



Understanding Smallholder Beef Production: Cost Structures, Market Channels, and Pathways to Enhanced Profitability

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Abstract | This study investigates the cost structures, market channels, and profitability of smallholder beef production systems in Phayao Province, Thailand. Focusing on three market segments: Traditional Market Production (TMP), Medium Market Production (MMP), and Premium Market Production (PMP). This study analyzes the socio-demographic characteristics of farmers, production practices, and the costs and returns of each segment. Data were collected from 100 farms using structured questionnaires and analyzed using descriptive statistics and one-way ANOVA test to assess significant differences between production systems. The findings reveal that profitability varies significantly across market segments, with PMP farms providing the highest net profit per cattle, whereas TMP farms face challenges related to pricing and cost sensitivity, resulting in lower profit margins. This study highlights the key role of market segmentation in enhancing smallholder performance, suggesting that focused expenses on cattle purchases, feed management, animal health, and market position can significantly improve financial outcomes. Furthermore, this study enhances the understanding of the economic dynamics of beef production systems in Thailand by discussing the limitations faced by smallholder farmers and by supporting sustainable practices. The findings provide information insights for improving the competitiveness and sustainability of smallholder beef production systems in Thailand and other similar agricultural contexts.

Keywords | Beef cattle, Cost structure, Market aspect, Phayao province, Profitability

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INTRODUCTION

Beef cattle production plays a significant role in the agricultural income of farmers in rural areas of Thailand. In

2023, the beef cattle population totaled 9.7 million heads, and the farmer population totaled 1.4 million head, increasing both cattle and the farmer populations by approximately 54.98% and 56.76% compared with in 2020 (DLD,

2023). The northeast region is the country's main source of beef cattle production, followed by the central, north, and south regions. Thailand has one of the largest cattle populations in the ASEAN area and is a significant exporter of beef products for the international market. Thailand is logistically and cross-borderly well-positioned to service regional export routes to key markets, including China, Vietnam, Cambodia, Laos, and Malaysia (Angkuraseranee *et al.*, 2019). In 2020, Thailand exported live beef cattle accounting for 98.58% of the total export value, which exported a large number of live beef cattle 304,367 heads, valued at 142 million USD (Information and Communication Technology Center, 2022). Over the last few years, beef consumption has increased by approximately 170,000 tons per year, with per capita consumption of approximately 1.8 kg annually. Beef is becoming more popular and can be found in a variety of restaurant menus, including grills, stews, BBQ, stir fry, and hotpots (USDA, 2021). Especially younger consumers aged under 30 enjoy beef more often and tend to purchase premium meat products, eating an average of 3.3 beef meals per week, compared to 2.4 for older Thais (MLA Global Tracker Thailand, 2018). The demand for cattle is expected to rise above domestic production by 25% from 2022 to 2025, providing both opportunities and challenges for smallholder cattle producers.

Smallholder beef producers in Phayao Province are fundamental to the local agricultural economy, with approximately 6,289 farmers managing 58,678 cattle by 2023. Smallholders provide an essential source of income for rural households. However, they face significant challenges such as limited market access, investment barriers, and competition with larger business companies. Phayao serves as a case study for understanding the dynamics of smallholder beef production and the broader challenges in Thailand's beef industry.

Thailand's beef production can be categorized into three market segments: traditional, medium, and premium. In the traditional market, most beef is produced domestically. Thai native and Brahman crossbreds are major breeds in this production. Consumers are not concerned about marbling and tenderness attributes but are price sensitive. The Thai market share is considered a traditional market at approximately 50%. Medium beef market is commonly sold in fresh markets, supermarkets, hotels, and restaurants. The medium beef is produced from *Bos taurus* crossbreds such as Brahman crossbred, Charolais crossbreds and Angus crossbreds. The expansion of medium beef has grown by beef as an option and can be found in almost every restaurant, so the market share is approximately 49%. The premium beef market is generally sold in supermarkets, hotels, restaurants, butcher shops, and luxury stores, accounting for only 1% of the total beef market. Consumers' concerns about high-quality beef include marbling, tenderness, color, and fat. Appropriate breed types for premium-grade beef pro-

duction are Charolais, Simmental, Limousin, and Angus, which have a European Bloodline ratio of 50%. Most premium beef producers are members of beef cooperatives or have invested in their enterprises at high levels within intensive systems (Intasiri 2015; Smith *et al.*, 2018). The profitability of beef production systems requires improvements to achieve target market specifications with appropriate genotypes and management practices for beef production (Greenwood, 2021).

Despite the growth of Thailand's beef industry, smallholder farmers play a crucial role, particularly in rural areas, such as Phayao Province in northern Thailand. These smallholder farmers are essential contributors to beef production but face distinct challenges related to production efficiency, market access, and profitability compared to larger commercial operations. However, studies on smallholder beef producers, especially in locations such as Phayao, are limited, resulting in a lack of understanding of the factors that influence their ability to compete in an increasingly competitive market. Prior research has primarily concentrated on overall production statistics and consumer preferences without considering specific cost structures, socio-demographic characteristics of producers, and market channels associated with different quality levels of beef production.

The objective of this study is to fill this gap by investigating the production of beef by smallholders in Phayao Province. Focusing on sociodemographic characteristics, production systems, cost structures, profitability, and market channels. Phayao is an example of Thailand's cattle sector that shows both national trends and specific local challenges. Understanding the cost structure, market channels, and challenges faced by farmers is essential to evaluate the profitability of farming operations. This analysis examines three market segments traditional, medium, and premium and how different production approaches and investments influence profitability, particularly the higher returns associated with premium markets. We hypothesize that the production system and market segment significantly influence profitability, with premium beef producers requiring more investment but receiving higher profit margins than traditional and medium beef producers.

The objectives of this study are to 1) evaluate the socio-demographic characteristics of farmers, 2) analyze production systems, 3) assess cost structures and profitability, and 4) investigate market channels. The findings will help identify the most profitable systems and offer recommendations to improve smallholder profitability and efficiency, providing a valuable resource for both current and prospective beef producers.

This research provides smallholders with guidelines to adjust their practices according to available resources, outlin-

ing investments in more profitable segments. The insights gained from Phayao's smallholder farmers could also serve as models for other regions in Thailand facing similar challenges in small-scale beef production.

MATERIALS AND METHODS

DESCRIPTION OF THE STUDY AREA

The study was conducted in Phayao Province, located in the upper-northern part of Thailand (Figure 1). Its astronomical location is at 19°N and 99°E with a human population estimated at 454,983 heads (OSRS, 2023). Most of the population is in the agricultural sectors (crops, livestock, and fishery production).

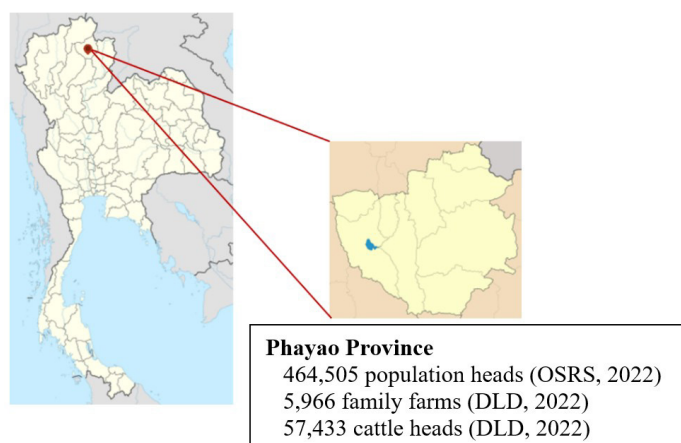


Figure 1: Map of Phayao Province and socioeconomic context of cattle production.

FARM SELECTION

Data on beef cattle farms used in this study were chosen based on data from the national census of the livestock sector in 2022-2023 from the Phayao Provincial Livestock Office, DLD. The sample was selected based on the characterization of beef cattle production systems supplied to different markets in the study area, including traditional market production on 50 farms, medium market production on 25 farms, and premium market production on 25 farms. The selection criteria included ownership of at least three beef cattle and a rearing duration of over one year.

QUESTIONNAIRE DESIGN

The questionnaire was developed based on information from literature and field experience. The questionnaire comprised 4 areas of interest: 1) socioeconomic information, 2) beef cattle production characteristics, 3) cost structure and profit, and 4) market aspect. The researcher conducted quality control of the instrument by administering the developed questionnaires to three experts to verify content validity and determine the item-objective congruence (IOC) index. The index of item-objective congruence was 0.85.

DATA COLLECTION AND ANALYSIS

Data were collected from November 2022 to June 2023 using a combination of methods including semi-structured interviews and on-farm observations. Historical data on farming covering production costs and profits from the previous year were also collected. Personal interviews were conducted face-to-face for approximately 30-60 minutes. With the respondents' approval, we audio-recorded the interviews and recorded the responses on structured questionnaire forms.

Beef cattle farm production was classified into three groups based on market segment.

TRADITIONAL MARKET PRODUCTION (TMP): This segment primarily involves domestically produced beef, focusing on Thai native and Brahman crossbreds. Consumers in this market are price sensitive and have little concern for marbling or tenderness.

MEDIUM MARKET PRODUCTION (MMP): Beef in this segment is produced mainly from *Bos taurus* crossbreds, such as Brahman, Charolais, and Angus crossbreds. Beefs are sold in fresh markets, supermarkets and restaurants.

PREMIUM MARKET PRODUCTION (PMP): The premium segment focuses on high-quality beef, with emphasis on attributes such as marbling, tenderness, and fat content. Suitable breeds for this market include Charolais, Simmental, Limousin, and Angus, with a strong European bloodline (50% or more). This beef is sold in high-end outlets, such as luxury stores, hotels, and butcher shops.

In this study, the production costs were calculated according to different farm groups in the cost and profitability analysis of beef cattle farm production in different market segments. To calculate production costs were grouped into variable and fixed costs. The data on beef cattle production costs were divided into 1) total variable costs (TVC) consisting of beef cattle, forage feed, concentrate feed, medicine and vaccine, labor, water and electricity, transportation, and miscellaneous; 2) total fixed costs (TFC), including the depreciation cost of the building and equipment; 3) total revenue (TR) consisting of beef cattle sales and manure sales; and 4) net profit obtained by calculating the total revenue minus the total cost. The variables used for calculating production costs in this study are presented in Table 1.

Data collected through the questionnaire were exported to Microsoft Excel® for organization and cleaning. All statistical analyses were conducted using R software. Descriptive statistics, including mean and standard deviation (SD), were used to summarize the data. Differences between farming categories were assessed using one-way analysis of variance (ANOVA), followed by Tukey's honest significant

difference (HSD) test for post-hoc comparisons. Statistical significance was set at $P < 0.05$.

Table 1: Variables used to estimate production costs in this study.

Variables	Definition
Beef cattle sales	The income from selling live beef cattle per head.
Manure sales	The income from selling manure produced by beef cattle per head.
Depreciation cost of building	The annual reduction in the value of cattle farm buildings is due to wear and tear or age. This is calculated over the expected useful life of the building for 10 years.
Depreciation cost of equipment	The annual reduction in the value of equipment used for cattle farming (machinery, and tools) due to regular use and aging.
Cattle purchase	The initial purchase price of the cattle.
Forage feed	The cost of growing or purchasing forage per head.
Concentrate feed	The cost of concentrated feeds per head.
Medicine/vaccine	The expenses related to veterinary care, including the cost of medicines, vaccines, and treatments needed to maintain cattle health and prevent diseases per head.
Labor	The cost of hired labor involves beef cattle farming, including wages or salaries paid to workers responsible for tasks such as feeding, cleaning, animal health care, and general farm maintenance.
Water/electricity	The costs associated with utilities, including water for drinking and cleaning, and electricity for lighting, equipment, and other operations necessary for the farm's functioning.
Transportation	The expenses incurred for transporting cattle, feed, equipment, or manure. This includes fuel, vehicle maintenance, and hiring transport services.
Miscellaneous	Other indirect or minor expenses related to beef cattle farming do not fall under the primary categories.

ETHICAL APPROVAL

The research protocol received ethical approval from the Human Ethics Committee of the University of Phayao (approval number: UP-HEC 2.2/010/63). All participants provided informed consent before participation.

RESULTS AND DISCUSSION

DESCRIPTION OF BEEF CATTLE PRODUCTION SYSTEMS IN PHAYAO PROVINCE

Beef cattle farming in Phayao Province is primarily small-scale, with farms averaging approximately 7 cattle per farm,

which is consistent with the national average of 6.77 cattle per farm (DLD, 2023). Based on market classification, the research area categorizes production systems into three main operational sectors: traditional market production (TMP), medium market production (MMP), and premium market production (PMP). Figure 2 illustrates the characteristics of the production system in the three market sectors.



Figure 2: Characteristics of the production system for the three market sectors in the study area.

Traditional market production (TMP) is the main source of beef cattle production in the study area. The majority of cattle raised are Thai native (*Bos indicus*), Brahman, and crossbred Brahman, and the rearing period depends on breed and age. These cattle, suitable for smallholder farmers, have adapted genetically to local conditions, feed, climate, heat tolerance, and pathogenic and parasite resistance, and utilize low-quality roughage but low growth rate, carcass percentage, and marbling score (Jaturasitha *et al.*, 2009; Umpapol *et al.*, 2019). The cattle in this production were small to moderate in size to increase their body weight and muscle mass. Before slaughter, the cattle were fattened for 8-12 months until their body weight reached 350-400 kg. They mostly used a semi-intensive rearing system to release grasslands. During the fattening period, feed roughage about 8-10 kg/head/day and concentrate 1-4 kg/head/day. The distribution channels were mainly from farmers to middlemen through sight evaluation, weighing the traditional beef market.

Medium market production (MMP) is based on consumer demand, and it improves the quality of native cattle breeds. The producer in this system raised crossbred bulls' blood portion 50% or more such as Charolais × Thai native cross-

bred and Angus × Thai native crossbred, etc. Charolais crossbred bulls showed high carcass, meat yields, and better meat quality than Brahman crossbred (Warithitham *et al.*, 2010). These cattle were reared in semi-intensive and intensive systems. The criteria for this system usually selected young bulls aged less than 2 years with a body weight of approximately 250-350 kg, and cattle were fattened for 3-6 months until their body weight reached 500-550 kg. Compared to steers, bulls have a much higher potential growth rate and better feed efficiency (Rutherford *et al.*, 2021). The advantage of slaughtering cattle at an early age is that they have a better dressing percentage and total lean meat content than steer cattle (Nogalski *et al.*, 2018). The fattening period feed concentrates 5-6 kg/head/day and roughages 8-10 kg/head/day or TMR 9-10 kg/head/day. The distribution channels for the medium beef market are mostly farmers to traders and farmers to community enterprises using the standard weighing system and carcass grade.

Premium market production (PMP) needs high-blood *Taurus* crossbreds such as Charolais crossbreds, Angus crossbreds, Tak and Wagyu, etc. For crossbreds with high European blood, 50-62.5% are raised within an intensive system. Most producers are members of beef cooperatives or have invested in their enterprises at a high level and have set prices based on carcass grade and meat quality. Typically, the fattening period for producing high-quality beef is 12-15 months from the start of fattening a steer aged 20 months with a body weight of 400 kg, and the body weight reaches 700-800 kg after fattening. This system is characterized by production under a farmer group of cooperative programs. The feeding system concentrates 7-8 kg/head/day and roughages 7-9 kg/head/day or TMR (6 kg/head/day) supplemented with molasses 1-2 kg/head/day. The distribution channels mainly range from farmers to cooperatives, based on carcass grade and meat quality, to the premium beef market.

SOCIOECONOMIC CHARACTERISTICS OF BEEF CATTLE FARMERS

Table 2 presents the socioeconomic characteristics of beef cattle farmers in the study area, based on a survey of 100 farmers divided into three groups: traditional market production (TMP, n = 50), medium market production (MMP, n = 25), and premium market production (PMP, n = 25). The characteristics analyzed included age, education, farming experience, household income, income from cattle sales, and farm size.

The average age of farmers across all groups was similar, ranging from 55.82 to 56.85 years, with no statistically significant difference (P = 0.88). Thailand's transition to an aging society has led to an increase in the average age of farmers, making it one of the fastest-aging countries in the world. The Thai Farmer Registration Database indicates

that the percentage of farm operators over 65 years of age increased from 17% in 2016 to 25% in 2022 (Bunyasiri *et al.*, 2024). These data agree with Rigg *et al.* (2019), who found that the average age of farmers in ten Asian countries is 53 years and is steadily increasing.

Our findings demonstrate significant differences in education among farmers (P<0.01), with PMP farmers exhibiting the highest average years of education at 12.32±4.50 years, followed by MMP farmers at 10.72±4.58 years, and TMP farmers at 8.68±3.27 years. These findings correspond with those of other studies that indicate that higher levels of education facilitate the adoption of modern agricultural technologies, thereby directly enhancing productivity and reducing the rural-urban income gap (Paltasingh and Goyari, 2018; Liu *et al.*, 2022).

Table 2: Socioeconomic characteristics of beef cattle farming among farmers in Phayao Province (n = 100).

Characteristics	TMP (N=50)	MMP (N=25)	PMP (N=25)	P
Age (year)	56.85±8.12	55.82±8.11	56.80± 8.54	0.88
Educational (years of formal school)	8.68±3.27a	0.72± 4.58ab	12.32± 4.50b	<0.01
Farm experience	8.00±5.26	7.76± 4.16	6.28±2.91	0.14
Household income (\$/household/year)	3,302.52± 1,285.97a	4,695.60± 1,725.46b	4,336.03± 866.94b	<0.01
Selling cattle income (\$/year)	2,275.42± 914.95a	2,943.38± 548.27b	2,743.89± 695.53b	<0.01
Farm size (head)	4.42 ± 2.38a	5.67± 3.34ab	6.95± 4.08b	0.02

a, b Means with a different in the same row differ (P<0.05).

Farming experience does not differ significantly between the groups (P=0.14), with TMP farmers averaging 8.00±5.26 years of experience, MMP farmers 7.76±4.16 years, and PMP farmers 6.28±2.91 years. The analysis of household income indicated significant differences between beef cattle farming groups (P<0.01). Farmers in the MMP reported the highest average household income, with an amount of 4,695.60±1,725.46 \$/year, followed by the PMP group at 4,336.03±866.94 \$/year. The TMP group reported the lowest average household income of 3,302.52±1,285.97 \$/year. Furthermore, significant differences were also observed in the income from selling cattle (P<0.01). MMP farmers reported the highest average income from cattle sales at 2,943.38±548.27 \$/year, followed by the PMP group with an income of 2,743.89±695.53 \$/year, and the TMP group with the lowest average income from cattle sales at 2,275.42 ± 914.95 \$/year. Additionally, farm size exhibited statistically significant differences (P=0.02), with the PMP group having the largest average herd size of 6.95±4.08 head, followed by MMP with 5.67±3.34 head, and TMP with 4.42±2.38 head.

Table 3: Average costs and returns per cattle in the study area (N=326).

Items	TMP (N=39)		MMP (N=148)		PMP (N=129)	
	\$/animal	%	\$/animal	%	\$/animal	%
Beef cattle sales	1,105.63a	97.44	1,685.74b	94.74	2,578.06c	92.80
Manure sales	29.10a	2.56	93.56b	5.26	199.95c	7.20
Total revenue (TR)	1,134.73a	100.00	1,779.30b	100.00	2,782.41c	100.00
Depreciation cost of building	90.24a	8.81	149.19b	9.47	258.39c	10.91
Depreciation cost of equipment	56.83b	5.55	62.67a	3.98	39.71a	1.68
Total fixed cost (TFC)	147.07a	14.36	212.26b	13.45	303.95c	12.59
Beef cattle purchase	769.70a	75.18	1,024.13b	65.02	1,008.13b	42.58
Forage feed	22.42a	2.19	81.75b	5.19	75.91b	3.21
Concentrate feed	25.40a	2.48	153.22b	9.73	488.48c	20.63
Medicine/vaccine	13.13b	1.28	7.48a	0.47	11.94b	0.50
Labor	20.86a	2.04	62.13a	3.94	447.77b	18.91
Water/electricity	5.14b	0.50	3.19a	0.20	8.71c	0.37
Transportation	10.03a	0.98	8.11a	0.52	14.63b	0.62
Miscellaneous	10.11a	0.99	23.33b	1.48	14.04a	0.59
Total variable cost (TVC)	876.77a	85.64	1,363.35b	86.55	2,069.61c	87.41
Total cost (TC)	1,023.84a	100.00	1,575.21b	100.00	2,367.70c	100.00
Net profit (TR-TC)	110.89a		204.09b		410.31c	

a, b, c Means with a different in the same row differ ($P < 0.05$).

COST STRUCTURE AND PROFIT OF BEEF CATTLE FARMING

Table 3 reveals significant differences in cost structures and profitability across the three different productions according to market segment: TMP, MMP, and PMP. There were significant differences in the total cost structure between groups ($P < 0.05$).

Traditional Market Production (TMP) is characterized by significantly lower revenue and costs per cattle than the other two market groups. TMP generates a total revenue (TR) of \$1,134.73 per cattle, mainly from beef cattle sales, which amount to \$1,105.63. The total fixed cost (TFC) was \$147.07 per cattle, or 14.36% of the total cost. This comprises depreciation costs for buildings (\$90.24) and equipment (\$56.83), reflecting small investments in fixed assets. The total variable cost (TVC) represents 85.64% of the total cost, with the largest spending involving cattle purchases (\$769.70), followed by concentrate feed, forage feed, and labor. TMP expenses had the lowest total costs, totaling \$1,023.84 per cattle, providing an average net profit of \$110.89 per cattle. Therefore, TMP are more appropriate for small-scale farming operations with limited profit margins.

Medium Market Production (MMP) represents the middle ground in terms of costs and returns. The total revenue for MMP is \$1,779.30 per cattle, primarily driven by beef cattle sales (\$1,685.74), with additional income from ma-

nure sales (\$93.56). The fixed costs in MMP were moderately higher than TMP, with a total fixed cost of \$212.26 per cattle, accounting for 13.45% of the total costs. The significant components of this fixed cost include depreciation of buildings (\$149.19) and equipment (\$62.67). The total variable cost is considerably higher at \$1,363.35 per cattle, resulting in 86.55% of the total cost. Major expenditures include cattle purchases (\$1,024.13), concentrate feed (\$153.22), and forage feed (\$81.75). The overall total cost per cattle was \$1,575.21, leading to a net profit of \$204.09. MMP provides the middle between cost and profitability, ideal for producers aiming at middle markets with higher profits compared to TMP.

Premium Market Production (PMP) generates the highest revenue and net profit, but also has the highest costs. The total revenue from PMP is \$2,782.41 per cattle, mostly sourced from beef cattle sales at \$2,578.06, with substantial revenue from manure sales amounting to \$199.95. The fixed costs were also the highest among the three groups, with a total fixed cost of \$303.95 per cattle (12.59% of total costs), mostly because of the high depreciation cost of buildings (\$258.39). Total variable cost is significant totaling to \$2,069.61 per cattle (87.41% of total costs), mainly caused by cattle purchase (\$1,008.13), concentrate feed (\$488.48), and labor (\$447.77). The total cost for PMP is highest at \$2,367.70 per cattle, but the net profit of \$410.31 per cattle is also the highest. PMP is well suited for producers targeting high-end markets, where premium

pricing may compensate for the high cost of supplies and lead to higher profitability.

The selection of TMP, MMP, and PMP is dependent on the producer's resources, market access, and profit goals. TMP is suitable for small-scale, limited producers with insufficient investment, low risk, and limited profitability margins. MMP offers an appropriate approach to mid-scale producers who are ready to invest moderately in enhanced profits. PMP is optimal for large, provided that funding producers target premium markets, where major expenditures on feed, labor, and infrastructure provide maximum profitability. Each system serves different market segments, providing differing levels of risk and profit determined by the ability to invest and market perspective.

MARKET CHANNELS

The distribution channels of the three-group operating system listed in Figure 3 are merchant middlemen (65%), secondary market sales (25%), and community enterprises (10%).



Figure 3: Domestic beef market channel and proportion of distribution in the three operating systems.

TRADITIONAL MARKET: Farmers sell their cattle to middlemen with a large proportion of market share. They usually approximated the weight of a live animal simply by observation, and the prices were determined by the satisfaction of the middleman due to the farmers' poor bargaining position, while some farmers sold cattle to community enterprises. In this system, cattle are slaughtered by local butchers in the government or privately owned slaughterhouses. Local butchers generally sell meat in a regularly organized local market (low-end market). Consumers in this market prefer a high lean percentage and tenderness, with a lower fat percentage, for local dishes.

MEDIUM MARKET: Farmers sell their cattle to community enterprises for the middle market, and some farmers still sell their cattle to the middleman. Farmers who sell cattle to community enterprises obtain prices based on live weight measurements using scales. Usually, a dressing

percentage of 50% or more of the live weight is applied after slaughter. Middle-quality beef is traded on beef shops, Thai barbecues, and grilling platforms. Consumers in this market favor meat tenderness and affordability. Producers have taken this opportunity to offer consumers a variety of ready-to-eat products.

PREMIUM MARKET: The conditions for premium beef become competitive and more demanding in the beef market. The demand for premium beef has increased over the past few years. Increasing economic growth, urbanization, and rising living standards may cause changes in meat consumption by focusing on juiciness, tenderness, and marbling (Smit *et al.*, 2018). New lifestyles, especially among the middle-class population, have changed their consumption habits since the trend of grilling platforms, Japanese barbecues, and Korean-style restaurants became popular in Thailand.

Current situations affect the beef supply chain, including COVID-19, inflation, labor shortages, and the pandemic, but open new opportunities for online channels to increase the sales of fresh and chilled products. To take advantage of this situation, producers should adapt to selling their products online and offer a variety of products. In conclusion, the market channels available to beef cattle farmers in Phayao Province present distinct opportunities and challenges. Understanding these channels is essential for farmers to optimize their market participation and profitability. The insights gained from this analysis can inform strategies to improve market access and enhance the overall profitability of smallholder beef producers.

MAJOR CHALLENGES FOR BEEF CATTLE PRODUCTION

Currently, beef cattle producers face significant challenges when attempting to improve their production systems in terms of appropriate breeding, feeding, and housing techniques to enhance productivity, efficiency, and profitability. There are several factors and challenges for new beef cattle production.

CLIMATE CHANGE

Numerous factors can affect livestock productivity. The most significant factors are climate change and global warming, resulting in decreased animal productivity, impact of pastures, and crop production and quality (Nienaber and Hahn, 2007; Nääs *et al.*, 2010; Lamy *et al.*, 2012). Climate change has resulted in additional price increases for the most important feedstuffs, maize, soybeans, and roughage. Higher feed prices lead to higher production costs and a decrease in farmers' income. The effects of temperature changes on rainfall patterns could influence drought and floods, leading to changes in forage quality and quantity (Aydinalp and Cresser, 2008; Thornton and Gerber, 2010). The effects on beef cattle, the higher temperatures would likely result in a decline in beef cattle

production, weight gain, feed conversion ratio, health, and reproduction (Scholtz *et al.*, 2013; Gebregeziabhear, 2015). Another aspect of climate change and global warming on livestock productivity is the likely increase in the incidence of disease spread, disease transmission, and acceleration of pathogen or parasite growth (Lamy *et al.*, 2012; Chauhan and Ghosh, 2014; Rojas-Downing *et al.*, 2017). Some suggestions include adopting more effective farming practices and modifying production systems to use fewer resources for production (Rust and Rust, 2013).

PRODUCTION COST

Understanding and managing production costs are key to long-term profitability in the beef cattle industry. Many factors lead to dramatic price increases in beef cattle production, including feedstuff prices, disease outbreaks, energy costs, and lack of labor. The challenge for beef cattle farmers is to minimize both fixed and variable costs. Feed has the highest cost, accounting for over 70% of the variable costs on beef farms. With higher prices for crops and feedstuff, producers can reduce feed costs with enhanced management by understanding the nutritional requirements of cattle at the production stage and avoiding over-feeding nutrition. Cattle can utilize a wide range of feedstuffs in addition to forage; therefore, farmers have various options when developing a nutritional program. Many producers could improve efficiency in their feed programs by understanding what nutrients they have available in their forages and managing those nutrients, so that they are appropriately allocated according to the changing needs of the herd. To reduce feedstuff costs, producers must consider the feeds available in their areas, including crop residues, waste products from processing various foods, and new or alternative grains and forage. However, many alternative feedstuffs for beef cattle are available locally; farmers should consider nutrient composition (energy, protein, and significant minerals) and select alternative feeds that suit the farm situation.

DISEASE PROBLEM

The outbreak of diseases and parasitic infections results in a slower growth rate and productivity loss, contributing to economic losses. Animal disease outbreaks have affected consumption, meat trading patterns, and directly impact the beef cattle industry by imposing higher costs (Morgan and Prakash, 2006). FMD significantly affects the loss of productivity, trade restrictions, and control and prevention costs. In recent years, lumpy skin disease (LSD) outbreaks have been reported Asian countries such as Bangladesh, India, China, Nepal, Bhutan, Vietnam, Myanmar, Sri Lanka, Thailand, Malaysia, Laos, and for the first time and represent a cause of serious concern for their livestock and dairy industries. The first outbreak in Thailand was reported in April 2021, which affected 10 beef cattle in Roi Et

Province (Azeem *et al.*, 2022). The most successful way to reduce the risk of an outbreak is early detection and immediate response to active investigations and surveillance programs (Arjkumpa *et al.*, 2021). To prevent disease outbreaks, producers should enhance biosecurity on their farms and train farmers in Good Farming Management (GFM) or Good Agricultural Practices (GAP).

ANIMAL WELFARE

Currently, there are global concerns regarding sustainability and animal welfare, particularly in intensive systems. Animal welfare issues are becoming increasingly political in many countries to improve sustainability. Producers may ignore regulations on infrastructure design and management for farming profitability (Hultgren *et al.*, 2022). Previous studies have demonstrated the importance of animal welfare, including animal health, reduced disease, lower mortality, improved growth rate, and improved economic efficiency. Apart from product-based economic benefits, improving welfare offers commercial opportunities for higher-market products and increases opportunities to export to Western nations (Sinclair *et al.*, 2019). In addition, high-welfare farming can be less damaging to the environment by producing animal-friendly products that are healthier, safer, and more hygienic (Zwolińska and Żakowska-Biemans, 2020).

SMART FARMING

Challenges in many aspects of beef cattle production have resulted in a changing pattern in the environment, production costs, health issues, and animal welfare. Moreover, there are an increasing number of aging farmers and labor shortages in agriculture. Thus, initiatives of smart farming systems for small farmers will inevitably cascade to farmers in the future. In the past decade, smart farming has been developed for large-scale production, with technology and equipment aimed at achieving high efficiency while minimizing labor costs. Farmers in developing countries still use traditional methods and lack technology, making their farms less productive. Advanced farming and modern technologies have improved rural economies and communication. Smart farming provides more advantages than conventional farming owing to the use of modern equipment, facilities, and data collection during agricultural operations. Using digital technology, the Internet of Things (IoT), cloud computing, robotics, sensors, positioning systems, and artificial intelligence in agriculture are commonly known as smart farming. Currently, cattle farming is concerned with using technological knowledge for planning feeding programs, monitoring health and welfare, and reproduction of the herd, in addition to the construction of infrastructure. The profit of cattle farms depends on the optimum growth and good health of cattle, whereas modern farming practices can ensure healthy cattle production.

Good monitoring and recording systems that collect useful information about the herd are a future strategy that should be considered with information and communication technology (ICT)-based smart farming, which includes auto-identification, remote monitoring, feeding behavior, animal welfare, diseases, nutrition and feed quality, labor management, and farm operations, to enhance beef production in the cattle industry. The application of ICT knowledge in agriculture is not only beneficial for smart livestock farming but is also essential for communication between the government, farmers, and middlemen associated with markets and consumers, which improves the production and profitability of the farm.

CONCLUSIONS AND RECOMMENDATIONS

This study provides a comprehensive analysis of beef cattle production systems in Phayao Province, Thailand, emphasizing the socioeconomic characteristics, cost structure, profitability, and market channels of smallholder farmers. The results indicate significant differences in profitability across three production systems: Traditional Market Production, Medium Market Production, and Premium Market Production. TMP is the most cost-effective alternative for small-scale producers with limited investments, however, it returns lower profit margins. MMP offers a balanced option between modest costs and enhanced profitability, whereas PMP provides the highest revenue but requires the largest investments. The economic viability of each system depends on the resources available to farmers and their market access, with premium market producers earning the highest benefits due to their high-quality products, leading to higher prices. This study highlights the significance of market segmentation in enhancing smallholder cattle producers' financial performance. However, this study has several limitations. First, it is geographically restricted to Phayao Province, which limits the generalizability of the findings to other regions. Expanding the sample size and comparing the results with data from other areas may overcome this limitation. Second, data collection was mainly based on self-reported information, which tends to introduce bias. Lastly, the study focuses on short-term profitability without addressing long-term sustainability challenges, such as climate change, disease outbreaks, and rising feed costs. Nevertheless, farmers should make production decisions by adopting appropriate management practices and evaluating their farms' status based on available resources and budgets. This approach enhances performance, particularly by managing production costs according to the market segment, thereby decreasing costs and improving farm productivity. Governments should emphasize supporting smallholder beef farmers by promoting access to various markets, upgrading farmers' infrastructure, and providing

training programs to challenge the long-term viability of the beef production sector.

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NOVELTY STATEMENT

This study analyzes the cost structures and profitability of smallholder beef cattle farmers in Phayao Province, Thailand, with an emphasis on traditional, medium, and premium market segments. This demonstrates various limitations faced by farmers, including restricted market access and investment barriers. These results provide practical recommendations for enhancing the operational efficiency and profitability of smallholder beef production. This research improves the understanding of the economic dynamics of small-scale farming by providing important information to producers.

AUTHOR'S CONTRIBUTIONS

Sureeporn Saengwong: Designed the study, conducted research, and wrote the manuscript.

Wiranut Thannithi and Nattanaporn Kongmuang: Collected and analyzed the data. Payungsuk Intawicha: Edited manuscript.

Wilasinee Inyawilert and Attapol Tiantong: Guided the study and analyzed the data.

All authors have read, reviewed, and approved the final manuscript.

CONFLICTS OF INTEREST

The authors have declared no conflict of interest.

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