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A Nutritional, Physicochemical, and Sensory Evaluation of Tempe Combination from Cowpea and Soybean

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Abstract— Tempe is a traditional Indonesian food typically made from soybeans fermented by the mold Rhizopus spp. Indonesia heavily relies on imported soybeans, and substituting soybeans with cowpea (Vigna unguiculata) could reduce this dependency while promoting local raw materials. This study aimed to develop an optimal tempe formula combining cowpea and soybean, ensuring quality parameters comparable to conventional soybean tempe (the gold standard). Formula optimization was conducted using response surface methodology, facilitated by Design Expert 12 software. The recommended optimal formula consists of 30% cowpea and 70% soybean, achieving a desirability value of 0.87. This formulation resulted in tempe with L* (brightness), a* (red-green), b* (yellow-blue), hardness, water activity, and pH values that were not significantly different from those of soybean tempe. The proximate composition of the optimally formulated tempe complies with the quality standards of SNI 3144:2015, with moisture, ash, fat, protein, and carbohydrate contents of 60.28, 0.64, 10.28, 17.67, and 11.67% respectively. Sensory evaluation using a 1-7 hedonic scale (ranging from "very dislike" to "very like") on fresh and fried tempe from the optimal combination indicates that attributes such as color, aroma, texture, and overall acceptability fall within the range of "somewhat liked" to "like" by consumers. The favorable reception of the soybean-cowpea tempe suggests its potential for reducing soybean imports by substituting 30% of the soybean with cowpea.

Keywords— Cowpea, design expert, formula optimization, soybean, tempe

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I. INTRODUCTION

Tempe is a traditional Indonesian food consumed since the early 1600s, generally made from soybeans processed through a fermentation process using *Rhizopus* spp. mold [1]. Indonesia is the world's largest producer and consumer of tempe. Tempe is the cheapest and most accessible source of protein for around 278 million Indonesians. Tempe consumption in Indonesia per capita per year is around 7.47 kg [2].

The biggest problem in producing tempe is soybeans' low supply and productivity. Total soybean production in Indonesia is 0.63 million tons/year, with a productivity of 1.57 tons/ha of land. The average soybean demand in Indonesia reaches 3.09 million tons per year, of which 70% is used for tempe production. The gap between the need and availability of local soybeans has led to the need for soybean imports. Over the past ten years, soybean imports have reached 2.5 million tons/year [2].

Indonesia has a very high dependence on imported soybeans. Therefore, there is a need for a solution to reduce this dependence. One of the efforts that must be made immediately is to empower the use of local non-soybean beans as raw materials for tempe. The problem is that Indonesians are very familiar with soy-based tempe, so it is challenging to accept non-soybean tempe [3].

One of the local non-soybean beans that can be empowered is the cowpea (*Vigna unguiculata*), known in Indonesia as "kacang tunggak". These beans can be used as a substitute for imported soybeans to make tempe and diversify processed products. Cowpeas are classified as local beans in Indonesia that have great potential to provide plant-based protein. The productivity of cowpeas is higher than that of local soybeans, which is around 3.88–4.69 tons/hectare [3]. Globally, total cowpea production reached 8.9 million metric tons in 2019, a 2.7-fold increase compared to production in 2000. The increasing trend of plant-based diet has led to increasing research on the potential for novel applications of plant-based protein source such as cowpea due to its high protein content (~24%), dietary fiber (~11%), and potassium (1112 mg/100 g), while low in lipids (<2%) and sodium (16 mg/100 g) [4].

Cowpea processing such as soaking and boiling have been shown to increase the bioavailability of nutrients due to reduced anti-nutritional compounds such as trypsin inhibitors, raffinose, stachyose, phytic acid, and tannins, thereby increasing protein digestibility [5]. Meanwhile, the germination and fermentation can also reduce flatulence-causing carbohydrates such as raffinose, stachyose, and verbascose, as well as trypsin inhibitors, thereby reducing flatulence and increasing protein digestibility [6], [7], [8]. Cowpea can be fermented into tempe with the help of *Rhizopus* spp. Several studies have been conducted on the use of cowpea as a raw material for tempe, such as the development of cowpea tempe with an optimal fermentation time of 35 hours and the combinationof cowpea and koro bean [9], [10][9][10]. However, non-soybean tempe is still not in demand because people are not yet accustomed to its taste and appearance when compared to soybean tempe as the gold standard.

Soybeans and cowpeas have different physicochemical characteristics. The kidney-shaped cowpea seeds are yellowish-white with dimensions of 8.20–8.53 mm long, 4.72–5.81 mm wide, and weight per 100 grains 13.88-13.98 g. Dried cowpea seeds have a protein content of 23.98–24.26, fat 0.19–1.36, and fiber 3.87–4.04%, dry base [3]. Yellow oval, round soybean seeds with dimensions of 7.66–8.65 mm in length, 5.18–6.01 mm in width, weight per 100 seeds 14.65–19.53 g. The composition of soybeans is protein content 37.10–41.79, fat 14.76–21.14, and carbohydrates 35.43–38.82%, dry base [11].

The difference in the raw materials' physical characteristics and nutrient composition will significantly determine the nutritional composition of the tempe produced. The nutrient and sensory composition of soybean tempe is still superior to tempe made from raw materials other than soybeans [12]. The difference in the characteristics of raw materials also requires different ways of processing tempe. Therefore, proper processing of cowpea is required to produce tempe equivalent to tempe made from soybean by the tempe quality standards regulated in Indonesian National Standard (INS) 3144:2015 [13]. One way to increase the acceptability of tempe made from local non-soybean raw materials is to combine it with soybeans in a specific ratio [14]. Moreover, research focusing on a combined formulation of cowpea and soybean has not been previously explored, despite the potential benefits of combining these legumes to improve the quality of cowpea tempe.

This study addresses this gap by optimizing a tempe formulation using cowpea and soybean, employing Response Surface Methodology (RSM) to achieve quality parameters comparable to traditional soybean tempe. RSM is a set of mathematical and statistical methods used in modeling and analysis to see the effect of one or several quantitative independent variables (factors) on a response variable, which aims to optimize the response variable [15]RSM can quickly be done through *software applications*, one of which is with Design Expert. The advantages of RSM include that it does not require a large amount of experimental data and only takes a short time, so its application is critical in the design, development, and formulation of new products and in improving existing product designs [16].

The optimization of tempe formulas using local raw materials (cowpeas) and imported raw materials (soybeans) through RSM represents an effort to reduce Indonesia's reliance on soybean imports and enhance the country's food security. The novelty of this research lies in its development of cowpea-soybean combination with physical, chemical, and sensory characteristics that align with consumer preferences. This approach not only promotes the utilization of local resources but also ensures that the resulting tempe achieves high quality and marketability.

II. MATERIAL AND METHODS

A. Material

The main ingredients used in this study include Albina IPB variety of cowpeas obtained from the Department of Agronomy and Horticulture, Faculty of Agriculture, IPB University, as well as imported non-GMO soybeans (from the United States), obtained from the Indonesian Tempe and Tofu Producers Cooperative in Bogor. The inoculum used was a commercial tempe starter under the Raprima trademark. Polypropylene plastic was selected as tempe packaging because it is widely used in tempe production due to its availability, affordability, and suitability for fermentation. Its properties, moisture resistance and gas permeability are essential for optimal mold growth during the fermentation process [17].

B. Methods

Preliminary Research

The preliminary research included the physical analysis of soybeans and cowpeas, which consisted of dimensional and weight tests per 100 seeds, volume, and bulk density. The test was carried out twice in a triple for each parameter and then analyzed using SPPS 25 with an independent sample t-test. In this preliminary research, the process of making tempe with a combination of cowpea and soybean was carried out based on the production process previously developed [18].

Tempe Formula Optimization

The optimization of the tempe formula combined with cowpeas and soybeans was carried out using the RSM. Optimization of the combination of cowpeas and soybeans was carried out using the Design Expert 12 (DX12) program of the linear D-optimal model with two factors (cowpea and soybean concentration) and two responses (tempe protein content and hardness).

The determination of the maximum and minimum limits for the use of soybean and cowpea was carried out by trial *and error*. The next stage was tempe production, which was done with the right process conditions and formula recommendations based on the experimental design. In the resulting tempe, the response of protein content and hardness were then measured. The responses obtained from each treatment were then fed into the DX12 program to determine the optimal solution.

The verification stage was carried out after the optimization stage, which aimed to validate the prediction of the optimal response value given by the DX12 program. At the verification stage, tempe was made and analyzed based on the best formula or optimal solution suggested by RSM. Verification was carried out by two repetitions. The actual response value was obtained from the verification stage, which was then compared with the predicted response by the DX12 program.

Physicochemical and Sensory Analysis

The tests on tempe resulting from the optimum formula of cowpea and soybeans included color, texture, water activity, pH, proximate analysis, and hedonic rating sensory test. The same test was also carried out on samples of 100% cowpea and 100% soybean tempe, which were then compared with the optimum combination of cowpea and soybean.

Color analysis was performed with a chromameter [19], while textures were done with a texture profile analyzer [20]. Analysis of water activity, pH, moisture, ash, fat, protein, and carbohydrates (by difference*)* content was carried out using the AOAC method [21]

Sensory analysis of tempe was carried out using a hedonic rating method with 53 untrained panelists. The sample consisted of two types of tempe, including fresh and fried tempe. The attributes tested in fresh tempe were color, aroma, texture, and overall*,* while fried tempe, added taste attributes. The panelists gave an assessment/score on a scale of 1-7, where (1) they did not like it very much; (2) dislike; (3) somewhat disliked; (4) neutral; (5) somewhat liked; (6) like; and (7) very fond of it.

Data Analysis

Microsoft Office Excel® and SPSS version 25 processed the data. The variance and significance determination between the samples was analyzed using a DMRT posthoc test at a 5% significance level.

III. RESULT AND DISCUSSION

Preliminary Research

The physical analysis results of cowpeas and soybeans are shown in **Table 1.** Information on the physical characteristics of raw materials is beneficial in determining the treatment in making tempe. Based on Table 1, the physical characteristics between cowpeas and soybeans differ significantly across all parameters tested. Cowpeas are longer, but the seeds' width, thickness, roundness, and volume are more petite than soybean seeds. Significant differences in the physical characteristics of the two ingredients cause the processing of cowpea and soybean seeds to be carried out differently. Therefore, in the manufacture of combination tempe, cowpeas and soybeans were processed separately before the mixing process with the tempe inoculum.

TABLE I
PHYSICAL CHARACTERISTIC OF COWPEA AND SOYBEAN SEEDS

Parameter	Cowpea	Soybean
Seed dimensions		
Length (mm)	8.51 ± 0.26^{b}	7.74 ± 0.26^{a}
Width (mm)	5.49 ± 0.14^{a}	6.82 ± 0.27^{b}
Thickness (mm)	4.64 ± 0.14^{a}	6.02 ± 0.27^{b}
Roundness	0.69 ± 0.01^{a}	0.86 ± 0.02^{b}
Weight per 100 pcs (g)	13.52 ± 0.28^{a}	16.34 ± 0.16^{b}
Bulk density (g/mL)	0.81 ± 0.02^{b}	0.69 ± 0.02^{a}
Volume (mL/g)	0.12 ± 0.01^{a}	0.14 ± 0.02^{b}

Note: Means followed by different letters in the same row show significantly different at α = 0.05.

Processing soybeans as raw materials into tempe was carried out using the processing procedures usually carried out by Rumah Tempe Indonesia in Bogor. In the processing of cowpeas, modifications were made at the first soaking stage, which was done in a shorter time. The first soaking in the cowpea aims to increase the moisture content of the ingredients so that it can shorten the boiling time.

The observation results showed that the higher the temperature of the soaking water used, the more turbid the soaking water would be. In addition, the cowpea kernels will be softer, which is in line with the increase in the temperature of the soaking water used. The longer the soaking time, the larger the size of the seeds (swells) to the maximum limit and then constant. The 3 hours of immersion with warm water at 44-46°C showed the most optimal swelling or water absorption results.

Boiling functions to mature the seeds, making it easier for mold to grow and penetrate the cotyledons of beans, inactivate anti-nutrients and kill pathogenic microbes. The boiling stage of cowpeas was shorter than that of soybeans because of their smaller size than soybeans, thus accelerating their ripeness. The optimal boiling for ripening the cowpea was 6-8 minutes in boiling water (96-97°C). The flow diagram of the procedure for making tempe with a combination of cowpea and soybean is shown in **Fig 1**.

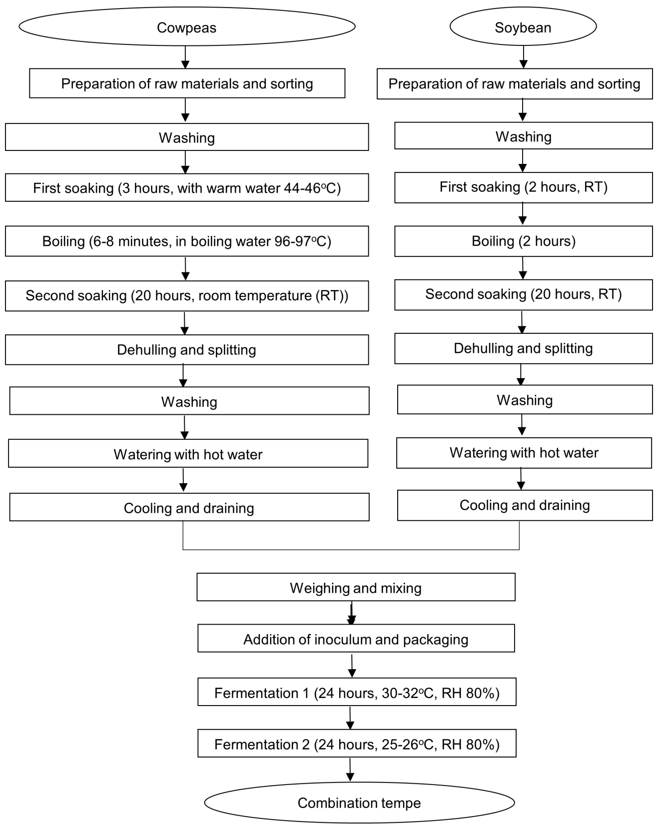

Fig. 1 Combination tempe processing procedure

Tempe Formulation and Response Measurement

In this study, the independent factors or variables were the concentration of cowpeas and soybeans. In contrast, the response or bound variable was the protein content and hardness of the tempe produced. The method used in the DX12 program was a D-optimal Mixture Design to obtain a combination of factors to produce an optimal response. The determination of the combination of factors by the DX12 program was obtained based on the minimum and maximum limit value of each factor obtained from trial and error that had been carried out previously.

The minimum-maximum limit for the concentration factor of cowpea was 30-40%, and for the soybean was 60-70%. This concentration refers to some previous literature on combination tempe, which states that the use of soybeans in the range of 60-70% can produce combination tempe with sensory acceptable to consumers and protein content that meets the requirements of tempe standards [14]. Ten combination factors (runs) were obtained based on the limit value of these factors. Furthermore, the protein content response and hardness of tempe were measured based on the ten runs. The results of the response measurement are shown in **Table 2**.

TABLE II
RESPONSE OF PROTEIN CONTENT AND HARDNESS FROM THE DESIGN OF THE DX12 PROGRAM

Run	Component 1: cowpea (%)	Component 2: soybean (%)	Protein content (%)	Hardness (Kgf)
1	30.00	70.00	17.72	12.43
2	35.00	65.00	16.80	13.63
3	40.00	60.00	16.05	13.85
4	36.67	63.33	16.23	13.66
5	35.00	65.00	15.36	13.35
6	33.33	66.67	15.81	12.71
7	30.00	70.00	16.99	12.52
8	32.50	67.50	17.36	12.84
9	40.00	60.00	15.70	14.41
10	40.00	60.00	15.53	14.66

Protein Content Response

The protein content is an essential parameter in tempe, which is a minimum of 15%, as required by INS 3314:2015. Based on the measurement of the response from 10 runs shown in Table 2, the protein content of tempe was in the range of 15.36–17.72%, so it is to the quality requirements set by INS. The initial protein content in an ingredient will determine the protein content in the processed food product. The higher the protein content of a raw material, the higher the protein content in the processed food it produces [22].

The response of tempe protein content based on the results of the DX12 program was predicted to have a linear model. The results of the analysis of variance (ANOVA) showed that the recommended model was significant ($p<0.05$). The mathematical equation for the response of tempe protein content in a combination of cowpea and soybean was:
Protein (%) = 0.064949A + 0.217229B .... (1)
Note:
A = Cowpea (%)
B = Soybean (%)

From the mathematical equation (1), the increase in the use of cowpea (A) and soybean (B) as raw materials causes an increase in the response of protein content in tempe. This relationship is marked by the coefficient of each factor with a positive value. From this equation, the concentration of soybean use was more influential than that of cowpea in increasing the protein content of the tempe produced. This was characterized by a more enormous soybean coefficient value than cowpea. Based on the model, the combination of cowpea : soybean = 30 : 70 produces the highest protein content in tempe.

Hardness Response

Hardness is one of the essential texture profiles in a food product. The hardness of a food product affects its sensory quality. The hardness value will affect the physical characteristics of fresh and processed tempe products. If the hardness value is too low, the tempe will be easily crushed, brittle, or not solid, making it difficult to slice. If the hardness value of the tempe is too high, the tempe will have a low texture quality because it is too hard to consume. The texture of fresh tempe products should be compact and tender.

Based on Table 2, the value of the hardness range of tempe produced was 12.43–14.66 Kgf. The response of tempe hardness based on the results of the DX12 program was predicted to have a linear model. The ANOVA results showed that the recommended model was significant ($p<0.05$). The mathematical equation for the hardness response of tempe combined with cowpea and soybean was:
Hardness (Kgf) = 0.25678355A + 0.0672593B .... (2)
Note:
A = Cowpea (%)
B = Soybean (%)

Based on the mathematical equation (2), the hardness response will increase along with the increase in the number of soybeans and cowpeas, characterized by a positive coefficient value. From the equation, the concentration of the use of cowpea has a more significant influence than the soybean use in increasing the hardness of the tempe produced. A coefficient value in cowpeas larger than soybeans characterizes this. Based on the model, the combination of cowpea : soybean = 30 : 70 produces the lowest hardness in the resulting tempe.

Selected Formula Verification

The optimization step is always preceded by setting the desired goals for each factor and response. The concentration factor of cowpea was set in the range of 30-40% and the concentration factor of soybean was set in the range of 60-70%. The target response of tempe protein content was maximized, and the tempe hardness response was minimized. The importance value was used to determine the significance level of the selected factors or responses. Each factor and response were assigned an equal importance value of 3.

The DX12 program then searched for superimposed areas of all response contour graphs to get the optimal area according to the set goals. An optimized combination solution was then offered by the DX12 program, as shown in **Table 3**.

TABLE III
SELECTED COMBINATION SOLUTION

Number	Cowpea (%)	Soybean (%)	Protein content (%)	Hardness (Kgf)	Desirability	
1	30.00	70.00	17.15	12.41	0.87	*Selected*

The optimal combination solution chosen was a mixture of 30% cowpea and 70% soybean with a desirability value of 0.872. The desirability value is the ability of a program function to fulfill desires based on criteria that have been set on the final product [23]. According to Raissi and Farsani [24], the desired product result is perfect if the desirability value gets closer to 1. Furthermore, the optimal solution selected was verified by re-measuring to check the actual value of each response that had been selected. The actual protein content was measured by the Kjeldhal method [21], and the actual tempe hardness was measured by a texture profile analyzer. The measured actual response from the verification stage is shown in **Table 4**.

TABLE IV
ACTUAL RESPONSE AND PREDICTION OF TEMPE RESPONSE OF OPTIMAL COMBINATION OF COWPEA AND SOYBEAN

Response	Prediction	Actual	95% CI		95% PI	
			Low	High	Low	High
Protein (%)	17.15	17.99	16.40	17.91	15.93	18.38
Hardness (Kgf)	12.41	12.35	12.08	12.74	11.87	12.95

Note: CI = confidence interval; PI = prediction interval

The verification stage produced an actual response of protein content of 17.99%, higher than the predicted result of 17.15%, and a hardness response of 12.35 Kgf, lower than the predicted result of 12.41 Kgf. The actual value of the two responses was within the range of CI (confidence interval) and PI (prediction interval), each at a 95% confidence level. This shows that the results of optimizing the production of tempe from cowpea and soybean with a ratio of 30:70% have been verified. In the protein response, the actual value produced was slightly above the 95% CI value of the upper bound. This difference in the response of the predicted and actual results may be due to variations in conditions during the fermentation process, such as boiling and fermentation times, which may differ slightly from the conditions controlled during the initial study [25]. Another factor is the difference in the quality of the raw materials used, including cowpea and soybean, which have slight differences in nutrient composition or freshness after storage [26]. The appearance of the optimized combination of cowpea and soybean tempe samples is shown in **Fig 2**.

Fig. 2 Optimized combination of cowpea and soybean (30:70%) tempe

Physicochemical Characteristics

Physicochemical characteristics were measured on three types of tempe, including tempe with an optimal combination of cowpea and soybean (30:70%), 100% cowpea, and 100% soybean tempe. The physicochemical characteristics parameters of tempe measured include color, hardness, water activity, and pH. The results of the physical test analysis are shown in **Table 5**.

The L value indicates the brightness level of an object, where the higher the L value, the lighter the color of the object. The L value of the three tempe did not differ significantly ($p>0.05$). This shows that the three tempe have the same brightness value, which ranges from 75.43-78.10. The value of "a" shows the level of red (+) and green (-) colors. The results of color analysis on a value parameter showed that the three types of tempe tended to be red compared to green with significant differences ($p<0.05$).

The value of b indicates the level of yellow (+) and blue (-) colors. The results of color analysis on the value parameter b showed that the three types of tempe tend to be yellow rather than blue. The value b of the optimum combination of cowpea and soybean and 100% cowpea were not significantly different ($p>0.05$), and both were significantly lower ($p<0.05$) than 100% soybean tempe. This shows that 100% soybean tempe has a more yellow color compared to the other two tempe. The use of soybeans as raw material for tempe produces a yellower color due to the presence of natural pigments such as carotenoids and isoflavones found in soybeans [27].

The hardness value measurement showed that the three tempe's hardness levels were significantly different ($p<0.05$). The 100% cowpea tempe had the highest hardness value, while 100% soybean tempe exhibited the lowest value. The difference can be attributed to the structural and compositional properties of the raw materials. Cowpea seeds are smaller, denser, and have a firmer texture compared to soybean seeds, which makes them less susceptible to breaking during processing, resulting in the denser final product. *Rhizopus* spp. mold more easily penetrates the smaller pieces of cowpea seeds, enhancing its growth and the formation of a dense mycelial network. This mycelial growth increases the strength of the bonds between the seed pieces, resulting in a more compact and harder tempe structure. Furthermore, the higher starch content in cowpea compared to soybean may also play a role, as starch can affect the texture and gel-like properties of fermented products [28]. Another factor is the protein and its interaction with the mycelium, which has been shown to affect the firmnness and structure of a product [29]. The optimum combination of cowpea and soybean had a significantly different hardness value ($p<0.05$) compared to the other two types of tempe, which was between the range of the other two types of tempe. Several other studies have shown that using other non-soybeans such as chickpeas, white beans, red lentils, and broad beans as raw materials for tempe also provide a higher hardness value than soybean tempe. In contrast, black beans and green lentils provide a softer texture [30].

TABLE V
COMPARISON OF THE PHYSICAL CHARACTERISTIC OF COWPEA AND SOYBEAN COMBINATION, 100% COWPEA, AND 100% SOYBEAN TEMPE

Parameter	Types of tempe		
	Optimal combination	**100% Cowpea**	**100% Soybean**
Color			
L	77.01 ± 5.43^a	75.43 ± 537^a	78.10 ± 4.65^a
a	0.55 ± 0.05^b	0.36 ± 0.15^a	1.72 ± 0.08^c
b	12.55 ± 0.90^a	10.50 ± 0.75^a	17.29 ± 2.74^b
Hardness (Kgf)	12.62 ± 0.35^b	19.54 ± 2.40^c	10.53 ± 0.47^a
Water activity	0.99 ± 0.00^a	0.99 ± 0.00^a	0.99 ± 0.00^a
pH	6.16 ± 0.01^b	6.40 ± 0.03^c	5.84 ± 0.09^a

Note: Means followed by different letters in the same row show significantly different at $\alpha = 0.05$.

The measurement of the water activity value (a_w) of the three types of tempe showed no significant difference. Water activity indicates the amount of free water contained in a food ingredient used by microbes for their growth. The higher the a_w value, the more vulnerable the food is to the growth of microorganisms [31]. The water activity value of 0.99 indicates that the three types of tempe were very susceptible to damage by microbes (bacteria, mold, and yeast). This causes the shelf life of fresh tempe to only reach 1-2 days at room temperature and 5-7 days at refrigerator temperature. To extend the shelf life and increase the opportunity for product diversification, fresh tempe can be processed into tempe flour [32].

The pH values of the three types of tempe were significantly different ($p<0.05$). The 100% cowpea tempe had the highest pH value, while 100% soybean tempe had the lowest value. The pH value of tempe raw materials (beans) at the soaking stage will decrease to 3.5–5.2 due to the activity of lactic acid bacteria but will increase during the fermentation process into tempe [33]. The increase in the pH value of tempe occurred due to the proteolytic activity of the mold *Rhizopus* spp. in breaking down protein compounds in the raw materials into free amino acids and simple peptides, as well as the use of lactic acid for mold growth [34], [35]. Protein that is hydrolyzed during tempe fermentation can produce alkaline-free ammonia, causing the pH of tempe to continue to increase until it reaches a value of 7. The 100% cowpea tempe had a significantly higher pH value ($p<0.05$) than the other two types of tempe.

In contrast, tempe with an optimal combination had a pH value in the pH value range of the other two types of tempe. These results showed that the level of protein hydrolysis in cowpeas was higher than that of soybeans. The discovery of trypsin inhibitors in soybean compared to cowpea is also believed to contribute to the hydrolysis process during fermentation by *Rhizopus oligosporus*. [36] showed that soybean tempe still contained 6.10 mg/g trypsin inhibitors, while not in cowpea tempe.

Composition of Tempe

The chemical characteristics of tempe were measured through proximate analysis, including moisture, ash, fat, protein, and carbohydrate contents. The results of the proximate analysis are shown in **Table 6**.

TABLE VI
THE PROXIMATE COMPOSITION OF THREE TYPES OF TEMPE COMPARED TO THE QUALITY REQUIREMENTS OF TEMPE (INS 3144:2015)

Parameter (% wb)	Types of Tempe			INS tempe
	Optimum combination	100% Cowpea	100% Soybean	
Moisture	60.28±1.38ᵃ	62.23±0.09ᵇ	58.91±1.39ᵃ	max 65
Ash	0.64±0.06ᵇ	0.48±0.03ᵃ	0.72±0.02ᶜ	-
Fat	11.11±1.46ᵇ	5.57±0.27ᵃ	13.24±2.61ᵇ	min 7
Protein	17.67±0.48ᵇ	14.04±1.04ᵃ	18.42±0.19ᵇ	min 15
Carbohydrate	10.28±2.47ᵃ	19.76±2.27ᵇ	8.70±2.24ᵃ	-

Note: Means followed by different letters in the same row show significantly different at $\alpha = 0.05$.

The soaking and boiling process will increase the raw materials' moisture content, which will then drop back down after the draining process. The raw material's water content serves to grow mold and form mycelium tissue. The moisture content of the tempe made from 100% cowpea was higher than that of the other two types of tempe. The moisture content of the optimum combination and 100% soybean tempe did not show a significant difference. This showed that the substitution of soybeans with 30% cowpea does not significantly affect the moisture content of the tempe produced. The moisture content value of the three types of tempe is based on INS quality requirements, which is no more than 65%. The moisture content of tempe is limited to a maximum of 65% of the wet base to avoid the growth of pathogenic bacteria and rot.

The standard for ash content in tempe was specified as a maximum of 1.5% in INS 3144:2009, however, this parameter has been removed in the latest regulation, INS 3144:2015. Ash content indicates the presence of mineral content in a food ingredient, where the higher the ash content of a material, the higher the minerals contained in it. Soybean ash content is 5.53-5.89% [37], while in cowpea, it is 3.13-3.97% [38]. The ash content in 100% soybean tempe was the highest compared to the other two types of tempe. Soybeans have a higher mineral content than cowpeas, so the large proportion of soybean in tempe affected the ash content value. The minerals contained in tempe are generally in the form of phosphorus, calcium, iron, potassium, sodium, zinc, magnesium, and manganese [39]. The optimum combination tempe of soybean-cowpea has a soybean proportion of 70% so that it can increase the ash content in the resulting tempe.

The fat content of the optimum combination and 100% soybean tempe did not differ significantly, which showed that the substitution of soybean with 30% cowpea did not significantly affect the fat content of the tempe produced. The fat content of 100% cowpea tempe was lower than the other two types of tempe. Cowpea has a much lower fat content than soybean, causing the fat content in the resulting tempe to be less. Based on INS, tempe is required to have at least 7% fat content. This shows that the optimum combination and 100% soybean tempe had a fat content according to INS requirements, while 100% cowpea tempe does not follow INS. It may be viewed negatively based on the standard of tempe products, but cowpea tempe can be used for diet foods with a fat content half as low as 100% soybean tempe.

The protein content of the optimum combination and 100% soybean tempe did not differ significantly. It showed that substituting 30% soybean with cowpea did not significantly affect the protein content of tempe produced. On the contrary, the protein content of 100% of cowpea tempe was lower than that of the other two tempe due to cowpea's lower protein content than soybean. Based on INS requirements, tempe is required to have at least 15% protein content. It showed that the optimum combination and 100% soybean tempe were in accordance with INS requirements, while cowpea tempe only contained 14.04% protein, so it did not meet the minimum INS requirements.

The standard carbohydrate content in tempe is not explicitly set in the SNI requirements. The carbohydrate content of the third tempe was calculated using the "by difference" method. The carbohydrate content in tempe in the optimum combination and 100% soybean tempe did not differ significantly. The carbohydrate content of 100% cowpea tempe was higher than the other two types of tempe due to cowpea's higher carbohydrate content than soybean. Moreover, the longer boiling time in soybean processing (**Fig. 1**) can also decrease the carbohydrate content in soybean tempe due to the soluble carbohydrate release into the water, such as sucrose, stachyose, and raffinose [40].

Sensory Characteristics of Fresh Tempe

The sensory test results of the three types of tempe are shown in **Table 7**. Testing on fresh tempe will provide an overview of the panelists' preferences as consumers when choosing food products to buy. The results of the fresh tempe color attribute test showed that the hedonic average of the optimum combination tempe was 4.38 (neutral to somewhat liked), significantly lower than 100% soybean tempe with a value of 6.25 (like to very like), and significantly higher than 100% cowpea tempe with a value of 2.47 (dislike to somewhat dislike). The concentration of cowpea as much as 30% significantly affected the parameters of a and b values, which reduced the intensity of yellow color and impacted the hedonic value of the color attribute in the combination tempe, which was lower than 100% soybean tempe.

TABLE VII
COMPARISON OF SENSORY CHARACTERISTIC OF THREE TYPES OF TEMPE

Sensory attributes	Optimum combination	100% cowpea	100% soybean
Fresh tempe			
Color	4.38±1.28^b	2.47±1.23^a	6.25±0.81^c
Aroma	4.89±1.07^b	3.06±1.43^a	5.55±1.03^c
Texture	4.81±1.19^b	3.98±1.67^a	5.42±1.13^c
Overall	5.02±0.93^b	3.30±1.50^a	5.77±0.80^c
Fried tempe			
Color	4.55±1.53^b	2.66±1.26^a	6.04±1.05^c
Aroma	5.34±1.30^b	4.25±1.43^a	5.45±1.14^b
Texture	4.91±1.40^b	3.74±1.50^a	5.36±1.29^b
Taste	5.09±1.26^b	3.28±1.60^a	5.38±1.18^b
Overall	5.02±1.14^b	3.13±1.22^a	5.70±1.07^c

Note: Means followed by different letters in the same row show significantly different at $\alpha = 0.05$.

The results of the aroma attribute test on fresh tempe showed that the hedonic average of the optimum combination tempe was 4.89 (neutral to somewhat liked), which was significantly lower than 100% soybean tempe, which was 5.55 (somewhat liked to like) and was higher than 100% cowpea tempe, which was 3.06 (somewhat disliked to neutral). The high carbohydrate value of 100% cowpea tempe allows the fermentation of carbohydrates by yeast, resulting in an unpleasant sour aroma. The presence of simple carbohydrates or sugars that are higher in cowpeas than in soybeans makes them a more suitable substrate for yeast for the fermentation process. Yeast contributes more to the formation of volatile components in tempe than mold. The sour aroma produced by yeast fermentation is called *yeasty odor*, while the preferred aroma of soybean tempe is mushroom odor [41].

The results of the fresh tempe texture attribute test showed that the hedonic average of the optimum combination of cowpea-soybean was 4.81 (neutral to somewhat liked), significantly lower than 100% soybean tempe with a value of 5.42 (somewhat liked to like), and significantly higher than 100% cowpea tempe with a value of 3.98 (somewhat disliked to neutral). This test's results show that the texture attribute's hedonic value was inversely proportional to the physical value of tempe hardness shown in **Table 5**.

The results of *the* overall attribute test of fresh tempe showed that the hedonic average of the optimum combination tempe was 5.02 (somewhat like to like), which was significantly lower than 100% soybean tempe, which was 5.77 (somewhat liked to like) and significantly higher than 100% cowpea tempe which was valued at 3.30 (somewhat disliked to neutral). Statistically, the optimum combination and 100% soybean tempe had significantly different overall attributes. However, based on the value range, both had hedonic values in the same range, which were like to like. It showed that overall, the optimum combination tempe was acceptable to consumers.

Sensory Characteristics of Fried Tempe

Testing on fried tempe samples will provide an overview of the panelists' preferences as consumers when choosing food products to consume. The results of the color attributes of fried tempe were similar to those of fresh tempe (Table 7). It showed that the frying process does not significantly impact the color attributes of each tempe. In contrast to fresh tempe, the results of the fried tempe aroma attribute also showed that the hedonic average of the optimum combination tempe was 5.34 (somewhat liked to like), which was not significantly different from 100% soybean tempe, and significantly higher than 100% cowpea tempe which was valued at 4.25 (neutral to somewhat liked). In fresh tempe, the predominant note was beany, followed by boiled potatoes, nutty, mushroom-like and moldy. Meanwhile after frying process, the predominant notes were beany along with oily and fried odor, followed by nutty, boiled potatoes, mushroom-like and moldy odor, causing the aroma of fried tempe to be tastier and preferable [42,43].

The results of the texture attribute test of fried tempe samples showed that the hedonic average of the optimum combination tempe was 4.91 (neutral to somewhat liked), not significantly different from 100% soybean tempe and significantly higher than 100% cowpea tempe, which was valued at 3.74 (somewhat disliked to neutral). The results of the fried tempe taste attribute test showed that the average hedonic tempe of the optimum combination tempe was 5.09 (somewhat liked to like), no difference from 100% soybean tempe, and significantly higher than 100% cowpea tempe, which was valued at 3.28 (somewhat disliked to neutral).

Similar to fresh tempe, the results of the overall attribute test of fried tempe showed that the hedonic average of the optimum combination tempe was 5.02 (somewhat liked to like), significantly lower than 100% soybean tempe which was valued at 5.70 (somewhat liked to like), and significantly higher than 100% cowpea tempe which was valued at 3.13 (somewhat disliked to neutral). The positive acceptance of optimum combination tempe, both in fresh and fried tempe, allows the development of tempe products with a substitution of 30% soybean with cowpea to reduce the number of soybean imports. A comparison of the appearance of tempe with the optimum combination of cowpea and soybean (30:70%), 100% cowpea, and 100% soybean tempe can be seen in **Fig 3**.

Fig. 3 Comparison between fresh (top) and fried tempe (bottom). Optimum combination (left), 100% cowpea (center), and 100% soybean tempe (right)

IV. CONCLUSION

The optimal formula for the combination tempe developed in this study consisted of 30% cowpea and 70% soybean. This formulation produced tempe with brightness level, red-green value, yellow-blue value, hardness, water activity, and pH parameters that were not significantly different from those of 100% soybean tempe. The proximate composition of the optimally formulated tempe also met the standards set by INS 3144:2015. Sensory evaluations indicated that the optimal combination tempe was well-accepted by consumers, with acceptance scores for color, aroma, texture, and overall attributes falling within the "somewhat liked" range to "like". This positive reception demonstrates the potential for incorporating 30% cowpea to substitute for soybean in tempe production, suggesting that this approach effectively reduces the volume of soybean imports.

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