Thai Buffalo Product Development: A Systematic Review for Sustainable Practices and Market Opportunities

Nuttawan Pongkan[1] Nawarat Bunphila [2] and Danai Siriburee [3]*

ABSTRACT

This study aimed to analyze the potential of Thai buffalo in the context of sustainable product development and market opportunities both domestically and internationally. A systematic literature review was employed to collect data on trends in the development of Thai buffalo products. The study covered keyword analysis, network linkage, and research trends between 2009 and 2025. A PRISMA systematic review was used to screen 24 research articles, demonstrating clear screening and analysis of articles from sources in the Scopus database during 2009-2025. The results revealed that Thai buffalo products, especially buffalo milk and buffalo meat, have high potential to meet the demands of consumers who value quality, safety, and sustainability, especially in markets that emphasize alternative protein sources and local products. This study also emphasized the importance of developing technologies and innovations to enhance the quality standards and increase the competitiveness of Thai buffalo products in the global market. The results of the network analysis of keywords such as "buffalo", "milk", and "meat" reflect the roles of buffalo products in animal health and food production. In addition, the study emphasized international cooperation, such as Thailand, India, and the United States, in developing innovations and exchanging relevant knowledge. The findings offer valuable insights for researchers, entrepreneurs, government agencies, and the private sector in formulating strategies to enhance the value of Thai buffalo products and support sustainable development. Furthermore, these insights can inform policy-making and guide the development of business plans at both national and international levels.

Keywords: Thai buffalo, Thai buffalo products, Marketing opportunities.

[1] Bueng Kan College of Innovation, Udon Thani Rajabhat University, Thailand.

[2] Office of General Education, Udon Thani Rajabhat University, Thailand.

[3] Faculty of Technology and Engineering, Udon Thani Rajabhat University, Thailand.

*Corresponding author: Danai.Si@udru.ac.th

Introduction

The Thai buffalo (Bubalus bubalis) is considered an important part of the cultural and economic fabric of Thailand, especially in the agricultural sector. The Thai buffalo is a strong animal and serves an important role in growing rice and producing many valuable products. However, over the past several decades, the importance of the Thai buffalo has changed dramatically as agricultural methods have evolved, consumer needs have changed, and the demand for sustainable products has increased in both domestic and international markets. Statistics reveal a worrying trend, with the Thai buffalo population dropping from 6.4 million to just 1,817,289 in 2024. (Thairath Online, 2024). This rapid decline highlights the urgent need to maximize the potential of the remaining buffalo resources. Especially through the development of innovative products and sustainable production practices, market opportunities for Thai buffalo products are increasing. This is supported by several key factors: Today's consumers place importance on food safety and traceability. This has resulted in demand for products with reliable certification. With the increasing interest in protein sources the choice also opens the opportunity to cater to specific markets with buffalo products. This includes the rising popularity of native and local foods in international markets. It also causes products from Thai buffalo to be accessible. more target groups abroad

However, The development of buffalo products in Thailand faces several significant challenges. Thoroughly inspecting and solving problems such as research and development of processing technology that limits the variety of raw material quality. Tolerances in product standards Competition from substitutes and the complexity of environmental sustainability and regulatory compliance must be received Therefore, a comprehensive literature review is necessary to collect, analyze, and synthesize existing knowledge on the development of Thai buffalo products. Identify gaps in development and propose guidelines for sustainable growth. This study used the PRISMA methodology by reviewing the literature. Related from the past to the present Includes peer-reviewed academic articles, reports, industry and relevant government documents. The results of this research will be of great benefit to various stakeholders, including entrepreneurs who want to create new products. Policy makers who need information to make decisions Researchers who want to study further Investors exploring business opportunities and supporters of sustainable development. Ultimately, it is hoped that the insights gained will help develop the buffalo products industry. Thailand's economy will become more sustainable in the years to come. As traditional farming practices give way to commercial production, new approaches for product development and market expansion are emerging. Products from buffalo in Thailand has many It covers meat, milk, leather and various by-products. In the past, processing these products required techniques that had been passed down from generation to generation.

Today, modern technology and innovation are used in the production process to comply with changing market demands. This technological advancement not only allows the creation of new products but also raises quality standards. As a result, products from Thai buffalo have a limited ability to compete in both domestic and international markets.

Objectives

1. Analyze trends and market demand for products from Thai buffalo. Including guidelines for sustainable production that is appropriate in environmental, economic and social dimensions.

2. Propose strategic guidelines for developing products from Thai buffalo to increase value and competitiveness. in both domestic and international markets

Research methods

This research studies and collects relevant research that meets international standards. Information used in this research Scientific references were obtained from the Scopus database. The search guidelines were systematically defined as follows.

1. Search through the database. https://www.scopus.com/search/

2. Screening Identify keywords related to Buffalo, Processed Products, Thailand.

3. Selection: Identify search terms in the article title, abstract, and

keywords.

4. Extraction using the Prisma systematic literature review (which is a tool that uses international standardized systematic reviews and procedures. Data extraction is transparent and traceable) (Athikarisamy et al., 2021), which selects only articles that specify English research. The tool used in this study is a collection of research data in the form of a code list generated by the tool and must clearly specify the type of data. Formal objectives the study consists of a description of the problem, arranged in the following order:

1. Code – Set a 2-digit code in order from newest to oldest.

2. Name of published research – Name of published research work/manual.

3. Author's name - The researcher may work alone or in a research team.

4. Publication year – The year the work was published.

5. Keywords – Identify the author's main educational perspective. Helps filter the articles you want to study easily.

6. Include published journal research results presented according to the journal's scientific characteristics and credibility standards.

7. Institutions/Academic Institutions – Run by researchers. Affiliated institutions or educational institutions.

8. Bibliometric data analysis – Using the RStudio programming environment with the Bibliophagy application makes it easier to explore research networks by creating connections between academic works based on keywords and keyword clusters obtained from the Scopus research database.

Data analysis

The articles obtained from this collection were grouped and analyzed content-wise using descriptive statistics to find frequencies, percentages, and the most common trends in the analysis involving the aforementioned methods, which were divided into two parts: 1) trends in published works in three categories: year of publication, institution/institution, and scientific works/fields, and 2) issues related to the research results.

Research Conceptual Framework

Study the development of Thai buffalo products by using bibliographic analysis in the Scopus database to find trends and connections to the development of Thai buffalo products. The study is divided into 2 main parts.

1. Analyze publication trends such as the year of publication, institution, research field, etc.

2. Bibliometric analysis to link the development of buffalo products.
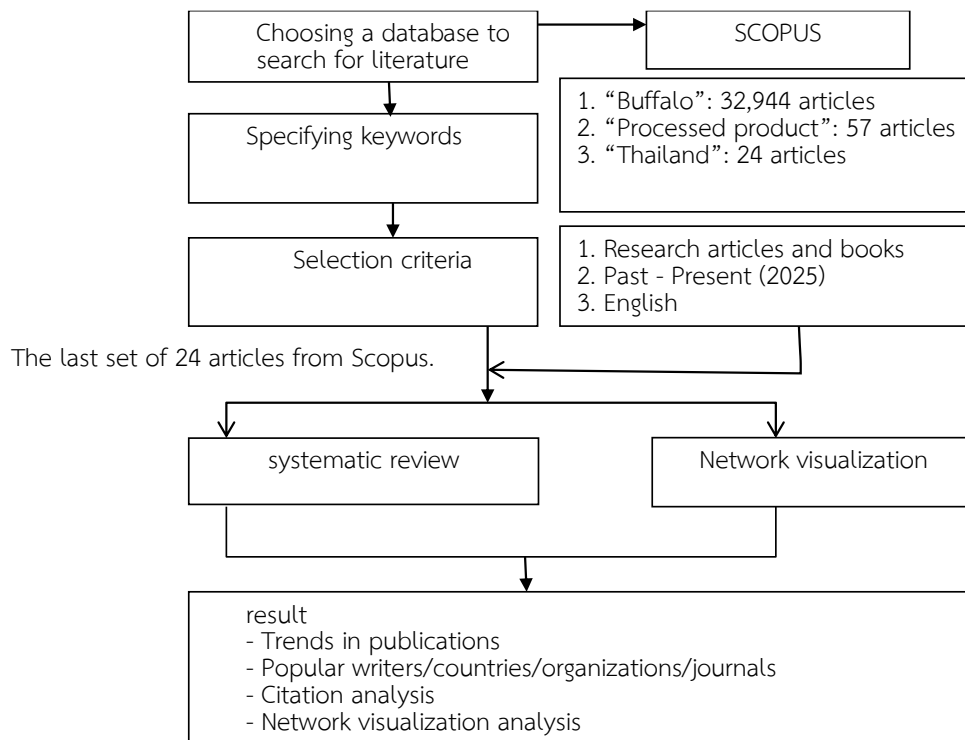
Figure 1 The structure of article selection methods used for systematically reviewing literature.

Research results

From the collected data, by selecting 3 keywords to search in the Scopus database: Buffalo, Processed products, Thailand, by searching for the first word "Buffalo" found 32,944 articles, the first and second words "Buffalo" and "Processed products" found 57 articles, the first, second and third words "Buffalo" and "Processed products" and "Thailand" found 24 articles. After checking and selecting that every article is a real research

article, the full text data can be downloaded, and it was found that every article from the educational and scientific institutions studied in Topics 2 and 3 had a total number of more than 24 articles. The first research study was conducted in 2009 and there has been continuous research, but the number of articles per year is still low.

Table 1 Shows the number of articles published each year and the number of citations (times) in 2009-2025.

Year	Number of articles	Number of references (times)
2009	1	33
2010	2	20, 392
2011	2	63, 45
2013	1	10
2014	3	3, 0, 6
2015	1	41
2019	1	30
2021	4	86, 6, 3, 3
2022	1	16
2023	3	0, 1, 4
2024	4	0, 1, 20, 1
2025	1	0
together	24	784

This table shows the number of articles

published and the number of citations each year between 2009 and 2025. A total of 24 articles were published and received a total of 784 citations. The number of articles that Published each year has variations. The year with the highest number of articles was 2021 (4 articles), while 2010 and 2011 had the highest number of citations, reflecting the importance of the articles during that period.
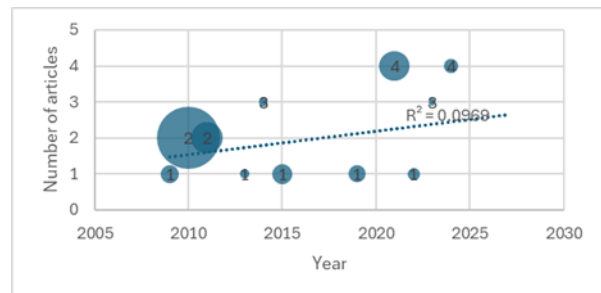

Figure 2 shows the relationship between the number of articles published annually and the number of citations.

Figure 2 illustrates the relationship between publication year, and the number of articles published each year, with an R^2 of 0.0969. This means that the trend over time explains only about 9.69% of the variation in the annual number of articles, indicating a weak correlation between publication year and article volume. Moreover, the relationship between the number of articles and the number of citations shows that years with more publications, such as 2021 and 2024, do not necessarily have higher citation counts. In contrast, certain years with fewer articles, like 2010 and 2011, received more citations. This confirms that the quality, relevance, and novelty of the articles are stronger factors influencing citations than the mere

number of publications per year. Therefore, the low R² value emphasizes that quantitative trends alone are insufficient for predicting academic impact — qualitative factors must also be considered.
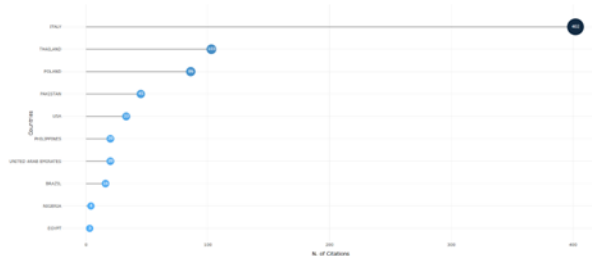
Figure 3 Presents the documents with the highest citation counts worldwide.

The graph shows the number of citations of research articles in each country. Italy has the highest number of citations, 402, reflecting the country's important role in related research. Thailand is in second place with 103 citations, indicating the international interest in the topic of Thai buffalo research. Other countries such as Poland (86), Pakistan (45), and the United States (33) have a lower number of citations. Countries with fewer citations, such as the Philippines, United Arab Emirates, Brazil, Nigeria, and Egypt, have citations in the range of 1-20, reflecting the distribution of research on the world level and the importance of the articles in the context of the relevant countries.
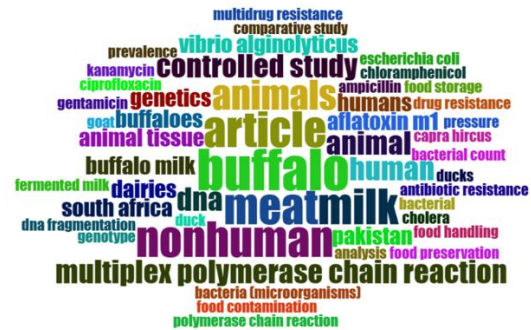
Figure 4 Displays a keyword word cloud from research data.

Word Cloud displays keywords from data or research documents. Larger words like "Buffalo" (7 hits), "Article," "Meat," "Milk," and "non-human" (6 hits) indicate the highest priority topics. related to buffalo Products from buffalo and non-human animals Meanwhile, less important words such as "Animals" (5 hits), "Animal," "Controlled Studies," "DNA," and "Human" (4 hits) reflect research involving animals, humans, controlled experiments. and use of biology technology Overall, it represents a study that covers both animal health animal products food contamination and genetic analysis in specific contexts, such as "South Africa" and "Pakistan", reflecting the breadth and diversity of research in the data.

Figure 5 Show co-occurring networks.

The co-occurring networks from both images show the connection between keywords in the research. It was found that keywords that have a clear relationship include "milk," "buffalo milk," "buffalo," "Analysis.," and "meat" had the highest co-occurrence (4 times), reflecting the important role of topics related to buffalo and buffalo products such as milk and meat. including analysis of related data while other keywords included "ampicillin," "DNA reaction," "chloramphenicol," "ciprofloxacin," and "gentamicin." There was a second common link (3 times), indicating the study of antibiotics and chemical substances in research related to animal health and animal products. The network structure shown in Figure 1 indicates the grouping of keywords according to the nature of the research topic, which is separated into colored groups, such as red highlighting keywords related to buffalo. Purple relates to analysis of buffalo milk and green focuses on antibiotics and pathogen resistance.
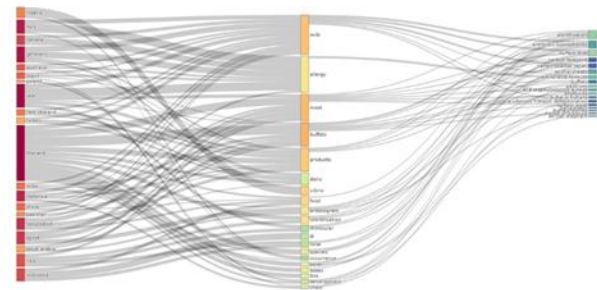

Figure 6 Three-Field Plot shows the strongest relationship. between articles available in each country, topic, and keyword

Figure 6 Three-Field Plot shows a strong relationship between country of origin of the study (such as the United States, India, Thailand, and Italy), main topic (such as "milk," "allergy," "meat," and "buffalo"), and keywords (such as "antibiotic susceptibility," "buffalo milk," " carbon footprint," and "food products") by key countries such as India and the United States. There is a clear connection to the main topic, such as "buffalo" and keywords related to animal health. Food safety and environmental impacts This reflects the participation of these countries in research that has a global impact. and emphasize the characteristics

Comprehensive study of important issues in health and food production in various contexts.
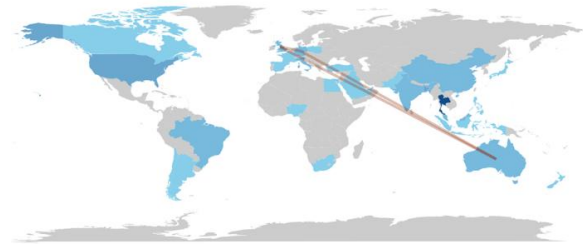
Figure 7 Displays international cooperation in research across major countries.

Countries' Collaboration World Map showing connections and academic cooperation between countries, with darker countries such as the United States, Australia, Thailand, and Western European countries. This indicates high participation in research. and international connection lines such as Australia-Thailand, Thailand-USA and Europe-Southeast Asia Shows cooperation in the field of Important research Overall, it reflects an international collaborative network that emphasizes Exchange knowledge and expertise on related research topics.

Summarize

A network analysis of co-occurring keywords in the articles studied found that "buffalo milk," "buffalo," "analysis," and "meat" were keywords that were linked to the main themes in many of the studies. dimensions, with studies on a variety of issues in terms of product quality Scientific analysis and use of antibiotics in the production process of products from Thai buffalo. In addition, the study found a strong relationship. Between the countries of origin of the research

such as India, USA, Thailand and Italy, which play an important role in the research. related to Thai buffalo especially in issues related to animal health and food safety**.** Such cooperation reflects the interdisciplinary nature of research and the exchange of knowledge across borders.

Studying the importance of product development from Thai buffalo in the context of sustainability by presenting in-depth information related to the production process and efficient use of resources, which will help add value to products and respond to needs. Market demands are changing rapidly, while government support and international cooperation are important factors in driving Research on Thai buffalo is progressing and can lead to development that is consistent with the development goals. Sustainable on a global scale.

Metaphysics

The results of this study indicate the importance of product development from Thai buffalo in the context of creating Sustainability and adding value to resources in the agricultural sector by the Thai buffalo, which was once an animal with an important role in the lifestyle and economy of Thai farmers. It has faced rapid population decline. Over the past few decades Due to changes in the agricultural system and changes in market demand However, the study highlights the potential of Thai buffalo as a valuable resource. in the economic, social and environmental dimensions. Especially around related products such as buffalo milk, buffalo meat, animal skins and other by-products. that has the ability to add value and respond to needs of the modern market which focuses on

quality food safety and sustainability in the production process, which the Thai government has used an economic model Bio-Circular-Green (BCG) to enhance safety and quality Post-pandemic food Including supporting local projects such as University to Tampon (U2T) committed to Strengthen community resilience and improve food production standards (Thanawat, Pimoljinda., Sunee, Hongwiset., 2023). From data analysis over a 15-year period, it was found that interest in research on buffalo Thailand has continued to grow. Even though there are not many related articles, but it shows interest in international level Countries that play an important role in research, such as India, the United States, Thailand, and Italy, are involved in studying issues related to animal health. The use of antibiotics in animal products and analysis of environmental impacts related to the production of buffalo products. Frequently appearing keywords such as "Buffalo," "Meat," "Milk," and "Antibiotic Susceptibility" reflect a trend in research that focuses on Develop Thai buffalo products in various dimensions. both qualitatively and strategically for the market Especially in groups Products that meet the needs of consumers who care about health and the environment, such as buffalo milk with high nutritional value, high protein and fat content: buffalo milk has approximately 4.61% protein and 6.02% fat, superior to cow's milk in terms of energy density (Zsolt et al., 2020), which buffalo meat is rich in protein and low in fat. This makes it a nutritious choice (Suthipong, Uriyapongson, 2013). But buffalo meat is sensitive. against spoilage and disease-causing

microorganisms Germ control is essential. which uses the HACCP system (HACCP) Hazard analysis of buffalo meat processing reduces the risk of foodborne illnesses (Pathera, A.K., & Kumar, N., 2014).

The study also points out the importance of international cooperation networks in research. Related to Thai buffalo such as research on "Mapping threats by Thai buffalo provides an opportunity for improvement. Conservation Outcomes in Asia" Ecological modeling is used to identify suitable habitat for buffalo, highlighting research areas in Thailand and India as potential conservation sites. This research can be Guidelines for international conservation strategies and habitat management plans (Wantida, Horpiencharoen et al., 2024) with the exchange of knowledge and technology between countries that have expertise in such issues, such as India and Australia. This cooperation helps increase research and development potential. products to have a better ability to compete in the world market but there are also other factors that directly affect business, such as international trade rules. The Indian buffalo meat industry, which is a major exporter, has been affected by changes in international trade. This change causes market uncertainty, affecting the national economy. (Varalakshmi, Kandanuri, 2019) Linking between keywords the research also shows the relationship between dimensions of animal health. Food safety and environmental sustainability These are all important issues that affect the direction of the future development of Thai buffalo products. For example, in Italy, buffalo

farming can contribute to the economic development of rural areas. significantly the buffalo industry is well developed with a focus on producing high quality food and Marketing which supports the local economy and preserves cultural heritage (Antonio, Borghese, 2013) and environmental branding can help promote buffalo products as a sustainable and friendly option. with the environment (Mathilda, Boklund, Lhonneur., Ida, Lindén, 2016).

In the modern world, an important challenge is integrating knowledge in various dimensions and presenting products that can effectively meet the needs of both domestic and international markets, while policy support from the government and cooperation International is still an important factor that helps drive the development of products from Thai buffalo can respond to market needs and development goals. Truly sustainable on a global scale.

Suggestions

Academic suggestions

1. There should be additional research on the nutritional properties and health values of products from Thai buffalo, such as buffalo milk and buffalo meat. To create new knowledge that can support product development. Because buffalo milk provides more energy per unit volume than cow's milk because it contains higher fat and protein. (Arora et al., 2022)

2. Promote research in the application of biotechnology and nanotechnology in production processes. Products from buffalo increase quality and reduce production costs. Nanomaterials can enhance the sensory and nutritional aspects of buffalo products, which can help improve taste. (Najeeb et al., 2025)

3. There should be a comparative study of foreign markets to identify market opportunities for products from Thai buffalo at the international level. (Especially the Indian market, which has about 54% of the world's buffalo population and is one of the major suppliers of buffalo meat in the international market. India's share of global buffalo meat exports increased from 3.34% in 2000 to 11.23% in 2020). (Sharma, I., Arora, K., Kumar, S., Bhoi, P. B., & Vatta, K., 2023)

Policy recommendations

1. The government should support budget for research and development that focuses on increasing the value of products from Thai buffalo, including the establishment of a Thai buffalo development fund for conservation and sustainable use.

2. Propose the creation of a policy to promote the production and processing of Thai buffalo products in an eco-industry format in line with sustainable development goals and promote sustainable practices that increase resilience in the agricultural value chain, supporting the SDGs related to economic growth and poverty alleviation (Kuwornu, 2017)

3. Support the creation of international cooperation networks in the field of research. technology development and marketing for products from Thai buffalo

Operational suggestions

1. Establish a learning center about buffalo

raising and product development from buffalo at the community level to transfer technology and appropriate practices.

    2. Promote branding for products from Thai buffalo, such as buffalo milk and buffalo meat, emphasizing uniqueness and quality. To increase confidence in the market both domestically and

.

abroad.

    3. Develop an online platform for selling products from Thai buffalo. to add channels Marketing and reaching consumers in the digital age

Reference

Antonio, B. (2013). Buffalo livestock and products in Europe. *Scientific Bulletin – Economic Sciences*, *12*(1), 47–73.

Arora, S., Sindhu, J. S., & Khetra, Y. (2022). Buffalo milk. In P. L. H. McSweeney & J. McNamara (Eds.), *Encyclopedia of Dairy Sciences* (3rd ed., pp. 784–796). Academic Press. https://doi.org/10.1016/B978-0-12-818766-1.00125-2

Athikarisamy, S. E., and Patole, S. (2021). Reporting of meta-analysis (PRISMA). In S. Patole (Ed.), *Principles and practice of systematic reviews and meta-analysis* (pp. 111–123)*.* Springer International Publishing Switzerland. https://doi.org/10.1007/978-3-030-71921-0_11

Boklund Lhonneur, M., and Lindén, I. (2016). Product guidelines developed within the areas of design for sustainable behaviour, green branding and compact living (Master's thesis, Chalmers University of Technology, Sweden). Chalmers Open Digital Repository.

Kuwornu, J. K. M. (2017). *Chained to Sustainable Development Goals? The changing role of entities for enhanced resilience along agriculture food value chains in Thailand*. Research Papers in Economics. https://doi.org/10.22004/AG.ECON.284866

Najeeb, S., Miskeen, S., Jahangir, M., & Khan, I. M. (2025). Nanobiotechnological interventions for sustainable food supplies and agricultural production. In A. Talha-Khalil & A. Islam (Eds.), *Expanding nanobiotechnology: Applications and commercialization* (pp. 150–159). CRC Press. https://doi.org/10.1201/9781003378563-7

Pathera, A. K., & Kumar, N. (2014). Food safety assurance in frozen boneless buffalo meat through HACCP application. *Wayamba Journal of Animal Science*, 6, 899–909.

Sharma, I., Arora, K., Kumar, S., Bhoi, P. B., & Vatta, K. (2023). Global trade competitiveness of Indian buffalo meat: Trends and determinants. *Buffalo Bulletin*, *42(1),* 105. https://doi.org/10.56825/bufbu.2023.4214974

Suthipong, U. (2013). Buffalo and buffalo meat in Thailand. *Buffalo Bulletin, 32*, 329-332.

Thairath Online. (2024, May 16). *Join in conserving "Thai buffalo" alongside "Thai people" forever*.
https://www.thairath.co.th/news/local/2785745

Thanawat, P., and Sunee, H. (2023). Food safety, consumer behavior, and government policy after the COVID-19 pandemic in Thailand: A review. *KnE Social Sciences*, *8*(3), 792–803.
https://doi.org/10.18502/kss.v8i3.12832

Varalakshmi, K. (2019). Indian buffalo meat exports: Issues of growth, instability, concentration. *Buffalo Bulletin*, *38*(3), 505–520. Retrieved from https://kuojs.lib.ku.ac.th/index.php/BufBu/article/view/541

Wantida, H., Muylaert, R. L., Marshall, J. C., John, R. S., Lynam, A. J., Riggio, A., Godfrey, A., Dusit, N., Gale, G. A., Ash, E., Bisi, F., Cremonesi, G., Clements, G. R., Yindee, M., Shwe, N. M., Pin, C., Gray, T. N. E., Aung, S. S., Nakbun, S., Manka, S. G., Steinmetz, R., Phoonjampa, R., Seuaturien, N., Phumanee, W., and Hayman, D. T. S. (2024). Mapping threatened Thai bovids provides opportunities for improved conservation outcomes in Asia. *Royal Society Open Science*, *11*(9), Article 240574.
https://doi.org/10.1098/rsos.240574

Zsolt, B., Savić, M., Ćirković, D., Rašeta, M., Puvača, N., Pajić, M., Đorđević, S., and Paskaš, S. (2020). Assessment of water buffalo milk and traditional milk products in a sustainable production system. *Sustainability*, *12*(16), Article 6616. https://doi.org/10.3390/su12166616