



Lotus Seed Tempeh Innovation to Increase Local Food Availability Through Sustainable Alternatives

Nur Evirda Khosyati¹, Rizal Justian Setiawan^{2,5*}, Khakam Ma'ruf³, Nur Azizah⁴

¹Culinary Technology Education, Faculty of Engineering, Yogyakarta State University, Yogyakarta, Indonesia

²Industrial Engineering and Management, College of Engineering, Yuan Ze University, Republic of China

³Mechanical Engineering Education, Faculty of Engineering, Yogyakarta State University, Yogyakarta, Indonesia

⁴International Public Health, School of Public Health, China Medical University, Republic of China

⁵Management, Faculty of Economics, Universitas Terbuka, Jakarta, Indonesia

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*Correspondence:
Rizaljustiansetiawan99@gmail.com

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Abstract. Limited food availability poses a significant challenge in keeping pace with rapid population growth. The impact is seen in the 30.8% of children under five in Indonesia who are stunted, signaling a serious nutritional problem. To solve this problem, it is important to find solutions that are healthy and affordable for the community. One popular, affordable and versatile Indonesian food is tempeh. However, the high consumption of tempeh poses a problem of domestic soybean availability for producers, prompting the search for alternative ingredients in tempe production. Lotus seeds (*Nymphaea* sp.) were identified as a potential substitute for soybeans in making tempeh. Chouaibi's research in 2012, lotus seeds contain 1.05% ash, 32.92% oil, 19.11% protein, 40.87% total carbohydrate and 6.05% moisture. This study tried to use lotus fruit seeds as raw material for tempeh, while measuring public response to this product regarding color, price, taste, and aroma. Based on the results of proximate analysis, the best treatment in the processing of lotus seed tempeh was boiling twice for 15 minutes each, because it can produce a high amount of protein, namely 37.38%. The results showed that tempeh from lotus fruit seeds has similar characteristics to soybean tempeh, the process of making tempeh from lotus fruit seeds is relatively similar to soybean tempeh, although further research is needed to optimize the use of lotus. It has the potential to increase the economic value of lotus seeds to be a more meaningful alternative in food fulfillment in Indonesia.

Keywords: Tempeh, Local Food, Lotus Seeds

Abstrak. Ketersediaan pangan yang terbatas menjadi tantangan signifikan dalam mengimbangi pertumbuhan populasi yang pesat. Dampaknya terlihat pada 30,8% anak balita di Indonesia yang mengalami stunting, menandakan permasalahan gizi yang serius. Untuk mengatasi masalah ini, penting ditemukan solusi yang sehat dan terjangkau bagi masyarakat. Salah satu makanan khas Indonesia yang populer, terjangkau, dan serbaguna adalah tempe. Namun, konsumsi tinggi tempe menimbulkan permasalahan ketersediaan kedelai dalam negeri bagi produsen, mendorong pencarian bahan alternatif dalam pembuatan tempe. Biji Buah Teratai (*Nymphaea* sp.) diidentifikasi sebagai pengganti potensial kedelai dalam pembuatan tempe. Penelitian Chouaibi pada tahun 2012, biji teratai mengandung 1,05% abu, 32,92% minyak, 19,11% protein, 40,87% karbohidrat total dan 6,05% kelembaban. Penelitian ini mencoba menggunakan biji buah teratai sebagai bahan baku untuk tempe, sambil mengukur tanggapan masyarakat terhadap produk ini terkait warna, harga, rasa, dan aroma. Berdasarkan hasil analisis proksimat, perlakuan terbaik dalam pengolahan tempe biji teratai adalah perebusan sebanyak dua kali masing-masing selama 15 menit, karena dapat menghasilkan jumlah protein yang tinggi yaitu 37,38%. Hasil penelitian menunjukkan bahwa tempe dari biji buah teratai memiliki karakteristik mirip tempe kedelai, proses pembuatan tempe dari biji buah teratai relatif mirip dengan tempe kedelai, meskipun perlu penelitian lanjutan untuk mengoptimalkan penggunaan teratai. Ini berpotensi meningkatkan nilai ekonomis teratai menjadi alternatif yang lebih berarti dalam pemenuhan pangan di Indonesia.

Kata kunci: Tempe, Pangan Lokal, Biji Teratai

INTRODUCTION

Food is one of the primary sources of human needs to fulfill the nutritional and nutritional needs of the body (Macdonald *et al.*, 2017 ; Arun *et al.*, 2021). However, in reality currently, the increase in the amount of food available is very minimal compared to the very high population growth (Suriadikusumah, & Herdiansyah, 2018). In terms of basic food needs, there is a gap between the supply and demand for rice, corn and soybeans at the national and regional levels from 2000-2019. The results show that the increase in production is less than population growth (Pudjianto, & Syawie, M. 2015). Based on FAO 2020 data, there are around 30.8% of children under five in Indonesia who experience stunting (stunted growth), this is due to several things such as the influence of food consumed that is insufficient or even non-nutritious (FAO, 2020). So an appropriate solution is needed to solve this problem, which does not produce new problems.

Stunting is a condition of impaired growth in children due to chronic malnutrition and repeated infections over a long period (Scheffler *et al.*, 2019). The causes are multifactorial, including insufficient nutrient intake, infectious diseases, poor environmental conditions, and inadequate parenting practices. Therefore, efforts to address stunting require cross-sector collaboration, such as improving access to nutritious food, improving environmental sanitation, optimizing maternal and child health services, and educating parents on good parenting practices (Askar *et al.*, 2023). Nevertheless, meeting nutritional needs remains one of the important components in overcoming stunting, starting from the food consumed by pregnant women (Dewey, 2016). Lotus seed tempeh has the potential to become an affordable, nutritious food source for the community, especially for pregnant women, and can be an alternative food menu. The protein and other nutrient contents in lotus seed tempeh can contribute positively to children's growth and development. However, lotus seed tempeh must be integrated with other nutritional interventions and supported by other factors such as access to clean water, immunizations, and adequate health care.

An alternative solution to solving food problems, especially in Indonesia, is to create food innovations that are healthy and affordable and whose raw materials are easy to obtain by all levels of society (Karinisari, 2022 ; Bigliardi & Galati, 2013). One of the authentic Indonesian foods that is easy to obtain, affordable and economical for all levels of society is tempeh (Babu *et al.*, 2009 ; Harti *et al.*, 2014), tempeh is a typical Indonesian food that is well known abroad (Cemapaka *et al.*, 2018). The level of tempeh consumption in Indonesia has reached quite high figures. Data from the Central Statistics Agency records that the average consumption of tofu and tempeh per capita in Indonesia is 0.304 kilograms (kg) every week in 2021. This figure is an increase of 3.75% compared to the previous year which amounted to 0.293 kg every week (BPS, 2021). This high level of tempeh consumption makes it a problem for tempeh makers to increase their production while they are faced with the problem of domestic demand for soybeans (Mani, & Ming, 2017) so there is a need for alternative ingredients to replace soybeans for making tempeh.

A raw material that can be used as a substitute for soybeans is Lotus Seeds (Nymphaea sp). In Indonesia lotuses are often found growing wild in swamps, lakes, and ponds (Hariyanto *et al.*, 2017). In general, lotuses are sought after by ornamental plant lovers because of their natural, exotic and decorative appearance so that they can make the garden more beautiful and soothing to the eye (Lin *et al.*, 2019), so in the end it will be very useless if it is only used as an ornamental and medicinal plant. There are many swamp and rural areas in Indonesia where lotus plants can be found. These plants can be used as alternative food ingredients that are relatively affordable and easy to produce. According to Chouaibi's research in 2012, lotus seeds contain 1.05% ash, 32.92% oil, 19.11% protein, 40.87% total carbohydrates and 6.05% moisture. Although not as much as soybeans, which are often used as the main ingredient for making tempeh, lotus seeds can still be a great substitute for making food, especially tempeh. In this research article, researchers made tempeh using lotus seeds as a substitute for soybeans and conducted trials regarding public responses to the color, price, taste, and aroma of lotus seed tempeh. The selection of lotus seeds as an alternative to soybeans in tempeh production is based on their potential as a local food source that has not been optimally utilized. The utilization of lotus seeds is in line with the research objective, which is to explore alternative food ingredients that are rich in nutrients to overcome the problems of soybean substitution and stunting. By utilizing abundant local resources, it is hoped that lotus seed tempeh can become an affordable, nutritious food solution for the community.

METHOD

MATERIALS

The main ingredient used in this research was lotus seeds (Nymphaea sp.) obtained from a specific location at Jln. Wiyoro Lor gang Flamboyan No.97, Banguntapan, Bantul. In addition, a tempeh starter inoculum packaged in two types of packaging, banana leaves and plastic, was used to support the fermentation process in making lotus seed tempeh. This research on making lotus seed tempeh was conducted at the Food Technology Education Laboratory, Yogyakarta State University. This laboratory has complete facilities for processing and developing food products, including equipment for sterilization, fermentation, and analysis of food composition. The controlled research environment enables the production process of lotus seed tempeh to be carried out with high hygienic standards.

TOOLS

To conduct this research, several simple tools were used, such as knives for ingredient preparation, bowls and pots for the fermentation process, a strainer for processing, stationery for note-taking, as well as a stove, spoon, scale, and camera for experimentation, measurement, and documentation purposes.

RESEARCH DESIGN

This research employed an experimental laboratory method. The research stages included the preparation of raw materials and tool, the production of tempeh from lotus seeds, and the fermentation and packaging processes. Afterwards, a series of trials were conducted on the lotus seed tempeh, involving public feedback on color, taste, aroma, appearance, and recommended product pricing to comprehensively evaluate consumer responses.

RESEARCH STAGES

Stages of Research Implementation

The research stages in this study consisted of three stages consisting of field study, manufacturing, and testing. The detailed steps can be seen in [Figure 1](#). Further explanations for the three stages are as follows:

1. Field Study Process of Tempeh Production Before starting the research, a field study of tempeh production was conducted for two days at a tempeh maker's place on Jln. Wiyoro Lor, Flamboyan Alley No. 97, Banguntapan, Bantul. The goal was to study the traditional tempeh-making procedure as a reference for this research.
2. Process of Making Lotus Seed Tempeh After understanding the tempeh-making procedure, the process of processing lotus seeds into tempeh was carried out. This process of making lotus seed tempeh was carried out at the Food Laboratory of the Food Technology Education Study Program, Yogyakarta State University, following the steps previously learned.
3. Testing of Lotus Seed Tempeh in the Community After the lotus seed tempeh was successfully produced, the tempeh was fried and tested with the community. In this test, an evaluation of consumer responses to the color, taste, aroma, appearance, and recommended price of the lotus seed tempeh product was conducted. This response is very important to assess product acceptance in the community and its potential for further development.

Analysis Method

In addition, in this research, proximate analysis (Cempaka *et al.*, 2018) was also carried out to determine the nutritional composition of lotus seed tempeh, as well as sensory evaluation by trained panelists to assess the organoleptic characteristics of the product more deeply (Setyaningsih *et al.*, 2014). Production cost calculations were also performed to estimate the economic feasibility of making lotus seed tempeh.

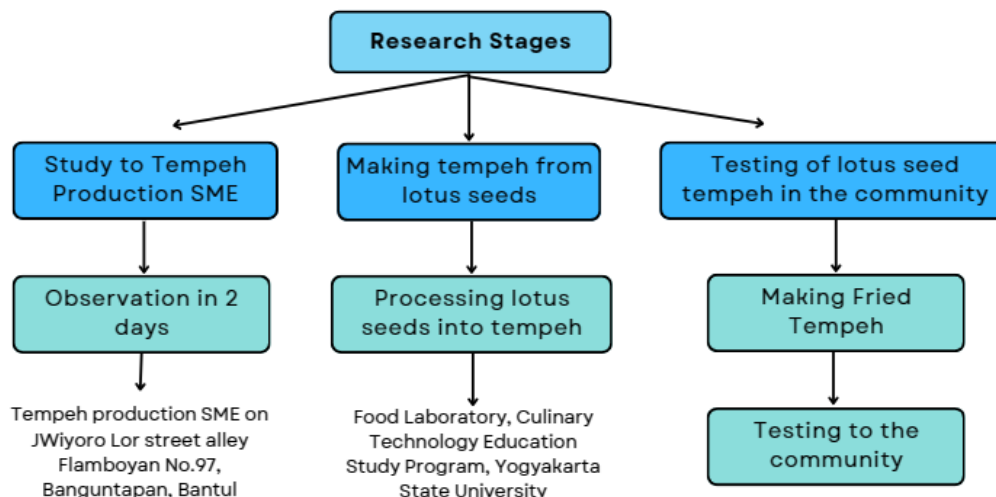


Figure 1. Stages of Lotus Seed Tempeh Research

RESULTS AND DISCUSSION

A. Process for Making Lotus Seed Tempeh

The process of making lotus seed tempeh was similar to making regular tempeh, the only difference being the replacement of raw materials and the length of the steaming process for the raw materials (lotus seeds). This is done in order to find a recipe measurement suitable for lotus seed tempeh and to meet consumer product preference levels. In this experiment, 250 grams of lotus seeds were soaked first using vinegar with a pH of around 4-5. Then in this experiment, 4 treatments were tested, namely (A1) the soybeans were soaked for 3 hours and steamed for 10 minutes, (A2) the soybeans were soaked for 3 hours and steamed for 15 minutes, (A3) the soybeans were soaked for 3 hours and steamed for 20 minutes, and (A4) boiling was carried out twice, for 35 minutes before soaking for 24 hours and after soaking, it was boiled again for 20 minutes. The detail pictures of the process can be seen in [Figure 2](#).

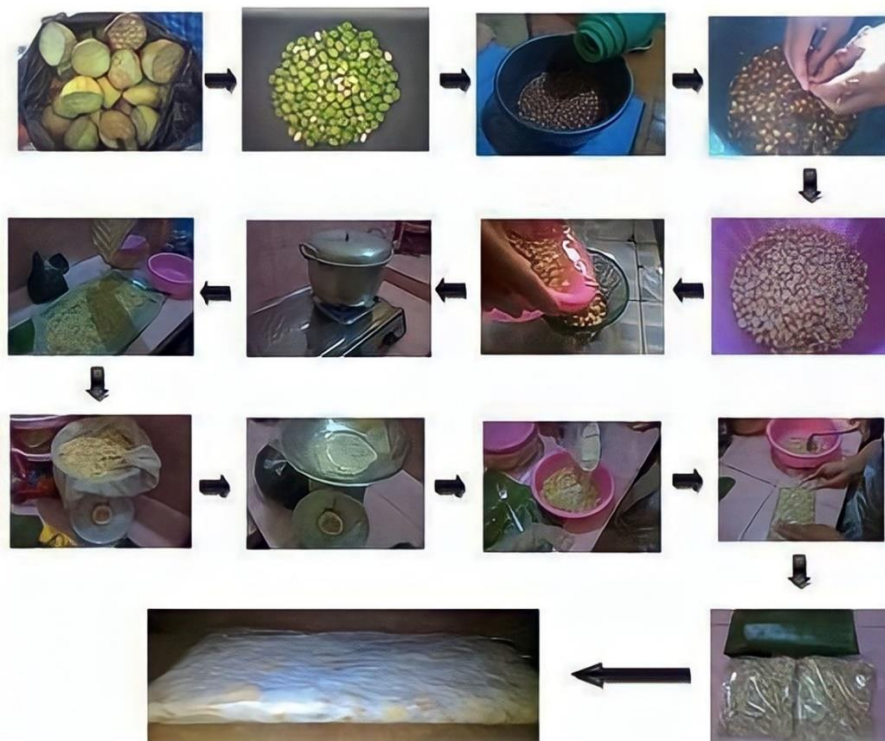


Figure 2. Process of Making Tempeh from Lotus Seeds

1. Preparation of Raw Materials and Tools

After the stage of preparing ingredients and equipment, the next process in making tempeh from lotus seeds involves important steps. This process includes soaking and steaming for treatments A1, A2, A3, and A4, separating the outer skin of the lotus seeds, grinding, mixing with tempeh starter (*ragi*), and packing the mixture into containers for the fermentation process. This step requires the use of basic equipment such as a gas stove for steaming, pots as containers, knives for ingredient preparation, a scale for measuring proportions, and bowls.

2. Fermentation

After each treatment was weighed at 250 grams, the lotus seeds were mixed with tempeh starter (*ragi*) with a ratio of 1 kg lotus seeds mixed with 1 gram of starter. This ratio was equalized with the typical ratio of adding starter obtained during field studies at tempeh makers. The lotus seeds and starter were mixed evenly. Then the lotus seeds that had gone through the starter process entered the evaporation process at 25°C, after which they were inoculated with packaging and fermentation process for 2x24 hours using *Rhizopus sp.* spores, with a ratio of 0.75% (w/w). The process of making lotus fruit tempeh can be seen in detail in [Figure 2](#).

3. Packaging

After the tempeh is weighed, the lotus seeds are mixed with yeast (fermentation) in the ratio of 1 kg of lotus seeds mixed with 1 gram of yeast. This comparison is equated with the ratio of yeast feeding in general that is obtained when conducting field studies on tempeh craftsmen. Lotus seeds and yeast are mixed evenly. Then the lotus seeds that have gone through the fermentation process enter the packaging and fermentation process for 2x24 hours. After the starter process and inoculation, the lotus seed tempeh was then packaged in plastic bags measuring 15 cm x 22 cm with a thickness of around 1.5 cm. This was beneficial in supporting the growth of the mold. The process of making lotus fruit tempeh can be seen in detail in [Figure 2](#).

B. Proximate Analysis

There were four experiments tested in proximate analysis, the first experiment (A1) was boiling Lotus seeds for five minutes. The second experiment (A2) is boiling for 10 minutes on Lotus seeds and the third experiment (A3) is boiling for 15 minutes on Lotus seeds. Meanwhile, in the fourth experiment (A4), boiling was conducted twice for 15 minutes.

In [Table 1](#), tempeh in lotus seeds has a high protein content of around 37.38% when boiled twice. This was the best experiment produced in the experiment. Meanwhile, it can be seen that there is no significant difference, namely the value ($P < 0.05$) in experiments A1, A2, and A3, except that during the steaming process there were different samples. Apart from that, in all the experiments on tempeh that had been conducted, it was found that compared to peas, the protein content of lotus seed tempeh was higher. As for the results of research on fat, there were no significant differences, only in the A2 sample experiment the levels were higher, namely around $7.27\% \pm$ (Table 1). In general, the water content of tempeh ranges from 53.59 ± 27 to $75.60 \pm 0.07\%$, this was also related to the metabolic reactions of microorganisms during the fermentation process, and also influences the nutritional value of the ingredients. food increases or decreases. The process of making tempe itself generally has three supporting factors, including the raw materials used (grains), the reaction of microorganisms, and the environmental conditions in which the microorganisms develop.

Table 1. Composition of Tempeh Proximate Test (%w/w, dry weight)

Experiment	Water (wet basis)	Ash	Fat	Protein	Carbohydrate
A1	53.59 ± 3.27^b	3.07 ± 0.34^b	5.03 ± 0.78^b	23.31 ± 1.03^b	64.58 ± 2.55^b
A2	60.81 ± 4.75^b	4.29 ± 0.51^b	7.27 ± 0.35^b	26.10 ± 5.10^b	58.33 ± 2.96^b
A3	60.57 ± 6.00^b	3.87 ± 0.47^b	6.13 ± 0.72^b	29.11 ± 1.75^{bc}	56.90 ± 3.73^b
A4	75.60 ± 0.07^c	3.48 ± 0.03^c	4.60 ± 0.48^c	37.38 ± 0.43^c	52.55 ± 0.68^b
Lotus Seeds	9.17 ± 0.53^a	3.40 ± 0.21^a	5.57 ± 1.24^a	17.98 ± 3.68^a	70.76 ± 3.17^a

After going through the 36-hour fermentation process for lotus seed tempeh, the protein and fat content increased compared to the raw materials, except for carbohydrates. Previous research conducted by Wickramasinghe (2017) also showed an increase in the nutrient content of lupin tempeh after fermentation for 48 hours, due to the biochemical reactions with oligosaccharides, free sugars, and polysaccharides during the fermentation process. Various other studies that have been conducted also explain that the manufacturing process of tempeh, seed size, pH, and fermentation time can affect the nutritional level of the resulting tempeh (Wickramasinghe, 2017). For example, the boiling process can cause the loss of many nutrients such as ash and fat which are more soluble in boiling water compared to using the steaming method (Kouakou *et al.*, 2018). However, it's not just that, the multi-step processing treatment can better preserve the proximate substances compared to the two previous methods, especially the increase in protein content in treatment A4, which is $\pm 37.38\%$ from 100 grams of tempeh. In addition, in treatment A3, there was an increase in protein levels, although not very significant. So by carrying out these 4 treatments, it was found that A4, with the method of boiling twice, namely 35 minutes before soaking for 24 hours and after soaking, it was boiled again for 20 minutes, resulted in the best functional food product physiochemically and enzymatically. Furthermore, the two-time boiling process is more effective than the single steaming modification.

C. Community Response to Lotus Seed Tempeh

Community response is the reaction, feedback, or input given by a group of people or a particular community towards something, an event, a product, a service, or a change that occurs in their environment. By identified and analyzed the community response, we knew the extent of acceptance or rejection towards a product or change, as well as identify areas that need improvement or should be maintained. This response is very important to ensure the sustainability and success of an initiative within a community.

1. Testing Lotus Seeds Seed Tempeh

After the lotus seed tempeh is ready, it is then fried ([Figure 3](#)) and tested in the community, by filling out a questionnaire to assess and provide price recommendations and comments. The respondents who fill out the questionnaire are people with the following criteria: Respondents being tested are not hungry, and do not have disorders of smell, sight, and taste. Meanwhile, the number of respondents is 40 because it shows that for exploratory research, a sample size of 40 people is sufficient to estimate Cronbach's alpha which is accurate enough to indicate the reliability of the scale used, this number is a sufficient number to represent the population.



Figure 3. Comparison before and after fried lotus seeds tempeh

2. Community Response

The following are responses from 40 respondents who tested tempeh from lotus seeds. This testimonial provides a real picture of the public's perception of this product and can be seen in the following table, which includes an evaluation of the color, taste, aroma, appearance, and recommended price of the lotus seed tempeh product.

Table 2. Opinions Regarding Lotus Seeds Tempeh

No.	Specification	Response	Number of Respondents
1.	Color	Brown or tawny	40 Respondents
2.	Taste	Savory, delicious, and softer than ordinary tempeh	38 Respondents
		It tastes bitter at the end after you finish eating it	2 Respondent
3.	Aroma	Same as the typical aroma of tempeh in general	37 Respondents
		Pungent	3 Respondent
4.	Appearance	Interesting	33 Respondents
		Same as ordinary tempeh from soybeans	7 Respondents
5.	Price	Below the normal price, which is an average of	34 Respondents
	Recommendations	IDR 1,500 per pack	
		The same price as regular soybean tempeh	6 Respondents

In Table 2, results have been obtained from the assessment of 40 respondents regarding the indicators in tempeh from lotus seeds. Discussion regarding the results of the questionnaire that has been conducted.

- a) Out of the 40 respondents, all stated that lotus seed tempeh and soybean tempeh share the same color, which is brown or brownish-yellow.
- b) 38 out of 40 respondents stated that lotus seed tempeh was savory, delicious, and softer than regular tempeh, while 2 respondent felt that the taste of lotus fruit tempeh tasted bitter at the end after eating it.
- c) 37 out of 40 respondents said that the fragrance of lotus seed tempeh was the same or exactly similar to regular tempeh (soybean tempeh), while 3 person felt it was pungent and the other person felt it was close to the typical tempeh fragrance.
- d) 33 out of 40 respondents stated that the appearance of lotus seed tempeh was more interesting than ordinary tempeh because the lotus seeds looked lined up and were pleasing to look at, while 7 other people felt that the appearance of lotus fruit tempeh was the same as ordinary tempeh.
- e) 34 out of 40 respondents recommended that the price of lotus seed tempeh be below the normal price with an average of IDR1,500/pack and 6 people recommended that the price be the same as the price of regular soybean tempeh.

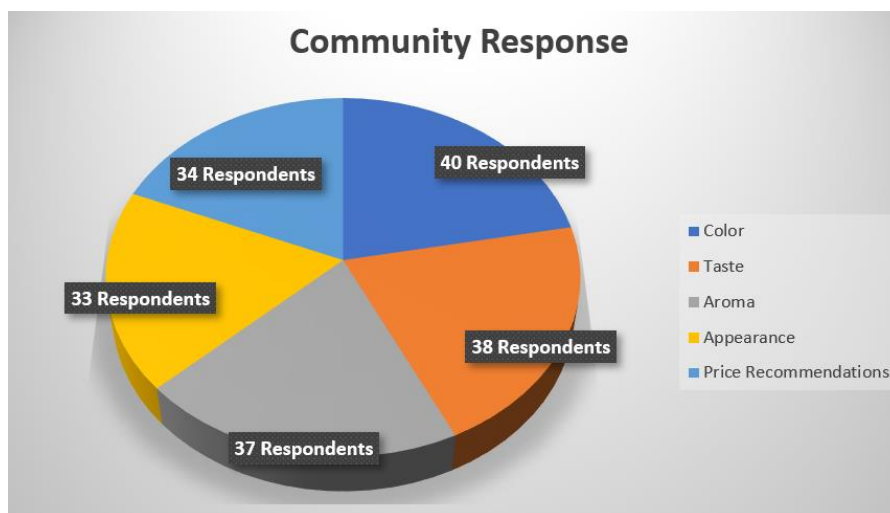


Figure 4. Diagram of Community Response Results

In Figure 4, there is a diagram of the public's response regarding Tempeh from Lotus Seeds. The graph illustrates the dominance of the five indicators.

3. Calculation of Costs and Prices of Tempeh from Lotus Seeds

After successfully producing lotus seed tempeh and receiving positive feedback from the community testing, the researchers turned their attention to analyzing the financial viability of this innovative product. A crucial aspect of any new food product development is understanding the production costs and determining a suitable pricing strategy that balances profitability for producers and affordability for consumers. The team conducted a comprehensive cost analysis, meticulously calculating the expenses associated with each ingredient and the overall production process. Notably, the lotus seeds, which served as the primary raw material, were obtained from natural sources and did not incur any direct costs, providing a significant advantage over traditional soybean-based tempeh production. The authors then conducted calculations related to financial analysis of production costs as shown in Table 3. The following sections present the detailed cost calculations, pricing analysis, and a comparison of potential profits against traditional tempeh production methods. This comprehensive financial evaluation was a crucial step in assessing the economic viability and long-term prospects of introducing lotus seed tempeh as a novel and nutritious food product.

Table 3. Calculation of Production Costs

Material Name	Price	Seed Tempeh Ingredients	Cost
Lotus Flower Seeds	Free (found in nature and not yet utilized optimally)	1000 gram	IDR -
Yeast	IDR 24.000,00/Kg	1 gram	IDR240,00
Total Production Costs			IDR240,00

Production Cost Calculation

The total production cost of lotus seed tempeh is IDR 240.00; for 8 packs of tempeh (125 grams/pack), so the production cost of lotus fruit tempeh is IDR 30.00;/pack, while from the results of a questionnaire regarding recommended prices for lotus fruit tempeh in the community, the price is IDR 1,500.00;/pack. From this explanation it can be concluded that the recommendation for lotus fruit tempeh is more than the production costs, thus the estimated profit that will be obtained from selling lotus fruit tempeh is IDR 1,460.00; per pack. It can be estimated that lotus fruit tempeh is superior to ordinary tempeh, where craftsmen, if they produce tempeh using lotus fruit, will gain greater profits, while consumers feel that Lotus tempeh is cheaper because it is below the price of ordinary tempeh.

Income Comparison

For ordinary tempeh from soybeans, 1 kg of soybeans produces 8 packs of tempeh weighing 125 grams which are sold for IDR 2,000.00/pack, so that a gross profit is obtained of IDR 16,000.00 while the net profit is IDR 6,790.00 after deducting the price of 1 kg of soybeans. IDR 9,000.00 and 1 gram of yeast IDR 210.00. Meanwhile, for lotus fruit tempeh, 1 kg of lotus fruit seeds produces 8 packs of tempeh with a selling price of IDR 1,500.00/pack. gross profit was obtained of IDR 12,000.00 while the net profit was IDR 11,790.00 after deducting the price of 1 gram of yeast IDR 210.00.

CONCLUSION

The research concluded that lotus seeds can be optimized as an ingredient by replacing soybeans in the process of making tempeh. The only difference aspect was the length of boiling of the raw materials and the three-step process of preparation, processing, fermentation, and packaging. Based on the results of the proximate analysis, the best experiment for processing tempeh from lotus seeds is boiling twice for 15 minutes each, because it can produce a high amount of protein, 37.38%. In the trial with respondents, all 40 Respondents agreed that the color of lotus seeds tempeh was brown or brownish-yellow, similar to soybean tempeh. Out of the 40 people, 38 found lotus seeds tempeh to be tasty, delicious, and softer than regular tempeh. However, one Respondent felt that the taste of lotus seeds tempeh was bitter at the end. 37 Respondents stated that the fragrance of lotus seeds tempeh to be the same as regular tempeh, while one found it to be pungent. 34 Respondents stated that the appearance of lotus seeds tempeh more attractive due to the clear lining up of the lotus seeds, while six found it to be the same as ordinary tempeh. 33 Respondents recommended the price of lotus seed tempeh to be below the normal price at an average of IDR 1,475/pack, while four recommended the same price as regular soybean tempeh. Based on the results, further research is needed to analyze the content of lotus and lotus seed tempeh. Additionally, further optimizations are required to increase the value of lotus as an ingredient in Indonesia, especially in Banten.

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Conflict of Interest Statements: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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