Tempeh: An Alternative Plant-Based Protein Source for Health

Thanyalak Nilnet[1]*, Puangpaka Sitthichan [2], and Supanan Prommak[3]

Abstract

Tempeh, a traditional fermented soybean product originating from Indonesia, has gained increasing attention as a sustainable and nutritious plant-based protein source. This project, titled *"Tempeh: An Alternative Plant-Based Protein Source for Health,"* aims to systematically study and develop tempeh production while exploring its practical applications in healthy menu development within food service operations. The objectives were to establish a standardized small-scale production process, ensure quality control and food safety, and evaluate the feasibility of incorporating tempeh into restaurant and hotel menus. The methodology included a literature review on plant-based proteins and fermentation, hands-on experimentation in tempeh production (covering raw material preparation, fermentation control, and quality assessment), and the development of various health-oriented dishes using self-produced tempeh. The results demonstrated that tempeh can be consistently produced under controlled conditions, achieving a satisfactory texture and flavor suitable for culinary applications. Menu trials indicated positive acceptance and highlighted tempeh's potential as a viable substitute for animal protein. Overall, the project confirms that tempeh is a practical, nutritious, and sustainable ingredient that supports healthy dietary trends and enhances menu innovation in the food service industry.

Keywords: Alternative Protein Source, Fermented Soybean, Food Service Innovation, Plant-Based Protein, Tempeh

Introduction

In recent years, growing awareness of health, environmental sustainability, and ethical food consumption has led to a significant increase in demand for plant-based protein sources. Consumers are increasingly seeking nutritious alternatives to animal protein that support overall well-being while reducing environmental impact. As a result, plant-based ingredients have become an important focus in modern food service and menu development.

Tempeh, a traditional fermented soybean product originating from Indonesia, is recognized for its high protein content, rich nutritional value, and enhanced nutritional properties resulting from fermentation. Compared to many other plant-based proteins, tempeh offers a firm texture and distinctive flavor that make it highly adaptable for various culinary

[1] Miss Thanyalak Nilnet, Undergraduate Student, Faculty of Humanities and Social Sciences, Thaksin University, Songkhla 90000, Thailand
[2] Dr. Puangpaka Sitthichan, Lecturer, Chinese Program, Faculty of Humanities and Social Sciences, Thaksin University, Songkhla 90000, Thailand
[3] Asst. Prof. Dr. Supanan Phrommak, Lecturer, English Program, Faculty of Humanities and Social Sciences, Thaksin University, Songkhla 90000, Thailand

Corresponding Author: 631011536@tsu.ac.th

applications. In addition, its fermentation process enhances digestibility and nutrient availability, making it particularly suitable for health-conscious consumers, vegetarians, and individuals following plant-based diets.

This project, titled *"Tempeh: An Alternative Plant-Based Protein Source for Health,"* was developed based on practical experience gained during an internship in a hotel food and beverage department. The study aims to systematically examine the tempeh production process and evaluate its potential for healthy menu development in food service operations. Through this approach, the project seeks to contribute to menu innovation, promote healthy dietary practices, and support the development of sustainable food systems.

Research Objectives

To examine the nutritional value, production process, and health benefits of tempeh as an alternative plant-based protein source, as well as to evaluate its potential to appropriately and safely substitute animal-based protein.

Literature Review

The increasing global demand for plant-based protein has been driven by growing concerns about health, environmental sustainability, and food security. Plant-based diets are associated with reduced risks of cardiovascular disease, obesity, and type 2 diabetes (Satija et al., 2017). In addition, replacing animal protein with plant-based alternatives can significantly reduce greenhouse gas emissions and resource use (Poore & Nemecek, 2018). As a result, plant-derived protein sources have become increasingly important in both nutrition science and the food service industry.

Tempeh, a traditional Indonesian fermented soybean product, has gained recognition as a nutrient-dense plant-based protein. It is produced through controlled fermentation with Rhizopus spp., which bind soybeans into a compact cake and enhance digestibility (Nout & Kiers, 2005). The fermentation process reduces antinutritional factors such as phytic acid while improving protein quality and mineral bioavailability (Kiers et al., 2000). Tempeh is rich in protein, dietary fiber, vitamins (particularly B vitamins), and essential amino acids, making it a complete plant protein source (Astuti et al., 2000).

Furthermore, fermentation contributes to the formation of bioactive compounds and may support gut health through beneficial microbial activity (Marco et al., 2017). Due to its firm texture and savory flavor, tempeh is highly adaptable in culinary applications and can effectively substitute animal-based protein in various dishes. Therefore, tempeh represents a promising ingredient for healthy menu development and sustainable food innovation in food service operations.

Research Methodology

This study employed a combined qualitative and experimental research approach to systematically investigate tempeh as an alternative plant-based protein source for health and its practical application in food service operations. The methodology was designed to ensure

both theoretical understanding and practical implementation, integrating academic research with hands-on experimentation in a real kitchen environment.

The first stage of the research involved an extensive literature review. Academic journals, textbooks, research articles, and reliable online databases were examined to establish a strong theoretical foundation. The review focused on plant-based protein trends, nutritional composition of soybeans, fermentation science, microbial activity of *Rhizopus* species, food safety standards, and the health benefits of fermented foods. This phase provided essential background knowledge for designing the production model, setting quality evaluation criteria, and understanding the broader significance of tempeh within sustainable food systems.

Following the literature review, an experimental phase was conducted to develop a standardized small-scale tempeh production process. High-quality soybeans were carefully selected and sorted to ensure uniformity and cleanliness. The beans were washed thoroughly, soaked for 36–48 hours to promote hydration, and then dehulled to improve fermentation efficiency. After dehulling, the soybeans were boiled to achieve appropriate softness and reduce unwanted microorganisms. The cooked beans were drained and cooled to room temperature before being inoculated with a controlled amount of *Rhizopus* starter culture. The inoculated soybeans were evenly mixed, packed in perforated food-grade plastic bags, and incubated at 30–32°C for 24–48 hours. Throughout the fermentation period, temperature, humidity, and visual changes were monitored regularly. Observations were recorded regarding mycelium growth, texture formation, aroma, color, and overall product consistency.

Strict hygiene and food safety practices were maintained during all stages of production. Equipment sanitation, proper handling procedures, and contamination prevention measures were implemented to ensure product safety. The finished tempeh was evaluated for uniform white mycelial coverage, firmness, clean aroma, structural integrity, and absence of spoilage signs. Any defective batches were documented and excluded from further use.

After establishing a consistent production model, the self-produced tempeh was incorporated into a healthy menu development process in a practical kitchen setting. Various dishes were designed using tempeh as a substitute for animal-based protein. The evaluation focused on taste, texture, appearance, adaptability to cooking methods, and overall acceptability. Informal sensory feedback was collected from kitchen staff and trial consumers to assess feasibility and consumer response.

Finally, all data gathered from the literature, production records, and menu evaluations were compiled and analyzed using descriptive statistics. The results were synthesized to assess the nutritional value, practical feasibility, and commercial potential of tempeh as a sustainable plant-based protein alternative in food service operations.

Discussion and Conclusion

The findings of this study demonstrate that tempeh is a viable and practical plant-based protein source that can be successfully produced and utilized in food service operations. The standardized small-scale production process proved to be consistent and manageable when appropriate hygiene practices, temperature control, and fermentation monitoring were maintained.

The study clearly identified that precise moisture control and the even distribution of Rhizopus starter culture are critical factors influencing product quality. Minor deviations in these variables directly affected texture and structural compactness, emphasizing the necessity of standardized procedures to ensure consistent product quality and food safety.

From a nutritional perspective, the results indicate that the fermentation process enhances protein digestibility and reduces antinutritional factors, thereby increasing the functional food value of tempeh. In culinary applications, tempeh demonstrated high adaptability across various cooking methods and effectively substituted for animal protein in multiple dishes. Feedback from kitchen trials suggested good acceptance, particularly among health-conscious consumers.

The findings of this study are consistent with previous research on fermented soybean products, which highlights the critical role of controlled fermentation conditions in determining product quality. Similar to earlier studies, this research confirms that temperature stability, hygiene control, and proper distribution of Rhizopus culture significantly influence texture formation and structural integrity. However, this study specifically emphasizes the practical feasibility of implementing a standardized small-scale production model within a controlled kitchen environment, an area that has been less explored in previous literature focusing primarily on industrial-scale production.

In terms of nutritional benefits, the observed improvement in protein digestibility and reduction of antinutritional factors align with existing literature identifying fermentation as a process that enhances nutrient bioavailability. These results reinforce prior findings that tempeh can be classified as a functional food due to its improved nutritional profile compared to non-fermented soybeans.

From a sustainability perspective, the study's results support broader literature on plant-based protein alternatives, which indicates that plant-derived proteins generally require fewer natural resources and generate a lower environmental impact than animal-based proteins. The present findings further extend this knowledge by demonstrating practical application within food service operations.

Culinarily, while previous studies have discussed tempeh's texture and flavor absorption properties, this research contributes additional insight by evaluating its adaptability in real kitchen trials. The positive consumer feedback observed in this study is consistent with research suggesting increasing acceptance of plant-based foods among health-conscious consumers. Nevertheless, compared to large-scale sensory evaluation studies, the limited sample size in this project suggests that future research incorporating broader consumer testing would strengthen statistical reliability and comparative analysis.

This study confirms that tempeh is a nutritious, sustainable, and commercially feasible plant-based protein alternative. A standardized small-scale production process can be effectively implemented in controlled kitchen environments while maintaining consistent quality and food safety standards.

Furthermore, tempeh demonstrates strong potential for integration into healthy menu development within restaurant and hotel operations. Its nutritional value, culinary versatility, cost-effectiveness, and alignment with global plant-based food trends position tempeh as a practical solution for enhancing menu diversity and meeting the growing demand for alternative protein sources in the modern food service industry.

Acknowledgement

The author expresses sincere gratitude to the staff of DoubleTree by Hilton Phuket Banthai Resort for their guidance, support, and valuable practical knowledge throughout the internship. Their professional experience and encouragement greatly contributed to the successful completion of this project.

The author would also like to extend heartfelt thanks to Dr. Puangpaka Sitthichan and Assistant Professor Dr. Supanan Phrommak for their academic guidance, constructive suggestions, and continuous support. Their expertise and encouragement were instrumental in the successful completion of this research.

References

Astuti, M., Meliala, A., Dalais, F. S., & Wahlqvist, M. L. (2000). Tempe, a nutritious and healthy food from Indonesia. *Asia Pacific Journal of Clinical Nutrition, 9*(4), 322–325.

Kiers, J. L., Nout, M. J. R., & Rombouts, F. M. (2000). In vitro digestibility of processed and fermented soya bean, cowpea and maize. *Journal of the Science of Food and Agriculture, 80*(9), 1325–1331.

Marco, M. L., et al. (2017). Health benefits of fermented foods: microbiota and beyond. *Current Opinion in Biotechnology, 44*, 94–102.

Nout, M. J. R., & Kiers, J. L. (2005). Tempe fermentation, innovation and functionality. *Journal of Applied Microbiology, 98*(4), 789–805.

Poore, J., & Nemecek, T. (2018). Reducing food's environmental impacts through producers and consumers. *Science, 360*(6392), 987–992.

Satija, A., et al. (2017). Healthful and unhealthful plant-based diets and the risk of coronary heart disease. *Journal of the American College of Cardiology, 70*(4), 411–422.*

Figure 1: The appearance of finished tempeh and the internal white mycelium structure.

Figure 2: The process of washing and soaking soybeans.

Figure 3: **The process of boiling soybeans.**

Figure 4: **The process of dehulling the soybeans and draining off excess water.**

Figure 5: **The process of inoculating with the starter culture.**

Figure 6: **The process of packaging into perforated bags for air circulation.**

Figure 7: **The arrangement of tempeh bags during the fermentation process.**

Figure 8: **Tempeh after the completion of the fermentation period.**

Figure 9: **Tempeh Stir-Fried with Holy Basil (Pad Krapao Tempeh).**

Figure 10: **Tempeh Salad.**

Figure 11: **Tempeh Omelet.**