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Formulation and Nutritional Evaluation of Non-Soy Tempeh for Science Learning within a Halalan Thayyiban Framework

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ABSTRACT

The decline in domestic soybean production has increased Indonesia's dependence on imports, creating the need to explore local non-soy raw materials to support sustainable food security. This study aims to formulate and analyze non-soy tempeh as an alternative to soybean tempeh and to examine its potential as a contextual learning resource in science education on the topic of nutrition, while considering the *halalan thayyiban* concept. The research was conducted in two stages: formulation of non-soy tempeh, proximate analysis of rain tree seed tempeh, and a literature review on the nutritional content of various types of non-soy tempeh and their potential as science learning resources aligned with *halalan thayyiban* principles. The results show that each type of non-soy tempeh has distinct nutritional characteristics and potential as a protein-rich fermented food alternative to soybean tempeh. From the *halalan thayyiban* perspective, the production process emphasizes nutritional value, cleanliness, safety, and compliance with halal food principles. The use of local ingredients also promotes independence and strengthens food security. In conclusion, non-soy tempeh is a nutritious and *halalan thayyiban*-compliant food that has potential as a contextual learning resource in science education.

Keywords: formulation, non-soy tempeh, nutritional value*,* halal food.

INTRODUCTION

Tempeh has now become a staple food or side dish that is always present in meals. With an affordable and low price, Indonesian people consume tempeh as a source of protein (Handoko et al., 2018). Tempeh is rich in nutrients and benefits, containing antibacterial properties in the form of glycoprotein compounds, antimicrobial peptides, and flavonoids produced by *Rhizopus* sp. during the fermentation process (Hill, 2011)

Soy-based tempeh contains higher levels of plant-based protein compared to meat and serves as a significant source of calcium equivalent to cow's milk (Kementerian Pertanian, 2019). Soybeans are commonly used as the main ingredient in producing tempeh and tofu, while by-products can be further processed into soy milk, soy sauce, and tauco (Gede et al., 2025; Herlina & Setiarto, 2025; Teoh et al., 2024). However, the increasing use of soybeans as a raw material for these food products has not been accompanied by a rise in national soybean production. Over the last few years, domestic soybean production has continued to decline, from 632.3 thousand tons in 2020 to a projected 558.3 thousand tons in 2024 (Hulu, 2023). This decreasing trend has resulted in a widening gap between production and demand, as national soybean needs reach around 2.6 million tons per year. Consequently, more than 70% of soybeans consumed in Indonesia are imported, primarily from the United States (36.51%), Argentina (36.18%), and Brazil (23.27%) (Kementerian Pertanian, 2020). This condition demonstrates Indonesia's heavy dependence on imported soybeans to meet domestic consumption demands.

The low level of domestic soybean production in Indonesia is also influenced by agroclimatic limitations. Soybean (*Glycine max*) was originally domesticated in East Asia and naturally adapted to subtropical and temperate regions (Dong et al., 2021). Although it can be cultivated in tropical areas, its productivity tends to decline under high temperatures and humidity, which are less favorable for pod filling and seed maturation (FAO, 2025).These climatic constraints, along with the crop's sensitivity to photoperiod and temperature stress, often lead to lower yields in tropical environments (Sedibe et al., 2023). Combined with the continuously increasing demand and limited expansion of cultivation areas, these factors further reinforce Indonesia's dependence on imported soybeans and contribute to rising market prices.

Food diversification is essential to reduce Indonesia's heavy reliance on soybeans and to mitigate the growing pressure on food demand and price fluctuations (Lestari & Mayasari, 2016). This can be achieved by substituting soybeans with other raw materials or by incorporating additional ingredients that provide comparable nutritional value without compromising the quality of tempeh. The primary goal of food diversification is to decrease the population's dependence on a single staple commodity (Marwanti, 2011). Such dependency can be addressed by replacing soybeans with locally available legumes such as rain tree seeds (*Samanea saman*), leucaena seeds (*Leucaena leucocephala*), jackfruit seeds (*Artocarpus heterophyllus*), mung beans (*Vigna radiata*), and peanuts (*Arachis hypogaea*). These crops are well adapted to Indonesia's tropical climate and are abundantly available, making them promising alternatives for sustainable tempeh production.

From a food security perspective, diversification plays a crucial role in ensuring the stability, availability, and resilience of the national food system (Hertel et al., 2021; Londoño, 2024). By utilizing locally available non-soy legumes, Indonesia can reduce its reliance on imported soybeans, thus minimizing exposure to global price fluctuations and potential supply chain disruptions. This approach supports food self-sufficiency, strengthens local agricultural production, and promotes sustainable farming practices by encouraging the cultivation of indigenous crops that thrive in local conditions (Canning, 2022; Micabalo et al., 2024). Ultimately, such diversification not only provides alternative raw materials for tempeh production but also enhances the country's ability to provide accessible, nutritious, and affordable food for its population.

Previous studies have shown that rain tree seeds and leucaena seeds can be processed into tofu or tempeh as soybean substitutes. Both belong to the legume family and have high nutritional value—20–25 g/100 g protein, B vitamins (thiamine, riboflavin, niacin, folic acid), minerals (Ca, Fe, P, K, Zn, Mg, etc.), and dietary fiber (Kamboj & Nanda, 2018). They also contain significant amounts of fat that are beneficial to human health. Research by Radiati (2016) has also demonstrated the successful production of tempeh from peanuts and mung beans, showing nutritional values comparable to soybean tempeh (Ristia et al., 2014) compared jackfruit seed tempeh with soybean tempeh and found that jackfruit seed tempeh contained higher carbohydrate levels, making it a potential substitute for staple foods.

High-quality tempeh is characterized by a firm and compact texture, uniform growth of *Rhizopus sp.* mycelium, a clean white appearance, and a pleasant, distinctive aroma and taste. Fermentation by *Rhizopus oligosporus* and *Rhizopus oryzae* plays a crucial role in developing these quality attributes through enzymatic activities that enhance nutrient availability and flavor (Kristiadi & Lunggani, 2022; Teoh et al., 2024). According to Indonesian National Standard (SNI 3144, 2009), good-quality tempeh has a moisture content of around 60–68%, high protein levels, a near-neutral to slightly acidic pH (5.5–6.5), and is free from pathogenic microbial contamination. The combination of physical, chemical, and sensory characteristics serves as key indicators of nutritious, high-quality tempeh. Therefore, this study aims to determine the optimal formulation for producing non-soy tempeh with physical, sensory, and nutritional qualities comparable to soybean tempeh. In addition, a proximate analysis was conducted to identify the nutritional composition of rain tree seed tempeh, which has not been previously reported.

In addition to its nutritional and sustainability aspects, the production of non-soy tempeh in this study is also examined from the perspective of the *halalan thayyiban* concept, which emphasizes that food should be not only permissible (*halal*) according to Islamic law but also wholesome (*thayyib*), meaning it is clean, safe, and produced with good manufacturing practices. This principle ensures that the ingredients, processing environment, and handling methods meet both religious and public health standards, making the final product suitable for diverse consumers, including Muslim communities.

The diversity of formulations and nutritional values found in non-soy tempeh can serve as a potential learning resource in science education, particularly in the topic of nutrition and food biotechnology at the junior high school level. The process of making tempeh involves biological concepts such as fermentation, the role of microorganisms (*Rhizopus sp.*), enzyme activity, and nutrient transformation, which are directly aligned with the learning objectives of biology and integrated science curricula. Engaging students in practical activities, such as comparing the nutritional content of tempeh made from different legumes (e.g., pigeon peas, durian seeds, and mung beans), promotes contextual learning, creativity, and problem-solving skills. Furthermore, utilizing locally available materials for non-soy tempeh production can help students understand the importance of food innovation, sustainability, and local wisdom in addressing real-world food security challenges (Khosyiati et al., 2024; Raya & City, 2024).

Based on the background described above, this study was designed to address three main objectives. First, it aims to formulate and analyze non-soy tempeh made from various local legumes rain tree (*Samanea saman*), leucaena (*Leucaena leucocephala*), jackfruit (*Artocarpus heterophyllus*), mung bean (*Vigna radiata*), and peanut (*Arachis hypogaea*) as alternative ingredients to soybean tempeh. Second, it seeks to determine the nutritional composition of the formulated non-soy tempeh, including energy, carbohydrates, protein, and fat. Third, this study explores the educational application of non-soy tempeh as a contextual learning resource for junior high school science education on nutrition topics, framed within the *halalan thayyiban* concept to ensure the product is nutritious, safe, hygienic, and compliant with Islamic dietary principles.

This study contributes not only to the scientific understanding of non-soy tempeh formulation and nutritional composition but also provides practical implications for promoting food diversification and sustainability through the use of local legumes. Furthermore, by integrating these findings into junior high school science learning, the research supports the development of contextual, inquiry-based learning resources aligned with *halalan thayyiban* principles. Collectively, these implications are expected to strengthen local food security, enhance students' scientific literacy, and encourage innovation in sustainable food production.

METHOD

This study was conducted in two stages. The first stage involved the formulation of non-soy tempeh and a proximate analysis of rain tree seed tempeh, while the second stage consisted of a literature review on the nutritional content of other types of non-soy tempeh leucaena seeds, jackfruit seeds, mung beans, and peanuts, followed by analyses of (1) their potential as science learning resources for junior high school (Junior High School Science) nutrition topics, and (2) their conformity with the *halalan thayyiban* food concept.

Stage I: Empirical Formulation and Proximate Analysis

The first stage was conducted at the Science Laboratory of Institut Agama Islam Negeri (IAIN) Kudus, while the proximate testing of rain tree seed tempeh was performed at the Chemistry Laboratory of Universitas Negeri Semarang (UNNES). This stage aimed to determine the feasibility and nutritional characteristics of non-soy tempeh formulations made from locally available legumes rain tree seeds (Samanea saman), leucaena seeds (*Leucaena leucocephala*), jackfruit seeds (*Artocarpus heterophyllus*), mung beans (*Vigna radiata*), and peanuts (*Arachis hypogaea*).

Each type of legume (100 g dry weight) was inoculated with 0.2 g of Rhizopus oligosporus and fermented for approximately 72 hours at a controlled temperature of 27 ± 0.5 °C with adequate aeration. The empirical approach was adapted from the conventional soybean tempeh production method using a trial-and-error refinement to achieve optimal fermentation results across different seed characteristics.

To ensure consistency and reproducibility, all formulations followed six standardized stages (Dwiatmaka et al., 2022), summarized in Table 1. Adjustments were made to soaking and boiling durations according to seed hardness, size, and moisture absorption capacity.

Table 1. Processing Steps in the Formulation of Non-Soy Tempeh

Step	Process	Description and Purpose
1	Soaking	Beans were soaked in clean water until fully expanded; water was changed periodically to maintain freshness.
2	Dehulling & Washing	Seed coats were manually or mechanically removed, and beans were rinsed until clean.
3	Boiling	Beans were boiled to soften texture, reduce microbial load, and inactivate anti-nutritional factors.
4	Cooling & Inoculation	After boiling, beans were cooled to ±30 °C, then evenly mixed with *Rhizopus* starter culture.

Step	Process	Description and Purpose
5	Packaging	The inoculated beans were wrapped in perforated plastic or leaves to facilitate air exchange.
6	Fermentation	Samples were incubated for 48–72 hours at room temperature (±27 °C) until white mycelium compactly bound the beans.

Fermentation quality was evaluated descriptively based on the uniformity of *Rhizopus* mycelium growth, texture compactness, color, and aroma. Any failed fermentations due to excessive moisture or contamination were recorded for analysis. To ensure reliability, a Completely Randomized Design (CRD) with three replications was applied to each formulation.

Proximate Analysis Procedures

Nutritional analysis focused on *rain tree seed tempeh* and followed the (SNI 3144, 2009) standard methods to determine its macronutrient composition. The analytical procedures used for carbohydrate, protein, and fat measurements are summarized in Table 2.

Table 2. Proximate Analysis Methods for Rain Tree Seed Tempeh

Nutrient Component	Analytical Method	Procedure Summary
Carbohydrates	UV–Vis Spectrophotometry	Samples were hydrolyzed and filtered; absorbance measured at 289 nm and compared against a standard calibration curve to determine carbohydrate concentration.
Protein	Kjeldahl Method	Samples underwent digestion, distillation, and titration to determine nitrogen content; total protein calculated using nitrogen-to-protein conversion factor.
Fat	Soxhlet Extraction	Fat extracted using petroleum benzene solvent; the extract was oven-dried and weighed to obtain total fat content.

The nutritional data of other non-soy tempeh types (leucaena, jackfruit seed, mung bean, and peanut) were collected from previous peer-reviewed studies for comparative purposes. Overall, the first stage established both the empirical foundation and nutritional evidence necessary for the educational and religious analysis in Stage II.

Stage II: Literature Review for Learning Resource Development and Halalan Thayyiban Analysis

The second stage consisted of a literature review aimed at (1) collecting nutritional data of various non-soy tempeh formulations from previous studies and (2) analyzing their educational and religious significance. The literature review was conducted using academic databases including Scopus, Google Scholar, ScienceDirect, and ResearchGate, covering publications between 2014–2025. The search employed the following keywords: *"science learning resources," "inquiry-based science education," "process skills approach," "contextual learning," "nutrition education," "sustainable food innovation," "non-soy tempeh," "food biotechnology," "real-world problem-solving," "environmental sustainability," "legume tempeh nutrition," "alternative tempeh formulation," "Rhizopus fermentation,"* and *"halalan thayyiban food."*

The inclusion criteria were: (1) peer-reviewed journal articles published between 2014–2025, (2) studies reporting the nutritional or biochemical composition of non-soy tempeh, and (3) publications in English or Indonesian. Articles that lacked proximate composition data or focused solely on soybean tempeh were excluded.

From an educational perspective, the nutritional and scientific aspects of non-soy tempeh were examined for their relevance to junior high school (*SMP/MTs*) science learning. Specifically, in topics related to nutrition, fermentation biology, enzyme activity, and food biotechnology. The literature analysis was used to design contextual learning approaches that connect local food innovation with classroom science concepts, supporting creativity, problem-solving, and sustainability awareness among students.

From the religious and ethical perspective, the *halalan thayyiban* analysis emphasized that food should not only be permissible (*halal*) according to Islamic law but also wholesome (*thayyib*), meaning clean, safe, and produced under good manufacturing practices (Akil et al., 2023; Azrini et al., 2024; Sungit & Abdullah, 2022). The production process emphasized cleanliness, hygiene, and safety at every stage, including thorough washing and sorting of beans, controlled soaking and boiling to prevent microbial contamination, and maintaining sterile conditions during inoculation with *Rhizopus* sp. The equipment was cleaned before and after use to avoid cross-contamination, and proper ventilation was maintained to support optimal fermentation. This ensured that the resulting non-soy tempeh met both Islamic dietary requirements (*halal*) and the standards of quality, safety, and wholesomeness (*thayyib*).

Data Analysis

Data analysis combined descriptive quantitative methods for proximate results and qualitative synthesis from literature. The integrated results were then interpreted to evaluate both (1) the nutritional and educational potential of non-soy tempeh as a contextual learning resource for science education, and (2) the alignment of production practices with *halalan thayyiban* principles emphasizing cleanliness, safety, and ethical food preparation.

RESULT AND DISCUSSION

Non-Soy Tempeh Formulation

The formulation of non-soy tempeh requires special attention to various factors that influence the success of fermentation. Each type of non-soy bean has different physical characteristics, textures, and nutritional contents, requiring adjustments in the processing stages. Therefore, the selection of raw materials, determination of composition, cleanliness of the production environment, and consistency in production stages are crucial aspects that determine the quality of the tempeh produced. In this study, four main factors were identified as key determinants of successful non-soy tempeh production.

The first factor is the selection of high-quality raw materials. Theoretically, the quality of raw materials determines the final quality of food products, including tempeh, as it affects the activity of fermentation microbes and sensory characteristics. The results of this study indicate that high-quality raw materials produce tempeh with optimal texture, aroma, taste, and color, whereas low-quality raw materials reduce product quality. This is consistent with the findings of (Hartantie et al., 2020), who stated that the quality of raw materials is directly related to the quality of the resulting tempeh.

The second factor is the formulation of composition and treatment of materials. Theory suggests that the ratio of starter culture to beans affects the growth rate of mold and the development of tempeh flavor. The results of this study show that although the ratio of starter culture is the same, each type of non-soy bean requires different soaking and boiling times due to differences in texture and hardness. These adjustments proved to yield optimal fermentation. This finding reinforces the report of Kadar et al., (2020) that the physical characteristics of beans influence the fermentation process and the quality of tempeh produced. The appropriate formulation of ingredients to produce high-quality tempeh is presented in Table 3.

Table 3. Formulation of Ingredients for Non-Soy Tempeh Production

Bean Type	**Bean Mass (g)**	**Starter Mass (g)**	**Soaking Time (minutes)**	**Boiling Time (minutes)**	**Tempeh Image**
Rain tree	100	0.2	–	120	 Figure 1. Rain tree Tempeh
Leucaena	100	0.2	–	45	 Figure 2. Leucaena Tempeh
Jackfruit Seed	100	0.2	–	30	 Figure 3. Jackfruit Seed Tempeh
Mung Bean	100	0.2	360	10	 Figure 4. Mung Bean Tempeh

Bean Type	Bean Mass (g)	Starter Mass (g)	Soaking Time (minutes)	Boiling Time (minutes)	Tempeh Image
Peanut	100	0.2	180	5	 Figure 5. Peanut Tempeh

The third factor is environmental cleanliness during inoculation. Theoretically, good sanitation prevents microbial contamination that can inhibit the growth of *Rhizopus* sp. The results of this study indicate that the use of clean equipment and water is very important, as cloudy or odorous water can carry bacteria that disrupt fermentation. This supports the view of Kustyawati et al., (2018) that the success of tempeh fermentation is highly influenced by the quality of the environment and media used.

The fourth factor is the consistency of production stages and timing. Fermentation theory states that each stage has a specific function that supports the others, so skipping or mistiming any stage can reduce product quality. The results of this study show that irregular production stages affect the texture, flavor, and overall quality of the tempeh. In the tempeh-making process in this study, several failures occurred: first, due to an insufficiently sterile fermentation area (Figure 6); and second, due to excessive water content in the beans (Figure 7). Both conditions hindered uniform mold growth, resulting in incomplete tempeh formation. These findings support the statement of Ahnan-Winarno et al. (2021) that successful tempeh production requires proper sequencing of processes, controlled fermentation time, and appropriate management of environmental conditions.

Figure 6. Failed tempeh due to an unsterile fermentation environment

Figure 7. Failed tempeh due to high moisture content

Nutritional Content of Non-Soy Tempeh

In theory, various types of legumes such as rain tree seeds, leucaena seeds, jackfruit seeds, mung beans, and peanuts have the potential to be processed into tempeh. The fermentation process with *Rhizopus* sp. can increase the bioavailability of nutrients, including protein, amino acids, and fatty acids, compared to their raw form. Fermentation can also break down complex components into forms that are more easily digested by the body, resulting in nutritional values of tempeh that can differ significantly from its raw materials.

Table 4. Nutritional Values of Tempeh

Tempeh Type	Nutritional Value per 100 g			
	Energy (kcal)	**Carbohydrates (g)**	**Protein (g)**	**Fat (g)**
Soybean (Radiati, 2016)	400	31.0	35.1	17.7
Rain tree (Proximate Analysis)	145	2.4	23.0	12.6
Leucaena (Ishartani et al., 2019)	367	32.5	46.4	5.4
Jackfruit Seed (Andaka et al., 2017)	165	36.7	4.2	0.1
Mung Bean (Radiati, 2016)	345	62.9	22.2	1.2
Peanut (Radiati, 2016)	606	16.1	28.5	47.5

The results of this study, as shown in Table 4, indicate that the highest energy value per 100 grams was found in peanut tempeh, at 606 kcal, which is higher than that of soybean tempeh. This high energy content is mainly due to the high fat content in peanuts. Leucaena and mung bean tempeh had nearly the same energy content, while rain tree seed and jackfruit seed tempeh had the lowest energy values among all non-soy tempeh types. These findings suggest that the energy content of non-soy tempeh is highly dependent on the nutrient composition of the beans used. The high fat in peanuts significantly contributes to their energy content, whereas rain tree and jackfruit seeds, which are low in fat, produce lower energy values. This is consistent with the statement of (Yang et al., 2023) that the energy content of food is strongly influenced by its macronutrient composition, particularly fat, which provides the highest energy per gram compared to protein or carbohydrates.

In terms of carbohydrate content (Table 4), the results showed that mung bean tempeh had the highest level, at 62.9 g/100 g, almost twice that of soybean tempeh, which contains 32 g/100 g. Leucaena tempeh also had a carbohydrate content comparable to soybean tempeh, whereas rain tree seed tempeh had the lowest carbohydrate value. This difference can be interpreted as the result of variations in starch and fiber types in the seeds, as well as the effect of fermentation, which breaks down some carbohydrates into other compounds. These findings are in line with the report of Adebo et al. (2022) that the fermentation process in tempeh not only increases protein availability but can also modify carbohydrate structure into simpler forms, thus improving digestibility.

Regarding protein content (Table 4), the results showed that leucaena tempeh had the highest level, at 46.4 g/100 g, higher than soybean tempeh, which contains only 35.1 g/100 g. The lowest protein value was found in jackfruit seed tempeh, at 4.2 g/100 g. This indicates that leucaena has the potential to serve as an alternative plant-based protein source to replace soybeans. The increase in protein during fermentation is due to the proteolytic activity of *Rhizopus oligosporus* and *Rhizopus oryzae*, which break down complex proteins into amino acids. This is consistent with the study of Zwinkels et al., (2023), which explained that molds utilize seed proteins as a nitrogen source for their growth, thereby increasing the measurable protein content in tempeh.

For fat content (Table 4), the results showed that peanut tempeh had the highest value, at 47.5 g/100 g, while the lowest was found in jackfruit seed tempeh, at 0.1 g/100 g. Rain tree, leucaena, jackfruit seed, and mung bean tempeh had lower fat levels than soybean tempeh. This can be explained by the variation in fat content among the different types of seeds. During fermentation, *Rhizopus* produces lipase enzymes that break down fat into triglycerides and free fatty acids, which are then used by the mold as a carbon source. This finding is supported by Gullian Klanian & Osorio Di Gianluca (2024), who identified linoleic acid as the dominant fatty acid in tempeh, highlighting the important role of fermentation in modifying fat composition.

The nutritional variation found among non-soy tempeh types reflects the natural differences in nutrient composition of the legumes and the biochemical changes induced by fermentation. Only rain tree tempeh underwent proximate laboratory analysis in this study, while the nutritional data of other non-soy tempeh types were obtained from previous studies, indicating that further research is needed to validate these comparisons using standardized analytical methods.

Halalan Thayyiban Perspective in Non-Soy Tempeh Production

Islam teaches the principle of *halalan thayyiban*, which refers to the consumption of food that is not only *halal* (permissible according to Islamic law) but also *thayyib* (good, healthy, and safe). Surah 'Abasa verse 24 *"Then let mankind look at his food"* emphasizes the importance of paying attention to the quality and wholesomeness of the food consumed. This principle addresses not only the legality of Sharia but also the quality, hygiene, and nutritional benefits of food for health (Astiwara, 2025; Salamon, 2021). The application of the halalan thayyiban concept in learning materials does not only emphasize the halal status of food but also highlights safety, health, and hygiene throughout the processing stages, making it highly relevant to science education (Raida & Immadudin, 2025).

The production of non-soy tempeh in this study adheres to these principles, considering three dimensions of halal: halal in substance (dzat), halal in acquisition, and halal in processing (Hasanah et al., 2021). Halal in substance means that the food ingredients are inherently permissible for consumption under Islamic law. All raw materials in this study rain tree seeds, leucaena seeds , jackfruit seeds, mung beans, peanuts, and *Rhizopus* sp. are plant-based ingredients that are halal to consume, as stated in Surah Al-Baqarah: 168, *"Eat of what is lawful and good on the earth".* According to Rohmah (2023), plant-based ingredients generally do not contain any haram elements unless contaminated by impure or harmful substances. Surah 'Abasa: 24–32 also shows that grains are among the sustenance provided by Allah to humans and livestock, affirming their halal status in substance.

Halal in acquisition means that food ingredients are obtained through lawful means. Surah Al-Baqarah: 275 affirms that Allah has permitted trade and prohibited usury. All materials in this study were purchased from traditional markets and supermarkets in Kudus Regency through lawful transactions, without fraud, theft, or practices that harm others. According to Kashim et al. (2015), the halal status of a product can change to haram if the acquisition involves prohibited elements, even if its substance is halal. By ensuring that the acquisition process complies with Sharia, this study safeguards the halal status of the ingredients from the perspective of transaction legality.

Halal in processing refers to the method of preparing food to maintain its compliance with Sharia. In this study, all stages of tempeh production—sorting, cleaning, soaking, boiling, cooling, inoculating, and fermenting—were carried out without involving any impure or haram substances, and with clean, contamination-free equipment. According to Miswanto & Musaffa (2023), the principle of halal processing requires that every production stage meets hygiene standards and does not alter the halal status of raw materials. For example, fermentation in tempeh production using *Rhizopus* sp. produces amino acids, peptides, and simple sugars that are safe, unlike grape fermentation, which produces intoxicating ethanol. Furthermore, the application of *Good Manufacturing Practices* (GMP) and *Sanitation Standard Operating Procedures* (SSOP) supports the *thayyib* principle, meaning that food must be safe, nutritious, and fit for consumption (Sirait et al., 2022)

From the *thayyib* perspective, this study emphasizes cleanliness, safety, and adequate nutritional value. This includes cleaning raw materials, controlling boiling time to prevent harmful microbial growth, using sterile equipment, and ensuring proper ventilation during fermentation (Mishra et al., 2024).

The integration of these three halal aspects with the *thayyib* principle not only ensures compliance with Islamic law but also enhances the quality, safety, and nutritional benefits of the resulting non-soy tempeh. In the context of science education, introducing this concept can help students understand that food should be evaluated not only based on its nutritional content but also on its safety, cleanliness, and ethical production practices.

Science Learning Resources for Junior High School (*SMP/MTs*) Science Nutrition Topics

Learning resources are components consisting of materials and conditions designed and provided to support the learning process for students, either individually or in groups (Suhirman, 2018). The benefits of learning resources include providing direct opportunities to support student development, expanding knowledge during learning activities, offering deeper understanding, and stimulating students to develop reasoning skills. In the context of learning theory, Andrews et al., (2023) emphasize that effective learning resources are those capable of connecting material with students' real-life experiences, thereby fostering meaningful learning. Learning resources should also help students understand concepts through observation, experimentation, and discussion, so that learning becomes more contextual and meaningful (Nadilla & Raida, 2025).

The integration of the *halalan thayyiban* concept into learning materials does not only emphasize the halal status of food but also highlights safety, health, and hygiene throughout the processing stages, making it highly relevant to science education. This concept strengthens the link between science learning and real-world application, particularly when students explore food-related topics that promote ethical and sustainable practices (Raida et al., 2025).

Learning resources linked to the concept of Natural Sciences can help students conduct research through physics, chemistry, or biology approaches, resulting in concepts that can explain natural phenomena in their surroundings (Ruf et al., 2019). According to the Ministry of Education and Culture, science education is oriented toward research and action to help understand the natural environment. Science learning is a process of engaging students with their surrounding environment to develop cognitive, psychomotor, and social skills (Hartman & Squires, 2024). This aligns with Adeyele (2023), who states that inquiry-based science learning positions students as young researchers actively exploring and constructing their own knowledge. This research is specifically integrated into the junior high school science subject (IPA), particularly the nutrition topic in the human digestive system where students are required to identify nutritional values in food and relate them to human body functions.

Nutrition material is part of the junior high school science curriculum, requiring students to identify and analyze the nutritional values in food and relate them to the functions of the human digestive system. The nutritional values studied include energy, carbohydrates, protein, and fat. The Merdeka Curriculum recommends the inquiry learning model and process skills approach in teaching. In the inquiry learning model, students are given broad opportunities to make observations and conduct experiments, guided by the teacher to build concepts based on their existing knowledge miliki (Kemendikbudristek, 2022). This is supported by Mandalawi (2024), who states that inquiry learning effectively builds critical thinking and problem-solving abilities; however, this study did not assess improvements in students' critical, creative, or collaborative thinking skills, nor use performance rubrics or a control class for comparison.

This research can serve as a learning resource for junior high school nutrition topics. Through this study, students can apply inquiry learning with a process skills approach. There are six inquiry skills that can be developed: observing, questioning/predicting, planning and conducting investigations, processing and analyzing data, evaluating and reflecting, and communicating results (Kemendikbudristek, 2022). According to Nur'ariyani et al. (2023), these six skills are the foundation of science learning that enables students to think and act like scientists. In this study, these skills were not evaluated quantitatively but were theoretically mapped to each stage of the tempeh-making activity to illustrate its pedagogical potential.

Observing phenomena or events is the initial stage of inquiry that continues to the next stages. At this stage, students carefully observe phenomena, take notes, and compare information to identify similarities and differences (Kemendikbudristek, 2022). In this research, students can be directed to analyze the phenomenon of soybean scarcity and find solutions through food diversification, such as replacing soybeans in tempeh with non-soybean seeds such as rain tree, leucaena, jackfruit seeds, mung beans, and peanuts. This aligns with Simeonova (2024), who emphasizes the importance of connecting lesson material to real-world contexts to make learning more relevant and meaningful for students.

The next stage is questioning and predicting, where students are encouraged to ask questions related to their observations (Kemendikbudristek, 2022). Students connect prior knowledge with new information to predict outcomes based on cause-and-effect relationships (Wisudawati & Sulistyowati, 2017). At this stage, students formulate hypotheses as solutions to the problem of soybean scarcity. This aligns with Bao et al. (2022), who highlight that the ability to ask investigative questions and make scientific predictions is a key feature of scientific thinking.

After that, students plan and arrange operational steps based on appropriate references to test their hypotheses. Experiments can be conducted by making non-soy tempeh, starting from determining the tools, ingredients, and procedures, either by following the formulation in this research or modifying the types of seeds used. Variations can be done heterogeneously or based on findings from other studies. This is consistent with Smadi & Al-friehat (2017), who emphasize the importance of students' active roles in designing, developing, and presenting authentic learning products as part of the learning process.

At the processing and data analysis stage, students organize the obtained information, interpret the data honestly, and draw conclusions (Kemendikbudristek, 2022). In this research, students can analyze the experimental results of making non-soy tempeh based on soaking and boiling times for various seed types. These findings are then linked to the quality of the resulting tempeh. This stage aligns with Chusni et al., (2022), who state that analysis is a higher-order thinking skill needed to differentiate, classify, and identify relationships between data.

The evaluation and reflection stage allows students to assess whether the process aligns with the initial objectives, review the learning experience, and identify improvements for the future (Kemendikbudristek, 2022). This reflection may include understanding the importance of skills in making non-soy tempeh for future food sustainability. This is reinforced by Kolb's theory, which states that critical reflection on experience allows students to internalize learning and apply it to real life (Raida & Immadudin, 2025; Sadat et al., 2022).

The final stage is communicating results, where students present their findings orally or in writing, using visual media such as charts, diagrams, and (Kemendikbudristek, 2022). After completing the experiment, students can create posters to present in class or publish on social media. This aligns with the statement Wisniewski & Zierer (2021) that sharing results with others through open communication strengthens understanding, as students receive feedback and opportunities to revise ideas based on others' perspectives.

By utilizing this research as a learning resource, science learning in junior high school nutrition topics can be more contextual, applicable, and oriented toward solving real-world problems. Integrating inquiry learning with a process skills approach enables students to actively engage from observing phenomena, formulating questions, conducting investigations, to communicating results. The activity of making non-soy tempeh not only provides practical experience in understanding nutrition concepts but also instills awareness of the importance of sustainable food innovation. Thus, the learning process does not stop at conceptual understanding but provides opportunities for students to practice critical, creative, and collaborative thinking skills during inquiry activities. However, this study did not measure these skills directly, and no assessment instruments (such as observation sheets or performance rubrics) were used to compare learning outcomes with a control class. The link to those skills is based on theoretical alignment with the inquiry learning model.

Limitations of this Study

This study has several limitations that should be considered in interpreting the results and planning future research. First, proximate analysis was conducted only on rain tree seed tempeh, while the nutritional data for the other non-soy tempeh types (leucaena, jackfruit seed, mung bean, and peanut) were obtained from previous studies, and therefore do not reflect results analyzed under the same laboratory conditions. Second, some raw materials, such as rain tree seeds and leucaena, are seasonal and not available year-round, which may limit reproducibility and the feasibility of large-scale production. Third, this study did not conduct allergenicity or food safety assessments, even though several legumes used (such as peanuts and leucaena) are known to have higher allergenic potential compared to soybeans. Fourth, the integration of non-soy tempeh production into science learning was mapped only theoretically; the study did not implement classroom testing or measure students' inquiry, critical, creative, or collaborative skills using observation rubrics or a control group.

These limitations provide opportunities for future research, including performing complete proximate analyses on all types of non-soy tempeh, evaluating food safety and sensory acceptance, and implementing the activity in classroom learning to assess its effectiveness in improving students' learning outcomes and scientific skills.

CONCLUSION

This study successfully formulated non-soy tempeh using five types of local legumes rain tree seeds, leucaena, jackfruit seeds, mung beans, and peanuts as feasible alternatives to soybean tempeh. The proximate analysis and supporting nutritional data show that each non-soy tempeh type has different nutritional characteristics: leucaena tempeh contains the highest protein, peanut tempeh has the highest fat and energy, while rain tree seed tempeh offers moderate protein with low carbohydrate content. These findings demonstrate that non-soy legumes have the potential to serve as alternative protein-rich fermented foods. Additionally, non-soy tempeh can be applied as a contextual learning resource in junior high school science, particularly on nutrition topics, by integrating the halalan thayyiban principles to ensure that the product is nutritious, safe, hygienic, and aligned with Islamic dietary values.

Recommendations

Based on the findings and limitations of this study, several recommendations can be made. Future research should conduct a complete proximate analysis on all types of non-soy tempeh to obtain nutritional data under the same laboratory conditions. In addition, food safety evaluation, including allergenicity testing, is needed, particularly for legumes such as peanuts and leucaena that have higher allergenic potential. Research on raw material availability and feasibility studies for large-scale production is also necessary, considering that some legumes used in this study may be seasonal. For educational implementation, further studies should apply the non-soy tempeh project in actual classroom settings using observation rubrics, performance assessments, or comparison with a control class to measure its impact on students' critical, creative, and collaborative thinking skills. Finally, researchers and educators are encouraged to develop instructional materials or learning modules based on non-soy tempeh production to support contextual and inquiry-based science learning in the nutrition topic.

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