



Research Article

Raising Native Cattle in Thailand: Status, Problems, Needs and the Development of a Model

¹H. Umpapol, ¹C. Songwicha, ¹T. Jitrajak, ¹A. Patkit and ²J. Sripandon

¹Program in Animal Science, Faculty of Agriculture Technology, Sakon-Nakhon Rajabhat University, Sakon Nakhon 47000, Thailand

²Mukdahan Provincial Livestock Office, Department of Livestock Development, Mukdahan 4900, Thailand

Abstract

Background and Objective: This study was designed to investigate the status and problems with raising Thai native cattle, as well as farmers' needs and developed a model to address these issues using a mixed research approach combining qualitative and quantitative research. **Materials and Methods:** The procedures included document reviews and focus group interviews in the form of participatory rural appraisals for a strengths, weaknesses, opportunities and threats (SWOT) analysis. In-depth and multilateral interviews were performed with 90 farmers of Thai native cattle. A model of methods was employed for raising Thai native (TN) cattle developed through participatory action research (PAR). A stratified random sampling technique was used across a study population of 40 groups of TN cattle farmers who were members of the Sakon Nakhon Provincial Livestock Office. The instruments used in this study included a measurement of training achievement, a test for satisfaction and a training evaluation form. **Results:** The problems faced by the farmers who raised Thai native cattle included a lack of shared knowledge about raising quality TN cattle, common problems in raising the cattle and housing management practices that are inconsistent with the cattle's reproductive states. Additional challenges include selecting local feed to be mixed with feed concentrates and hygienic management to avoid major diseases or parasites. The farmers need to gain additional knowledge and experience and to share technologies for raising quality TN cattle. This includes determining appropriate practices for managing housing and producing a feed formula for TN cattle that uses inexpensive, locally available feeds. The model for raising TN cattle included a training session intended to develop better management practices and to help farmers produce better animals. **Conclusion:** The training session demonstrated improvements in farmers' knowledge, the results of the training were positive and the farmers' satisfaction with the workshop was high.

Key words: Farmers training, hygienic management, lack of knowledge, local feed, Thai native cattle

Received:

Accepted:

Published:

Citation: H. Umpapol, C. Songwicha, T. Jitrajak, A. Patkit and J. Sripandon, 2019. Raising native cattle in Thailand: Status, problems, needs and the development of a model. Pak. J. Nutr., CC: CC-CC.

Corresponding Author: H. Umpapol, Program in Animal Science Faculty of Agriculture Technology, Sakon-Nakhon Rajabhat University, Sakon Nakhon 47000, Thailand

Copyright: © 2019 H. Umpapol *et al.* This is an open access article distributed under the terms of the creative commons attribution License, which permits unrestricted use, distribution and reproduction in any medium, provided the original author and source are credited.

Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Thai native (TN) cattle have highly beneficial characteristics and abilities. They are considered “factories” or “movable food production units” because they process raw materials by abundantly consuming naturally grown grass and converting it into useful food or other products suitable for human use¹. Cattle's ability to transform feed into food products is remarkable. They can produce 1 kilogram of milk for each 1.3-1.5 kg of feed consumed, which is highly efficient². A 1600-m² (1 rai) plot of land can be used to raise 1.5 head of TN cattle³. This level of efficiency leads to a milk production of 10 L per day throughout the year without supplementary feed of any kind. For comparison, the yearly milk production capacity of a 1-rai area is equal to approximately 800 L of dry milk⁴. This capacity is regarded as a high milk yield for cattle mixed with an Indian breed. TN cattle have existed in harmony with farmers and have been a part of their lives and wellbeing for a long time. Historically, according to Isan traditions and culture, Isan people are usually depicted accompanied by TN cattle⁵. The Isan elders, who are respected for their local wisdom, have passed stories down from generation to generation describing TN cattle as the main blood vessels that nurture the lives of Isan farmers⁵. A poem of the Isan people said “Set cattle free from their yokes, let those used to pulling heavy loads take a rest and graze under the bright sky; these cattle are born to become friends of the farmers as they pull carts unceasingly⁵.” TN cattle raising began with animals raised for pulling loads but has evolved; currently, farmers raise these cattle primarily for supplementary income and use them as their main source of protein, especially for important ceremonies and festivals².

TN cattle husbandry is practiced widely for both commercial and consumption purposes. However, farmers raising these cattle face a lack of appropriate evidence-based knowledge, which has led to low-quality beef and the spread of diseases and many types of parasites to consumers⁵. These problems could be reduced if the farmers could develop a scientific research-based system to raise cattle more hygienically. This approach would lead to healthier cattle and higher-quality beef for consumers. Such improvements would increase the value of raising TN cattle and the value of related products⁵. A previous analysis found that farmers raising TN cattle still lack relevant knowledge for developing quality cattle-raising methods⁵. Thus, there is a need for a body of shared knowledge concerning appropriate technologies that can enhance the ability of farmers to raise TN cattle efficiently and effectively. The goal is to develop procedures to

sustainably raise these animals. Therefore, this study was designed to explore the current status of TN cattle husbandry and its related problems to develop a model for raising these animals.

MATERIALS AND METHODS

This study adopted a mixed-method approach employing qualitative and quantitative research⁶ to identify the state and development of raising TN cattle and to investigate the problems and needs of cattle farmers in Sakon Nakhon. The procedure included document reviews and focus group interviews and participatory rural appraisal evaluations for a strengths, weaknesses, opportunities and threats (SWOT) analysis of the process of raising TN cattle. A vision statement, a set of responsibilities, a set of applicable strategies and a master plan to develop the competence of farmers for raising TN cattle were created. In-depth interviews were conducted among 30 leading farmers who raise TN cattle, along with multilateral group interviews and questionnaires focused on identifying potential factors relevant to raising TN cattle. The collected data were used to form a database for developing procedures to raise TN cattle⁷. Secondary data collected from Sakon Nakhon Meteorological Station, Department of Meteorological in Sakon Nakhon over three years (2009-2011) were used in a least-squares analysis.

A model was applied for farmers in Sakon Nakhon through a workshop aimed at improving the development of practices for raising TN cattle. The model included a sample population consisting of TN cattle farmers who were members of the Sakon Nakhon Provincial Livestock Office. Samples were composed of groups of 40 cattle farmers; 1 farmer was selected from each community by using a stratified random sampling technique⁸.

The instruments employed in this study included a test of training achievement, a satisfaction questionnaire and a training evaluation form. This study was conducted from March-May 2013.

RESULTS

Weather-related factors: The temperature-humidity index (THI) value was 78.40 ± 5.62 on average and 82.34 ± 6.72 in the summer, as shown in Table 1.

General physical characteristics of TN cattle: According to the interviews with the farmers, TN cattle have general and

Table 1: Mean of least square of the factors on weather in the years 2009-2011

Factors on weather	Seasons			
	Rainy	Winter	Summer	Average
Highest temperature (°C)	31.46±0.62 ^b	29.42±0.36 ^c	34.90±0.78 ^a	31.91±0.72
Lowest temperature (°C)	22.36±0.58 ^b	19.20±0.64 ^c	24.38±0.25 ^a	21.98±0.58
Average temperature (°C)	26.91±0.36 ^b	24.31±0.60 ^c	29.64±0.45 ^a	27.40±0.46
Span of temp. difference (°C)	9.10±0.28 ^c	10.22±0.46 ^a	10.52±0.28 ^b	9.95±0.26
Relative humidity (%)	87.18±5.63 ^a	73.64±7.48 ^c	78.72±5.68 ^b	79.85±6.24
Temperature humidity index (THI)	78.05±6.72 ^b	75.18±5.62 ^c	82.34±6.72 ^a	78.40±4.79

Table 2: Opinions of the farmers on the cattle's physical change based on various seasons

Behaviors	Changed		Unchanged	
	No. (Persons)	Percentage	No. (Persons)	Percentage
Rumination	4	13.33	26	86.67
Panting	7	23.33	23	76.67
Getting up and walking to drink water	6	20.00	24	80.00
Taking a rest	8	26.67	22	73.33

Table 3: Mean of the farmers' perception on the general, physical and reproductive characteristics

Characteristics	Mean	SD	Interpretation
General characteristics			
• The Thai native cattle are important to the lives and wellbeing of the farmers	4.86	0.24	Highest
• The raising of Thai native cattle is in a native style by letting it graze freely and naturally in the areas close to farms, public pastures, rims of highways and rice fields after the harvesting period	4.72	0.26	Highest
• The natural style of raising Thai native cattle to use it as workforce in order to make a living	4.80	0.28	Highest
Average	4.79	0.26	Highest
Physical characteristics			
• Thai native cattle are moderate in size, quick and strong	4.68	0.22	Highest
• Thai native cattle can adjust themselves to the environment, heat tolerance, pathogenic and parasite resistance	4.64	0.24	Highest
• Thai native cattle can take advantage of low quality roughage	4.58	0.30	Highest
• Thai native cattle obtain pathogenic resistance	4.50	0.26	High
Average	4.60	0.25	Highest
Reproductive characteristics			
• Female Thai native cattle are sensitive to fertility	4.46	0.20	High
• Female Thai native cattle are regularly in heat; quite high in fertility perfection, able to get fertility and parturition and easy to access to delivery and smart in raising their calves	4.42	0.29	High
• Thai native cattle can give birth to calves every year along with long life span	4.54	0.31	Highest
• The dominant characteristics of Thai native cattle include high protein and low fat	4.60	0.28	Highest
Average	4.50	0.27	High
Overview	4.63	0.26	Highest

physical characteristics and related behaviors that sometimes change across the rainy season, winter and summer. While some farmers reported changes in cattle behaviors (e.g., rumination, panting, getting up and walking to drink water and resting); most farmers reported no change in these behaviors; the percentages reporting no change were 86.67, 76.67, 80.00 and 73.33, respectively, for those behaviors, as shown in Table 2.

Table 3 summarizes the opinions of farmers regarding the general, physical and reproductive characteristics of TN cattle. The overall rating of these opinions was 4.63 ± 0.26 , belonging to the highest level. The mean rating of the general

characteristics of the cattle was 4.79 ± 0.25 , also at the highest level. The mean rating of the reproductive characteristics of TN cattle was 4.5 ± 0.37 , again at the highest level.

The state of raising TN cattle and problems and needs of farmers: In-depth interviews of farmers showed that most farmers identified 22-28 problems and 24-30 needs for raising TN cattle, as shown in Table 4.

Focus group results: A focus group study was conducted, consisting of multilateral groups of researchers, including faculty and staff of Sakon Nakhon Rajabhat University, a group

Table 4: Percentage of problems and needs of thai native cattle development

Characteristics studied	No.	Percentage
Problems of thai native cattle raising		
• The Department of Livestock Development pays attention to the significance of Thai native cattle raising in order to conserve genetic resource as well as the sustainable utilization	22	73.33
• Thai native cattle play an important role to life and living of the majority of Thai farmers	28	93.33
• The number of Thai native cattle decreases because of a shortage of natural animal feed plants and the areas used for natural grazing	26	86.67
• The promotion of the production for consumption and substitution for import of beef from foreign countries to encourage Thai farmers to turn to raise foreign-bred cattle both pure-bred and cross-bred	24	80.00
• The bringing of the European-bred cattle to breed with Thai native cattle along with the spread of grazing fields leading to getting crossbred cattle in a large number		
• The farmers faced a shortage of raw materials as animal feed with efficiency in locality	27	90.00
Needs for development		
• The development of the system on the production of native cattle is a sample of a guideline on the natural means both in terms of land and raising methods by letting cattle graze freely	22	73.33
• The management on feeding by fattening method with concentrate feed and roughage with quality in the short period of time before sending them to a slaughter house about 3-4 months. This would make a dominant characteristic of native cattle to have forms of high protein and low fat	25	83.33
• A study of developing raw materials as animal feed in locality used for the appropriate physical characteristics of an advantage in the environment as well as the heat tolerance	24	80.00
• The hygienic management in accordance with the context of feeding, promotion of good reproductive characteristics caused to get cattle beef that is safe and free from diseases and any types of parasites		
• The development of suitable housing in order to facilitate the Thai native cattle raising consistently with the physical characteristics of an advantageous and suitable behaviors	27	90.00
• The development of the breeding suitable for Thai native cattle by cross breeding to upgrade the competence on suitable production which is consistent with the native raising style	30	100.00

of government officials, animal husbandry academics and veterinarians and community groups, farmers and other sources of local knowledge. The results of the meeting were as follows:

- **State of raising TN cattle:** The system of raising TN cattle included grazing on natural feed in public grazing fields and the main roughage was hay obtained from rice fields. These methods are conducive to plant growth because they generate manure as a byproduct and it contributes positively. Overall, raising TN cattle was found to be beneficial for society, community and the farmers' way of life in the studied locality

Cattle were allowed to graze naturally and freely on the grass on nearby hills or mountains during the rainy season. These cattle naturally sought hay or herbs as feed in the mountains. The cattle sometimes acquired diseases but they recovered over time because some of their feed can be considered medicinal. The cattle were visited and examined once per month. The farmers never feared that their cattle would be stolen, possibly due to the mutual relationships and trust among the farmers. Additionally, cattle run away from people they do not trust and they recognize their owners' voices. In the dry season or summer, cattle were fed in fields

closer to their homes. Merchants visited the farms to negotiate cattle prices, confident that they would obtain cattle that would yield quality beef.

Physical characteristics and features of TN cattle: TN cattle are small size, slow growth, small ears and diverse colors (red, spotted, black, or yellow). The animals are quick and easily excited. The advantages of TN cattle are that they are easy to feed, resistant to diseases and insects, easily bred, give birth to calves every year and provide delicious and inexpensive beef. TN cattle are docile, strong and quick and have good heat tolerance and high fertility. Female TN cattle are highly fertile, give birth to calves easily, raise their calves well, tend to give birth to multiple calves and, most importantly, live long lives.

Breeding project: An extension of breeding TN cattle by small farmers in cooperation with research and development professionals, was operated by the Department of Livestock Development in every region of Thailand. It involved beef production and entering cattle in local competitions. The breeding project was undertaken to promote and distribute the program, plan data storage and produce a database of methods conducive to improving cattle conservation and production. The distribution of TN cattle genetics has been systematically improved and developed to improve cattle

export and to better adapt TN cattle to their environment in the future. These cattle are small, heat tolerant, resistant to diseases and insects, good at finding feed and prone to giving birth to many calves and can utilize roughage effectively. This makes them suitable for the current conditions in Thailand, as the country is currently facing a shortage of natural plants for use as animal feed. Furthermore, plots of land suitable for use in raising domestic animals are scarce. Raising TN cattle is regarded as a side business for small farmers and as a supplementary occupation for their family.

- **Problems with raising TN cattle:** Farmers who raise TN cattle lack a bodies of knowledge for developing cattle-raising management practices, particularly practices appropriate for the summer. The selection of raw materials from specific localities that can be mixed with concentrated feed may improve production quality. In conjunction with appropriate housing management based on the state of production and appropriate hygiene, such practices can be used to prevent diseases and parasites

High temperatures affected cattle growth because the animals were stressed from the heat.

Cross-breeding of European and TN cattle and the expansion of the land used to raise cattle have led to high-quality cattle that produce quality beef at a lower price. However, cross-breeding has also led to a reduction in the number of TN cattle.

The Department of Livestock Development has paid attention to raising TN cattle as a genetic resource and in terms of sustainable utilization because they are important for the life and wellbeing of the majority of Thai farmers.

Table 6: Effects of the training project appraisal

Topics	Mean	Standard deviation	Interpretation
Curriculum of the training			
Contents of the training curriculum	4.34	0.86	High
Knowledge, understanding on this issue before the training*	2.26	0.76	High
After the training	4.62	0.64	Highest
Benefits believed to take knowledge gained to apply for work	4.48	0.70	High
Average	4.48	0.73	High
Resource persons			
Transfer and knowledge of the resource persons	4.62	0.76	Highest
Answers to questions of the resource persons	4.56	0.70	Highest
Average	4.59	0.73	Highest
Management			
Period of time spent for training	4.24	0.68	High
Documents and materials used	4.20	0.70	High
Places and other facilities	4.76	0.48	Highest
Average	4.40	0.62	High
By summarizing the overview	4.49	0.69	High

*Do not bring Knowledge, understanding on this issue before the training

- **Farmers' needs:** The farmers need to develop bodies of knowledge to supplement their abilities and experience in raising TN cattle

The farmers also need essential and appropriate technologies for raising TN cattle, in terms of housing management and feed formulas that include inexpensive, local raw materials suitable for animal feed.

The farmers need to accelerate the development of new markets for native cattle to increase their income; however, they need guidelines for production practices that work in harmony with the philosophy of a sufficiency economy.

Development of a model for raising TN cattle: The outcomes of the workshop to develop a model for raising TN cattle by farmers in Sakon Nakhon were as follows:

- **Training achievements:** Before the training, the scores of farmers who raised TN cattle were 22.64 ± 2.46 , while after the training, they rose to 32.28 ± 2.16 , a significant increase ($p < 0.01$), as shown in Table 5
- **Perceptions of the training project:** The appraisal of the effects of the training project revealed that, overall, the training was well received, with a score of 4.49 ± 0.69 , representing the highest level. The training curriculum, experts and management were rated at 3.92 ± 0.74 , 4.59 ± 0.73 and 4.40 ± 0.62 , respectively, as shown in Table 6

Table 5: Comparison of training score test between before and after

Items	Mean	Standard deviation	t
Before training	22.64	2.46	26.847**
After training	32.28	2.16	

*Highly significant different ($p < 0.01$)

Table 7: Satisfaction of the farmers who raised Thai native cattle through a training session

Questions	Mean	Standard deviation	Level of satisfaction
Contents of training are easy to understand	4.40	0.72	High
Contents of training are consistent with needs	4.34	0.60	High
Help provided by resource persons and peers in the training session	4.50	0.72	High
Resource persons obtaining interesting training experiences	4.46	0.42	High
Resource persons can transfer knowledge, abilities and experiences	4.48	0.52	High
Farmers are careful, responsible for tasks assigned	4.18	0.68	High
Activities conducted help farmers gain knowledge and develop skills	4.56	0.62	Highest
Knowledge gained can be applied in daily life	4.52	0.68	Highest
Farmers are enthusiastic and joyful in the training session	4.60	0.46	Highest
The training makes progress on Thai native cattle raising among the farmers	4.68	0.42	Highest
Level of satisfaction	4.47	0.58	High

- Training session satisfaction:** Satisfaction with the training session among farmers who raise TN cattle was 4.47 ± 0.58 , which represents the highest level of satisfaction. Furthermore, it was also observed that the farmers were enthusiastic and happy when attending the training session. Other details, such as the number of farmers who were satisfied with the results of the training at the highest level, are shown in Table 7

DISCUSSION

The conditions of raising TN cattle in Sakon Nakhon are important for farmers' lives and wellbeing because these native cattle are used both as a source of food and as work animals for farming. The cattle are fed by allowing them to graze naturally in forested areas close to farms, on public fields and even on the farms after the harvest. Overall, TN cattle are of moderate size, active, quick, strong, able to adjust to their environment, heat tolerant and resistant to many diseases and parasites. Because they can utilize low-quality roughage, they have been raised widely to meet the needs of consumers².

The problems with raising TN cattle include a shortage of plants suitable for animal feed, a decrease in grazing field space and the use of low-quality hay in summer⁹. The use of hay as roughage in summer leads to slow growth. To solve this problem, feed should be supplemented with feed concentrates to upgrade feed quality as necessary. However, the cost of feed concentrates can become quite high over time. Most Thai farmers who raise TN cattle are not wealthy and they generally do not use high-quality feed concentrate to enhance existing feed during the summer. Thus, the cattle can become stressed and heat stress leads to slow growth due to changes in the levels of hormones and other metabolites in the blood. However, TN cattle have advantages over cattle cross-bred with European breeds because TN cattle adjust to high temperatures better than do imported European cattle. This adjustment can be observed through the mild effects of

heat stress and the rarity of these effects^{10,11}. However, when TN cattle experience summer heat for a long period of time, they continue to produce less body heat, mainly because they consume less feed. This result is consistent with reports by Johnson^{12,13}, Moody *et al.*¹⁴ and Okantahand Curran¹⁵, who concluded that environmental situations directly affect processes in the hypothalamus and adenohipophysis, leading to higher levels of cortisol secretion from the adrenal cortex¹⁶.

The farmers need to develop knowledge, understanding and experience through workshops in which they can share their best practices and experiences of successfully raising quality TN cattle. The training appraisal results showed both progress in developing bodies of knowledge and high farmer satisfaction. According to the analysis of the problems Thai farmers identified during meetings in every sector, they need an appropriate and essential transfer of technologies to develop methods for efficiently and effectively raising TN cattle. Appropriate technology refers to the development of suitable housing and the use of feed formulas incorporating raw materials that are locally available. As the farmers gain knowledge and understanding of appropriate technologies, they increase their ability to efficiently and effectively produce quality beef from TN cattle. This finding applies especially to farmers in Sakon Nakhon, where the number of TN cattle is high.

The model for raising TN cattle included a workshop to promote raising cattle in Sakon Nakhon. The evaluation of this workshop showed that farmers could effectively generate an important body of knowledge on raising TN cattle. The design of the contents and activities in the workshop met the needs of the farmers to facilitate this task. The workshop experts were knowledgeable and tended to have the abilities and experience required to transfer knowledge and understanding by establishing a fundamental body of knowledge for the farmers. This helped farmers efficiently incorporate this new body of knowledge. The workshop included some demonstrations necessary for raising TN cattle. The farmers

were allowed to ask questions freely and to express their opinions and provide explanations and exchanges of experiences occurred between the experts and the attendees. These results indicate that the workshop was conducted at a high level and that the farmers were satisfied with the training session¹⁷. Results of the present study agree with the previous studies which showed that the role of government in increasing awareness, providing information and training and facilitating sustainable development practices is important¹⁸ especially in Thailand¹⁹.

CONCLUSION

This study evaluated the state of cattle raising and the problems and needs of farmers raising TN cattle in Sakon Nakhon. TN cattle are of moderate size and have slow growth. TN cattle have diverse colors (e.g., red, black, spotted, or yellow) and small ears. They are strong, active, quick and easily excited, heat tolerant, resistant to diseases and many types of insects and easy to feed and they utilize roughage well. Female TN cattle are highly fertile and frequently in heat and they give birth easily. In addition, they are effective at raising their calves and live long lives. The farmers face a lack of collective knowledge for raising quality TN cattle, particularly in terms of management practices and the selection of local raw materials to mix with feed concentrates to enhance production quality. The farmers need to develop a body of knowledge and experiences and to transfer essential technologies for raising quality TN cattle using appropriate housing management practices and to develop a formula for cattle feed utilizing cheap, locally accessible raw materials. The model for raising TN cattle included the development of a workshop for Thai cattle farmers in Sakon Nakhon. The workshop assessments demonstrated improvements in farmers' knowledge after the training, the results of the workshop appraisal were positive and the farmers' satisfaction with the workshop was high.

ACKNOWLEDGMENTS

The authors are grateful for collaboration by the Sakon Nakhon Provincial Livestock Office, Sakon Nakhon, Thailand, during this research.

REFERENCES

1. Leng, R.A., 1993. Quantitative ruminant nutrition-a green science. *Aust. J. Agric. Res.*, 44: 363-380.

2. Mackle, T.R., C.R. Parr, G.K. Stakelum, A.M. Bryant and K.L. MacMillan, 1996. Feed conversion efficiency, daily pasture intake and milk production of primiparous Friesian and Jersey cows calved at two different liveweights. *N. Z. J. Agric. Res.*, 39: 357-370.
3. Ritruetchai, V., B. Lertrattanapong, T. Phonbumrung and C. Chansiri, 2012. Performance of Thai native steers under rotational grazing on guinea grass and guinea grass with tapra Stylo Legume pastures in Mahasarakham province of Thailand. Bureau of Animal Nutrition Development Annual Research Report, pp: 83-98.
4. Schukking, S., 1992. Dairy Cattle Husbandry in the Netherlands. In: Proceedings of the International Workshop Livestock Production in Rural Development: Development of Livestock Policies, 20-31 January 1992, Wageningen, Gootjes, C.P., G. den Hertog, R. de Jong and A.J. Nell (Eds.), International Agricultural Centre, Wageningen, pp: 159-164.
5. McKenzie, P.J., 1998. Beef cattle production in Northeast Thailand. M.Phil. Thesis, Development Studies. Massey University, New Zealand.
6. Naiyaphat, O., 2008. Design of Research: Quantitative, Qualitative and Mixed Methods. Chulalongkorn University Press, Bangkok, Pages: 401.
7. Ruekrai, D., 1992. Rural development focusing on strategies and indicators. Project on Rural Development. Kasetsart University, pp: 285.
8. Chit-Anan, B., 2003. Agricultural Promotion. Agricultural Promotion and Training. Kasetsart University Press, Bangkok.
9. Wanapat, M., 2004. Current livestock production and protein sources as animal feeds in Thailand. Proceedings Protein Sources for the Animal Feed Industry, Expert Consultation and Workshop, April 29-May 3, 2002, Bangkok, pp: 199-213.
10. Hafez, E.S.E., 1968. Adaptation of Domestic Animals. Lea and Febiger, Philadelphia, pp: 430.
11. Hefez, E.S.E., 1968. Behavioral Adaptation. In: Adaptation of Domestic Animals, Hafez, E.S.E. (Ed.). Lea and Febiger, Philadelphia, PA., pp: 202-214.
12. Johnson, H.D., 1985. Physiological Responses and Productivity of Cattle. In: Stress Physiology in Livestock, Yousef, M.K. (Ed.). CRC Press, Boca Raton, Florida, ISBN: 0849356679, pp: 3-24.
13. Johnson, H.D., 1987. Bioclimatology and the Adaptation of Livestock. Elsevier Science Publishers BV., Amsterdam, Netherlands, Page: 570.
14. Moody, E.G., F.J. van Soest, R.E. McDowell and G.L. Ford, 1967. Effect of high temperature and dietary fat on performance of lactating cows. *J. Dairy Sci.*, 50: 1909-1916.
15. Okantah, S.A. and M.K. Curran, 1982. A review on the effects of the environment in the central performance testing of beef cattle. *World Rev. Anim. Prod.*, 18: 39-48.

16. Singh, K. and N.K. Bhattacharyya, 1991. Thermosensitivity of *Bos indicus* cattle and their F₁ crosses with three breeds of *Bos taurus*. *Anim. Sci.*, 52: 57-65.
17. Umpapol, H., C. Vajrabukka, C. Songwicha, T. Chitchak, S. Thianklam and W. Sirikhun, 2007. Transferring technology for sustainable dairy production efficiency in Sakon Nakhon province. Research Report, Faculty of Agricultural Technology, Rajabhat University, Sakon Nakhon.
18. Gayatri, S., V. Gasso-Tortajada and M. Vaarst, 2016. Assessing sustainability of smallholder beef cattle farming in Indonesia: A case study using the FAO SAFA framework. *J. Sustainable Dev.*, 9: 236-247.
19. Bunmee, T., N. Chaiwang, C. Kaewkot and S. Jaturasitha, 2018. Current situation and future prospects for beef production in Thailand-A review. *Asian-Aust. J. Anim. Sci.*, 31: 968-975.