairy farming regularly visit to help educate and monitor the farmers’ milk production. Also, similar to the empirical findings of Chanthes

(2022), academics from regional public universities in this region who research agricultural promotion typically establish strong relationships with cooperative managers to create access and further linkages with farmers. Given these strong communication channels, the research findings confirmed a positive impact on demand stimulation.

The results of the study also indicate support for environmental innovations, which play a significant role in the economic development of Industry 4.0 (Noronha et al., 2023). Furthermore, similar to the study conducted by Kucher et al. (2022), adopting environmentally sustainable production practices was perceived as viable way for agricultural companies to achieve improved financial performance. Hence, the business model suggested by this study also included local knowledge providers, such as regional universities and rubber promotional authorities, who played a crucial role in facilitating the dissemination of innovative production knowledge and technology transfer. This support assisted local upstream farmers in pursuing eco-innovation in rubber production, aligning with the national initiatives of Industry 4.0 and BCG concepts.

This study has delivered a crucial contribution to knowledge in the field by providing evidence to support the business development of rubber floor mats, focusing on both the supply and demand sides based on the expectations of the targeted customers. These local dairy farm owners labour for their businesses. The study ultimately utilised the evidence to construct a resourceful business model for establishing cattle rubber floor mats made from low-quality RSS rubber, which are utilised for feeding and housing management to enhance labour productivity in dairy farming.

6. CONCLUSIONS

Livestock rubber floor mats has been proposed as a product with potential for the Thai market. However, existing studies from the country mainly focus on scientific experiments for processing rubber at the theoretical level. None has explored the demand analysis, especially in terms of business model development. This paper has filled the knowledge gap by delivering empirical evidence of the demand analysis targeting dairy farm use. The study used mixed-method research, starting with a questionnaire survey to collect quantitative data required for labour productivity analysis. Then, the results were used to guide the further qualitative investigation, using interviews to collect the data for scrutinising dairy farm management relating to the rubber installation to help increase its labour productivity, hence creating the demand for using the floor mats.

This study examined the labour productivity of dairy farming, as the demand side of cattle floor mats, using the OLS method for computing the multivariable regression model using the data collected by a questionnaire survey. Two factors of the proposed production function showed significant at a 99 % confidence level ($p < 0.01$). Total input costs (COST) positively influenced the average productivity of milk output in the sampled observations, meaning higher input costs in the business led to more milk

output. Conversely, household size (HOU) significantly negatively influences milk output's labour productivity, indicating that larger household sizes showed less labour productivity.

The survey data showed that the respondents of this study were 11.30 % straw-yard, 43.40 % free-stall and 45.30 % mixed-type farms. The findings showed that 68.60 % of the respondents had experience using the mats, and 64.70 % found rubber flooring helpful in promoting the cows' well-being. Given that the findings of total input costs positively influenced the productivity in dairy farming and interviews with the respondents helped explain the positive effects of the capital-labour ratio (CAP) on labour productivity (LP), these results suggested that free-stall farms invested more in construction design and housing facilities, such as permanent sheds and concrete flooring. It showed that increasing capital-labour ratios and input costs, such as enhanced farming construction materials and better housing design, could significantly promote the farm's output.

Based on the demand analysis, this paper suggests business development to promote rubber flooring in free-stall dairy farms as permanent superimposed installation on concrete, which is rare, providing the most available products in the market, which are detachable mats. However, despite the confirmed positive perceptions of rubber flooring, the recommended customer segment indicated the price ranges of their willingness to pay as low as 100–150 Baht/sq. m. This outcome implies limited market awareness of the product value despite its scientifically proven usefulness. Thus, further strategies for demand creation were recommended. Considering the national policy for promoting the rubber industry, this paper suggests creating demand through promotional schemes and financial and knowledge support from the public and educational sectors to expand market awareness and stimulate product value.

The paper also provided findings that led to two critical practical implications that are discussed in this paper. First, the market for cow mats targeting cattle farms or livestock use should target innovative knowledge-based farms ready to accept innovative products proven to help increase their productivity. Secondly, considering the available technologies and the possibility for knowledge transfer from the academic sector, the production of RSS rubber cow mats shows potential for business development for local farmers and small regional enterprises. This paper will help shed light on tackling problems rubber farmers face in the upstream industries.

In addition to the practical implications, this paper also contains three critical policy implications. First, concerning limited resources and knowledge, local rubber farmers and small regional RSS rubber enterprises will require public support for knowledge and technology transfer. Government authorities overseeing policies for agricultural extension and promotion of the rubber industries are advised to provide financial support and promotional schemes at the policymaking level to foster business development. Secondly, the Thai government should promote a sustainable ecosystem for RSS rubber production, which should involve not only targeted commercial products but also rubber biofuel production. Finally, outreach and engagement for

innovation and knowledge transfer of regional universities should be promoted at the policymaking level, which could shape the directions of future research and academic service delivery to impact regional economic development.

7. LIMITATIONS AND FUTURE RESEARCH

The limitations of this research and the implementation of the results relate to the contextual conditions of the empirical environment in which it was studied; the sampled observations were local dairy smallholders from the selected province in Thailand. Hence, studies in different environments, such as in larger farm sizes, farms managed at the corporate level, and farms in other regions or countries, may deliver different results.

Despite the limitations, this paper helps fill the knowledge gap by exploring the demand and supply elements of natural rubber floor mats for the development of knowledge-based businesses. Its novel demand analysis may be used as a benchmark for policymakers to evaluate their rubber promotion policies and for other stakeholders of the floor mats industry in search of practical business strategies. Given its contribution to knowledge, this paper encourages future research to use the demand characterisation to examine its practical implication for business development. Also, it recommends further studies to include rubber farmers in investigating the supply side of the business model canvas to make the practical business model ready to transform the proposed model into practice possible.

Additionally, although the empirical setting of this study was in Thailand, the practical and policy implications presented in this paper can be applied to a broad extent in agribusiness development in other comparable agricultural commodities not limited to the Thailand context.

Funding: this research project was financially supported by Mahasarakham University.

Acknowledgments: we are grateful to Dr. Peth Laupattarakasem, Khun Bank and Khun Pop of PPP Farm Khon Kaen, Thailand for their valuable information on modern cattle farming and farm management.

Conflicts of interest: the authors declare no conflict of interest.

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Appendix A

Supplementing materials

(a) Straw-yard land area

(b) Milking parlour area

Figure 2. Examples of a traditional straw-yard farm with a small milking parlour

Source: photos taken by the authors from the interview fieldwork.

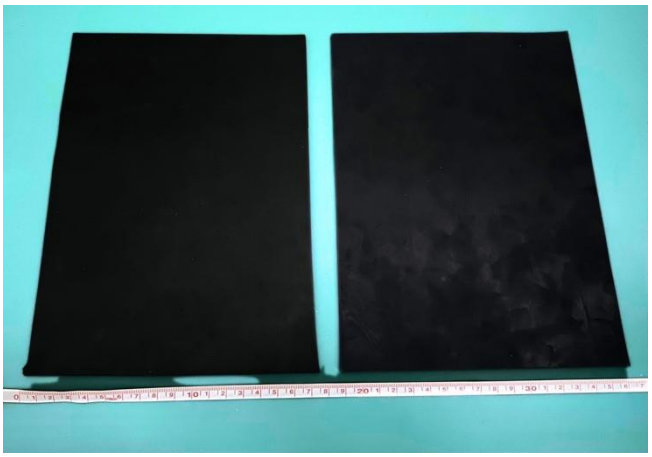
(a) Cubical housing area

(b) Open loafing area

Figure 3. Examples of modern free-stall farms with permanent sheds and open loafing areas

Source: photos taken by the authors from the interview fieldwork.

(a) Raw low-graded RSS rubber

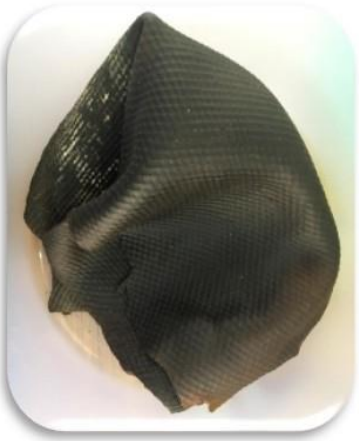


(b) Processed RSS rubber

Figure 4. Comparing raw low-graded RSS rubber and an RSS rubber sheet after processed

Source: photos taken by the authors from the focus group discussion fieldwork.

(a) Raw low-graded RSS rubber



(b) Processed RSS rubber waste

(c) Rubber biofuel

Figure 5. Comparing raw, waste of processed RSS rubber and rubber biofuel

Source: photos taken by the authors from the focus group discussion fieldwork.

Citation:

Стиль – ДСТУ:
Chanthes S., Sawangloke W., Luangsakdapich R., Pattiya A., Srithep Y. Business model development for installation of rubber floor mats to support productivity in dairy farming. *Agricultural and Resource Economics*. 2024. Vol. 10. No. 2. Pp. 215–241. https://doi.org/10.51599/are.2024.10.02.09.

Style – APA:
Chanthes, S., Sawangloke, W., Luangsakdapich, R., Pattiya, A., & Srithep, Y. (2024). Business model development for installation of rubber floor mats to support productivity in dairy farming. *Agricultural and Resource Economics*, 10(2), 215–241. https://doi.org/10.51599/are.2024.10.02.09.