Food Research 8 (Suppl. 4) : 20 - 32 (2024)
Journal homepage: https://www.myfoodresearch.com

FOOD RESEARCH

RESEARCH PAPER

Sensory profile of tempe made from a combination of velvet bean and soybean using rate-all-that-apply

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Article history:
Received: 16 August 2023
Received in revised form: 14 July 2024
Accepted: 22 July 2024
Available Online: 30 August 2024

Keywords:
Hedonic,
Mucuna pruriens,
Rate-all-that-apply,
Response surface methodology,
Velvet bean

DOI:
https://doi.org/10.26656/fr.2017.8(S4).3

Abstract

Velvet bean (*Mucuna pruriens* L.) has a high protein and carbohydrate content. However, it is only used by the community as processed plant-based foods. The lack of utilization of this bean is also due to the presence of cyanide and anti-nutritional compounds. This study aimed to find a new approach to improve the optimization of the combination of velvet bean and soybean tempe formula and consumer panelist acceptance by implementing the response surface methodology (RSM) and the rate-all-that-apply (RATA) method on sensory profiles. Preliminary research showed that 48 hrs-soaked velvet bean was chosen as the main treatment because it reduced the content of phytic acid 84.17% (1.78 mg/g) and cyanide 87.64% (1.09 mg/g) and had the highest protein content (28.82 g/100 g wb). The RSM showed that the variable formula of the velvet bean-soybean combination tempe (30.62: 69.37%) had a protein content of 18.47% and a hardness of 2.04 kgf. Sensory characteristics were evaluated by comparing the aroma, color, texture, appearance, taste, and overall characteristics of 100% velvet bean and combination tempe. The hedonic rating method revealed an increase in panelists' preference for the combination tempe on the aroma, texture, taste, and overall characteristics. Based on sensory characteristics, the optimal combination tempe has a somewhat like to like score on the overall attributes of fresh tempe (5.64) and fried tempe (5.48) higher than the velvet bean tempe. Furthermore, the RATA method was used to assess consumer perceptions of the intensity of fresh and fried 100% velvet bean, combination, and 100% soybean tempe attribute. Fresh tempe made from 100% soybean seemed to have soft texture characteristics as well as whiteness, yellow-white, and solid-compact appearance. Meanwhile, 100% fresh velvet bean tempe possessed rancid aroma, hardness, integrated texture, and fibrous appearance. The combination tempe had a yellow-ebony, brown-ebony and gray-ebony color as well as sweet, fermented and mushroom aroma. The 100% soybean fried tempe also had savory-umami aroma, beany, and golden-yellow color. Fried tempe made from 100% velvet bean had sweetness, aroma (rancid, fermented and mushroom), taste (oily and bitter) and sourness characteristics. Meanwhile, the combination tempe was shown to have dominant characteristics such as color (brown-ebony and gray-ebony), hardness and fibrous appearance.

1. Introduction

Tempe is a traditional Indonesian food that is widely consumed, apart from being cheap, tempe also contains a beneficial source of protein and bioactive compounds for the community. The increasing consumption of tempe resulted in an increase in soybean imports as the main raw material and it reached 2.2 million tons or 1.48$ million (Statistics Indonesia, 2020). Overall, this trend leads to the local food development in Indonesia.

Indonesia has many types of beans, one of them is the velvet bean (*Mucuna pruriens* L.). Velvet bean has been widely used as traditional medicine, for example as an antidiabetic, aphrodisiac, antineoplastic, antiepileptic, antimicrobial and neuroprotective (Misra and Wagner, 2007; Sathiyanarayanan and Arulmozhi, 2007; Lampariello *et al*., 2012). Kalidass dan Mahapatra

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eISSN: 2550-2166 / © 2024 The Authors.
Published by Rynnye Lyan Resources

(2014) found that velvet bean contains 28.82% protein (wb). Besides being processed into vegetables, velvet bean is also used as a raw material for making tempe, but its development is only confined to two provinces, Central Java and Yogyakarta. On the other hand, the lack of use of velvet beans is due to the harmful compounds inside, such as cyanide and phytic acid that can be reduced through soaking, boiling, steaming, and germination or fermentation processes (Nwaoguikpe *et al.* 2011). The research by Diniyah and Windrati (2015) showed that soaking the seeds for 48 hrs is able to lower the level of phytic acid content by 84.17% (1.78 mg/g) and cyanide by 87.64% (1.09 mg/g). The process of making tempe causes the phytic acid content in beans to decrease because phytic acid is able to dissolve in water by soaking or heating (Wikandari *et al.,* 2020). Additionally, the size of the seeds used in making tempe could also affect the phytic acid content. In another experiment, Rokhmah *et al.* (2009) made the tempe from velvet bean as a raw material which experienced a size reduction that was more easily penetrated by the mycelium of *Rhizopus* spp. This further results in a greater reduction in phytic acid content in the tempe.

This study focused on the acceptability of consumer panelists' sensory profiles of the fresh and fried tempe. Response surface methodology (RSM) was applied to optimize the tempe formula from the combination of velvet bean and soybean which allowed many factors and their interactions to be calculated simultaneously (Montgomery, 2013). Each food product has unique sensory characteristics so that the tempe combination of velvet bean and soybean sensory profile can be measured and identified precisely to the sensory characteristics. This study aimed to identify the sensory characteristics of 100% velvet bean, and the combination of velvet and soybean tempe upon aroma, color, texture, appearance, taste, and overall characteristics using the hedonic preference rating method, and consumer perception employing rate-all-that-apply (RATA) method.

2. Materials and methods

This research was separated into two stages: preliminary research and main research. In the preliminary research, it was determined by using RSM. There was a recommended treatment by considering the two most significant criteria: protein content and hardness value of the tempe. The optimum formula was obtained through design verification in RSM with the highest protein content in the main study. The tempe with the highest protein content and best hardness value was then subjected to sensory testing to find panelists' preferences regarding the color, aroma, taste, texture, appearance, and overall characteristics

2.1 Materials

The white velvet beans (*Mucuna pruriens* L.) used were obtained from Nganjuk and Situbondo City, East Java Province, Indonesia. Meanwhile, the soybeans were attained from the Indonesia Tempe House (Rumah Tempe Indonesia, RTI) situated in Bogor City, West Java Province, Indonesia.

2.2 Preparation of velvet bean

The pre-treatment of making tempe with velvet beans was different from using the soybeans. The velvet beans were firstly soaked for 48 hrs as an initial sorting and it aims to cut the cyanide content and antigenic compounds. After that, they were boiled for 95 mins and soaked again for 48 hrs to earn the appropriate acidic conditions. Next, the beans' skins were peeled using a machine and the velvet bean seeds were cut into smaller pieces. The cleaned velvet seeds were steamed for 15 mins to remove impurities and gain a softer texture of the velvet bean seeds. Finally, the velvet bean seeds in warmth then were cooled down.

2.3 Process of making tempe

The process of making tempe from a combination of velvet beans and soybeans was adapted from making soybean tempe in general with some modifications to the preparation of the velvet beans. It is known that velvet beans have a larger seed size and a harder texture than soybeans, so some experiments were carried out on the soaking and boiling process to find the proper time. The cooled velvet beans that had been pre-treated would have been mixed with soybeans by considering the recommended ratio of the RSM optimization formula (30.63% Velvet beans; 69.67% soybeans). After that, *Rhizopus* spp. 0.2% was inoculated, wrapped in polypropylene plastic, and then fermented for 48 hrs at 29-35°C.

2.4 Production of tempe formula optimal combination of velvet bean and soybean

The production of the optimal tempe formula was recommended by the RSM to combine the velvet beans and soybeans which was conducted at RTI. The formula composition based on the experimental design is presented in Table 1. The formula optimization resulted in an optimum velvet bean and soybean tempe formula that was compared with 100% soybean tempe according to the observed parameters of tempe protein content and hardness value.

2.5 Proximate analysis

Proximate analysis performed by AOAC (2012) method includes the following parameters: moisture

https://doi.org/10.26656/fr.2017.8(S4).3

Table 1. Formula composition based on the experimental design in RSM.

Run	Formula	
	Velvet beans (%) (W/W)	Soybeans (%) (W/W)
1	100	0
2	0	100
3	75	25
4	25	75
5	0	100
6	100	0
7	50	50
8	66.67	33.33
9	50	50
10	33.33	66.67
11	0	100
12	50	50
13	100	0

content by gravimetry, ash content by gravimetry, fat content by Soxhlet method, protein content by Kjeldahl method, carbohydrate content (by difference), and hardness utilizing TA-XT2 texture analyzer.

2.6 Sensory analysis rate-all-that-apply

A panel of 50 scorers participated in this test (mean age 23.6 years; female, n = 38; male, n = 12). During the selection, the panelists first filled out a form about the intensity of tempe consumption and their perception of tempe sensory characteristics. The panelists were asked to taste the characteristics of the tempe samples for 15–30 mins. Tempe samples were presented in the form of fresh tempe and fried tempe, as well as the participants, were given a questionnaire containing the characteristics found in the tempe. Sensory evaluation with descriptive tests aims to determine product characteristics and the intensity of the products characteristics (Fibrianto and Dwihindarti, 2016). The characteristics presented are color, aroma, taste, appearance, texture, and overall. The researchers randomized the order of tempe samples presented during the assessment for each panelist, and they rated each characteristic based on the hedonic preference scale and characteristic intensity.

Table 2 describes each characteristic to be assessed, where the characteristics were based on the results of focus group discussions that had been done before. Sensory research on the combination of velvet bean and soybean tempe had obtained ethical permission number: 753/IT3.KEPMSM-IPB/SK/2022 from the Ethics Commission for Research Involving Human Subjects, IPB University. Data from hedonic rating analysis and RATA test were processed using the SPPS 25 program. The independent sample T-test was used for statistical analysis with a 95% confidence level to determine the difference between characteristics of the fresh and fried tempe.

Table 2. Description of characteristics in tempe.

No	Characteristics	Descriptions
	Aroma	
1	Beany	Aroma associated with soybean/tempe characteristics
2	Mushroom	Aroma associated with mushroom characteristics
4	Sweetness	Aroma associated with sweet food characteristics; cake
5	Rancid	Aroma associated with rancidity; not fresh
6	Fermented	Aroma associated with fermentation process; sour smell
	Taste	
1	Nutty	Flavor associated with nutty characteristics
2	Savory/Umami	Flavor associated with monosodium glutamate characteristics; savory taste
3	Sourness	Flavor associated with sourness
4	Oily	Flavor associated with oily/fatty foods
5	Bitter	Bitter taste
	Color	
1	Whiteness	Pure white tempe color
2	Yellow White	Yellowish white tempe color
3	Gray White	Tempe color is grayish white
4	Brown-ebony	Tempe color looks brownish tends to be black
	Texture	
1	Softness	Soft and easy to press, bite or chew sensation
2	Hardness	Hard sensation and not easily decomposed when pressed, bitten, or chewed
3	Integrated	Compact and dense sensation in tempe when pressed, bitten, or chewed
	Appearance	
1	Tempe looks solid and compact	
2	Tempe looks fibrous when it was torn	

https://doi.org/10.26656/fr.2017.8(S4).3

3. Results and discussion

3.1 Response analysis in response surface methodology optimization

Analysis of the upper and lower limit response used in the optimization process was based on the results of literature studies and DX 12 software trials, this design resulted in 13 runs. Measurement of the response results of formula optimization (Table 3) shows the response of protein content ranging from 13.54 to 21.12% and the hardness value of tempe ranging from 1.91 to 2.71 kgf. The summary of analysis of variance (ANOVA) results for each optimization response can be seen in Table 3 while 2D optimization response curves are presented in Figure 1.

3.2 Response optimization analysis to protein content

The analysis is a macronutrient component that is favored in legume-based products. Protein in tempe plays an important role in fulfilling the nutritional needs of the human body. Tempe proteins have good quality and bioavailability due to their higher solubility, so it is more easily absorbed and utilized by the body (Astawan *et al.,* 2020). The standard for tempe protein content according to the Indonesian National Standard (SNI 3144:2015) is a minimum of 15%. Therefore the protein response was used as the main consideration in determining the optimum model. The recommended model for the protein level response is the quadratic model. This model has a lack of fit value of 0.2535 and the R2 value of the protein level response is 0.9623 (Table 4). The mathematical equation for the response of tempe protein content is as follows.

Protein content (%) = 14.50352A + 20.84914B – 3.38480AB

The value of protein content produced by tempe products ranges from 13.54% to 21.12% (Table 3). The mathematical equation shows that protein content is influenced by the concentration of velvet bean (A), soybean (B) and the interaction between the two raw materials used (AB). The response of protein content will increase along with the rising amount of the use of soybean, which is characterized by a positive constant. In contrast, the interaction between the use of velvet beans and soybeans can reduce protein levels and be marked by a negative constant value. The larger the substitutions

Table 3. Measurement result of the response to various optimization treatments of the protein content and hardness value of tempe.

Run	Formula		Results	
	Velvet beans (%) (W/W)	Soybeans (%) (W/W)	Tempe Protein Content (%)	Tempe *Hardness* (Kgf)
1	100	0	14.84	2.01
2	0	100	20.74	2.49
3	75	25	16.14	1.96
4	25	75	18.49	1.99
5	0	100	21.04	2.71
6	100	0	14.77	2.30
7	50	50	17.05	2.08
8	66.67	33.33	15.80	2.13
9	50	50	16.73	2.16
10	33.33	66.67	17.07	1.91
11	0	100	21.12	2.73
12	50	50	17.17	2.18
13	100	0	13.54	2.52

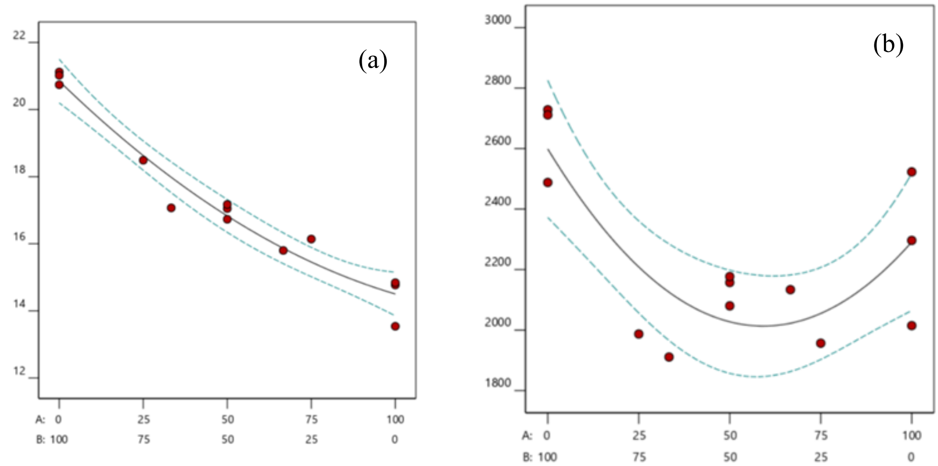

Figure 1. Response analysis curve (a) protein content and (b) hardness. A: Velvet beans (scale 0-100), B: soybeans (scale 100-0).

https://doi.org/10.26656/fr.2017.8(S4).3

Table 4. Result of analysis of variance (ANOVA) on experimental responses.

Responses	Model	Significant (p<0.05)	Lack of fit (p>0.05)	R^2	Adj. R^2	Pred. R^2	Adq. Precision
Protein Content (%)	Quadratic	< 0.0001	0.2535	0.9623	0.9548	0.9352	25.3066
Hardness (Kgf)	Quadratic	0.0050	0.3378	0.6538	0.5846	0.3856	6.5935

amount of soybeans, the higher the protein level of velvet beans tempe. According to Bavia *et al.* (2012), elevated protein levels in tempe were caused by the loss of some dissolved components such as minerals and sugar from soybeans. During the fermenting phase, mold mycelium with proteolytic activity can also contribute to an increase in protein levels (Rahayu, 2004). Puspitojati *et al.* (2019), proteolytic enzymes are produced by microbes and degrade proteins into low molecular weight peptides that are more soluble.

3.3 Hardness value response optimization analysis

The selection of hardness response is related to the physical quality attributes of tempe, where customers are hesitant to purchase harsh tempe products. As a result, a high hardness value may contribute to low customer acceptance of the tempe product. The linear model was selected by the program to explain the interaction among factors on hardness value response. This model has a lack of fit value of 0.3378 and the R2 value of the hardness response is 0.6538 (Table 4). The mathematical equation for the hardness value response of tempe is as follows.

$$\text{Hardness (kgf)} = 2.29A + 2.59B - 1.67AB$$

Hardness was measured by using a texture analyzer TA-XT2. The hardness response value ranged from 1.91 –2.73 kgf (Table 3). Based on the equation, the hardness response will rise along with the increasing usage of velvet bean and soybean, which is characterized by a positive constant value. Meanwhile, the interaction of the use of velvet bean and soybean can decrease the hardness which is marked by a negative constant value. According to Sudiyono (2010), the high carbohydrate content causes velvet beans to have a hard texture. This demonstrates that adding more soybeans can reduce the hardness value of the velvet beans tempe.

3.4 Optimization of tempe formula

The best optimization process on tempe formula was obtained by optimizing the response analysis. The desirability value was the value to be achieved based on the existing variable criteria. The response will be considered optimal if the desirability value is close to 1. The response selection of protein content was important so that the importance value with an importance scale of 5 was set to maximize. On the other hand, the determination of the optimal formula on the hardness response was set to minimize with an importance scale of 5.

The optimization results showed one optimum formula with a desirability value level of 0.695. The optimum formula obtained was 30.62% velvet bean and 69.37% soybean. The optimum formula was verified to observe the ability of the model to predict the optimum value. This study was considered as verified if the test response was at the value of Confidence Interval (CI) at 95% and the Prediction Interval (PI) at 95%. The verification results (Table 5) showed that the optimum formula for CI and PI was in the range of 95% for both. The results showed that the formula had a response test that was in accordance with the prediction results recommended by the software and the verified formula.

3.5 Proximate analysis of soybean and velvet bean combination

The study showed differences in the specific nutrient content of 100% velvet bean and the combination of velvet bean and soybean. Table 6 shows the nutrient content of the combined tempe from velvet bean and soybean, and 100% velvet bean. The results of the proximate content analysis on tempe can be seen in Table 6. Based on the Indonesian National Standard of tempe SNI 3144:2015, the parameters of both products meet the requirements set by SNI.

The protein content of tempe analysis results showed significant differences with the lowest protein content in 100% velvet tempe at 16.06%, and combined velvet bean -soybean tempe at 18.47%. The decrease in protein content in tempe is caused by several factors including steaming or the use of heating and the length of fermentation. The longer soaking of the seeds caused a decrease in protein content, this was caused by an increase in water content during processing and fermentation. In boiling, hydration occurs because water diffuses into the beans. Boiling beans can cause several quality changes, both physically, biochemically, and nutritionally (Pramita *et al.,* 2008). The longer fermentation can reduce protein levels because, during the fermentation process, enzymes produced by molds can hydrolyze proteins into amino acids that can be utilized by molds for growth and development (Amanah *et al.,* 2019). The low protein content in tempe is caused by protein denaturation, which causes the protein to agglomerate and its solubility to decrease (Kusyawati *et al.,* 2015).

https://doi.org/10.26656/fr.2017.8(S4).3

Table 5. Verification of the optimum formula recommended by RSM.

Variables	Pred. value	Verification value	95% CI		95% PI	
			Low	High	Low	High
Protein Content (%)	18.18	18.47	17.73	18.63	17.24	19.12
Hardness (gf)	21.49	20.41	19.92	23.06	18.22	24.76

Table 6. Chemical composition of tempe for the combination of velvet beans and soybeans, 100% composition of velvet tempe and 100% soybeans tempe.

Parameters	Velvet tempe	Combination of velvet-soybeans tempe	Soybeans tempe	*Standard (SNI 3144:2015)
Moisture (%)	64.02±0.01[b]	61.28±0.01[a]	58.06±0.03[a]	Max 65
Ash (%)	0.43±0.01[a]	0.42±0.01[a]	0.60±0.02[b]	Max 1.5
Fat (%)	0.36±0.01[a]	2.60±0.01[b]	5.51±0.19[c]	Min 7
Protein (%)	16.06±0.02[a]	18.47±0.66[b]	20.83±0.15[c]	Min 15
Carbohydrate (%)	19.13±0.04[b]	17.22±0.65[a]	14.99±0.23[a]	-

Values are presented ad mean±SD. Values with different superscripts within the same row are statistically significantly different at the $\alpha = 0.05$ level.
*Indonesia National Standard (2015).

The water content will play an important role in the growth of mold mycelia. On the other hand, high carbohydrate content affects the texture of the resulting tempe. According to Kusyawati *et al.* (2015), the texture of tempe was impacted by factors such as protein and water content. CO_2 molecules interact with protein molecules inside the tempe matrix via noncovalent interactions, specifically hydrogen and hydrophobic bonds. Denatured proteins originate from the interaction of supercritical CO_2 molecules with proteins. Proteins that have been denatured produce a gel structure. The lower water content caused by high-pressure CO_2 extraction aids in the creation of an elastic texture. The higher the carbohydrate value, the harder the texture of a food (Diniyah *et al.,* 2014). Conversely, high levels of carbohydrates will also affect the distinctive aroma produced through the fermentation process (Sudiyono 2010). According to Astuti *et al.* (2000), carbohydrates contained in soybeans are complex carbohydrates, including sucrose, starch and oligosaccharides that cause flatulence, such as stachyose and raffinose.

Measurement of ash content in tempe 100% velvet and tempe combination velvet bean-soybean showed results that were not significantly different where the higher the ash content in food, the higher the mineral content in the food. One of the determining factors in ash content is fermentation time, where a longer fermentation time will increase ash content. Research by Febriani *et al.* (2019) showed that the increase in ash content is caused by protein content in mung beans. Protein that binds to minerals during the fermentation process will be hydrolyzed by protease enzymes produced by microbes into simpler compounds, which will increase the ash content. There are various factors that can affect the ash content of tempe during the manufacturing process, namely washing, soaking, and the process of removing the epidermis. Furthermore, the loss of minerals is due to the leaching and physical separation processes. This indicates that there are many minerals in the epidermis layer of soybeans (Astawan *et al.,* 2013).

3.5 Sensory analysis

3.5.1 Hedonic rating

Sensory analysis was conducted by comparing 100% velvet tempe, the combination of velvet and soybean tempe, and 100% soybean tempe for consumer acceptance response. A total of 50 panelists have tested the characteristics of aroma, color, texture, appearance, taste, and overall characteristics. To avoid bias, the shape and size of fresh and fried tempe are similar. Tempe frying at 120°C for 5 mins produced an ensemble level of readiness. The test results can be seen in Table 7.

Based on the data, there was an increase in panelists' preference for the velvet-soybean combination tempe compared to 100% velvet tempe in all characteristics. This combination tempe also has an interest level that is close to 100% soybean tempe in aroma, texture, flavor, and overall characteristics. This indicates that the addition of soybean (65-70%) in the making of velvet tempe has a significant effect on improving the sensory acceptance of tempe. Feng *et al.* (2007), the aroma of tempe is produced from the breakdown of linoleic acid, which is the dominant fatty acid in soybeans, to 1-*octen*-3-ol by lipoxygenase and *hydroperoxide lyase* enzymes. The research by Rahmawati *et al.* (2021), there was an increase in sensory liking for the combination of soy-based tempe (75%) and red beans (25%) with an overall score of 7.18 on the hedonic scale, which means the panelists rated their liking as somewhat like. The optimum formula had an overall score of 5.64 on fresh tempe and 5.48 on fried tempe which means that

Table 7. Hedonic rating test result of velvet beans, optimal and soy tempe

Sensory characteristics	Velvet Tempe	Optimal tempe	Soybeans tempe
Fresh tempe			
Aroma	3.48±1.97[a]	5.58±1.10[b]	6.00±1.04[b]
Color	2.94±1.53[a]	5.22±1.03[b]	6.64±0.56[c]
Texture	4.08±1.58[a]	5.66±1.15[b]	6.04±0.80[b]
Appearance	3.60±1.74[a]	5.44±1.14[b]	6.50±0.58[c]
Overall	3.68±1.64[a]	5.64±0.92[b]	6.44±0.57[c]
Fried tempe			
Aroma	3.88±1.53[a]	5.64±1.02[b]	6.02±0.82[b]
Color	2.48±1.23[a]	4.74±1.36[b]	6.44±1.07[c]
Texture	3.60±1.44[a]	5.43±1.14[b]	5.88±0.93[b]
Appearance	2.86±1.41[a]	4.94±1.39[b]	6.22±0.91[c]
Taste	2.84±1.48[a]	5.14±1.17[b]	5.92±0.80[c]
Overall	3.04±1.32[a]	5.48±0.90[b]	6.04±0.60[c]

Values are presented ad mean±SD. Values with different superscripts within the same row are statistically significantly different at the $\alpha = 0.05$ level.

panelists rated the liking from somewhat like to like.

3.5.2 Rate-all-that-apply sensory profile

Analysis using RATA method aims to determine consumer perception in determining the characteristics of a product. The advantage of using this method is the opportunity given to panelists to describe how much the intensity of the characteristic is, so it is expected to provide an overview of the specific sensory profile and definition of each tempe sample (Vidal *et al.,* 2018). The results of RATA intensity testing 100% velvet bean tempe samples, soybean-velvet bean combination tempe, and 100% soybean tempe are shown in Table 8 and Table 9. Based on the table, it can be concluded that fresh tempe samples using 100% velvet bean, velvet bean-soybean combination, and 100% soybean have characteristics of color (grey-white) that are significantly different.

The color attribute (whiteness and yellow-white) of the optimal combination of tempe are significantly higher than those of velvet bean tempe. The research by Antarlina *et al.* (2021), 24-hour soaking treatment in sorghum flour can increase whiteness because this treatment can inhibit the enzymatic browning reaction caused by the phenolase enzyme found in the seeds. Furthermore, the soaking treatment triggers spontaneous fermentation resulting in the growth of lactic acid bacteria, so that the pH of the solution decreases and increases the degree of whiteness (Kinanti *et al*., 2014).

Table 8. Testing result of fresh tempe intensity.

Sensory characteristics	Velvet tempe	Optimal tempe	Soybeans tempe
Fresh Tempe			
Beany	7.98±4.42[a]	10.69±2.86[b]	10.51±3.34[b]
Mushroom	8.75±3.86[a]	8.22±4.14[a]	7.52±3.90[a]
Sweetness	3.35±3.52[b]	3.97±3.40[b]	3.51±2.91[b]
Rancid	6.06±4.67[c]	3.32±3.10[b]	2.68±2.52[b]
Fermented	10.23±3.59[c]	7.78±4.12[b]	6.33±4.19[ab]
Whiteness	4.91±4.07[a]	7.42±3.82[bc]	9.27±3.79[c]
Yellow-white	2.56±2.50[a]	8.33±3.15[b]	10.60±3.08[c]
Gray-white	11.59±1.87[d]	7.29±3.06[c]	2.08±3.06[b]
Brown-ebony	6.44±4.63[c]	3.58±3.29[b]	1.78±1.69[ab]
Golden-yellow	2.18±2.11[a]	4.99±3.72[bc]	6.57±4.29[c]
Yellow-brown	2.23±2.00[b]	4.42±3.57[c]	3.23±2.82[bc]
Softness	5.04±3.26[a]	7.61±3.70[b]	9.53±3.81[b]
Hardness	9.65±3.25[c]	7.03±3.56[b]	5.88±3.53[b]
Integrated	8.73±3.96[a]	7.84±4.18[a]	8.23±4.34[a]
Solid-compact	11.43±2.13[ab]	10.67±2.43[a]	11.12±2.34[a]
Fibrous	8.89±3.82[b]	8.82±3.19[b]	8.88±3.57[b]

Values are presented ad mean±SD. Values with different superscripts within the same row are statistically significantly different at the $\alpha = 0.05$ level.

Tabel 9. Testing result of fried tempe intensity.

Sensory characteristics	Velvet tempe	Optimal tempe	Soybeans tempe
Fried Tempe			
Beany	8.45±3.79^{a}	9.28±3.10^{ab}	10.87±2.49^{bc}
Mushroom	7.15±4.20^{b}	4.75±3.30^{a}	5.36±3.77^{ab}
Sweetness	3.45±3.17^{b}	3.29±2.84^{b}	3.94±3.17^{b}
Rancid	5.44±3.85^{c}	2.79±2.54^{b}	2.78±2.76^{b}
Fermented	7.68±4.11^{c}	4.92±3.46^{b}	4.59±3.57^{b}
Whiteness	2.27±2.30^{a}	4.46±3.37^{b}	5.19±3.97^{b}
Gray-white	2.34±2.44^{a}	6.45±3.54^{b}	7.32±4.46^{b}
Gray-ebony	8.43±4.45^{d}	5.43±3.23^{c}	2.27±2.05^{b}
Brown-ebony	8.80±4.02^{d}	5.11±3.49^{c}	2.06±1.99^{b}
Golden-white	2.86±2.64^{a}	8.49±3.14^{b}	12.01±2.05^{c}
Yellow-brown	2.88±2.59^{a}	8.04±3.15^{c}	6.40±3.38^{bc}
Softness	4.85±3.69^{a}	5.85±3.47^{a}	8.57±3.82^{b}
Hardness	9.06±3.53^{c}	7.21±3.51^{bc}	5.75±3.95^{b}
Integrated	8.73±3.28^{a}	8.97±3.10^{a}	9.75±3.01^{a}
Solid–compact	10.19±2.70^{a}	11.12±1.36^{a}	10.57±3.49^{a}
Fibrous	7.44±3.98^{a}	7.29±3.34^{a}	7.19±3.86^{a}
Nutty	9.89±3.94^{a}	11.25±1.78^{bc}	11.48±1.66^{b}
Savory/umami	4.11±3.01^{a}	6.04±3.51^{bc}	6.84±3.93^{c}
Sourness	6.75±4.17^{c}	3.85±2.81^{b}	3.36±2.89^{b}
Oily	6.82±3.841^{ab}	7.04±3.431^{b}	8.22±4.34^{b}
Bitter	6.99±4.23^{c}	3.04±2.57^{b}	2.36±2.11^{b}

Values are presented ad mean±SD. Values with different superscripts within the same row are statistically significantly different at the α = 0.05 level.

All color characteristics of tempe 100% velvet bean and tempe velvet bean-soybean combination showed a significantly different characteristic with tempe 100% soybean. It is caused by the natural color of velvet as the raw material for making tempe which is different from the natural color of soybeans.

The sensory characteristics in Table 8 and Table 9, showed that the two types of tempe samples produced characteristics of aroma (mushroom and beany), whiteness, and taste (nutty) that were not significantly different. Meanwhile, the use of a velvet bean can also provide aroma (mushroom and rancid), color (gray-ebony and brown-ebony), hardness and taste (sourness and bitter) characteristics that were significantly different from the combination of velvet bean and soybean tempe. The appearance of a bitter taste was reported by Aluko (2017) to be caused by the amino acid composition of valine, leucine, tryptophan and phenylalanine in red beans which contributes to the bitter taste of food. Furthermore, the release of low molecular weight peptides containing hydrophobic amino acid residues in the form of leucine and phenylalanine is the reason for the perception of bitterness (Cosson *et al.,* 2022).

The distribution of characteristics of fresh and fried tempe made from 100% velvet bean, a combination of soybean and velvet bean, and 100% soybean according to panelists are shown in Figure 2 and Figure 3. The position of the characteristic dots in the graph shows the correlation between characteristics. Characteristic points that are positioned close together and form an angle of less than 90° from the center point or are in the same quadrant indicate a positive correlation. Characteristics that are positively correlated with other characteristics will experience an increase in intensity if one of the characteristics experiences an increase in intensity. Conversely, characteristic points that are far apart and form an angle of more than 90° from the center point or they are in different quadrants have a negative

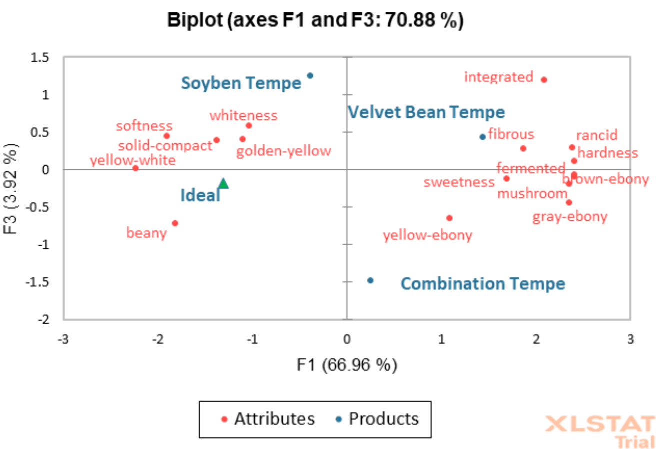

Figure 2. Biplot of characteristics of fresh tempe with 100% velvet bean. velvet bean-soybean combination, and 100% soybean as raw materials.

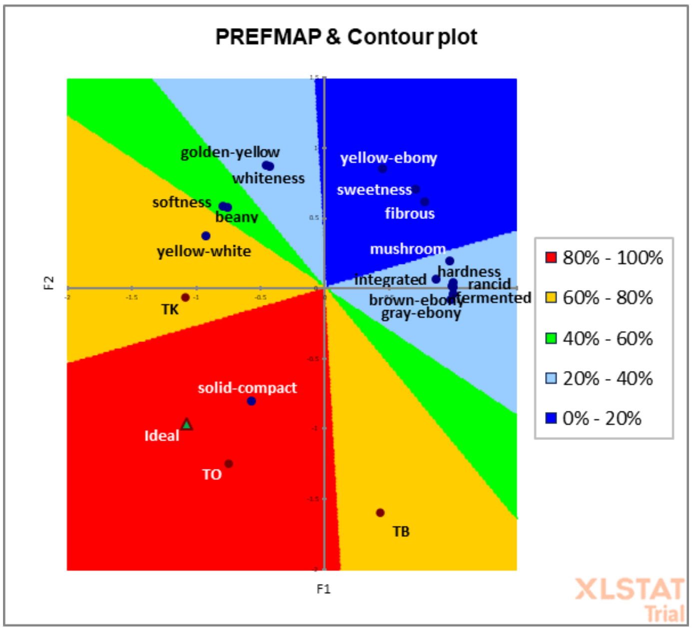

Figure 3. Preferences mapping of fresh tempe attributes and ideal products based on panelists' perceptions. TB: velvet bean tempe, TO: Optimal Combination Tempe, TK: Soybean Tempe.

correlation or no correlation (Xiao *et al.,* 2015). The F1 and F3 factors were chosen with the consideration that these two factors were better able to explain 70.88% of the variety and distribution of attributes in three types of fresh tempe and ideal tempe products (Figure 2). According to Rogness (2011), a good graph can explain at least 70% of the variance.

In fresh velvet bean tempe samples, the integrated characteristic is perceived to increase in intensity when the intensity of rancid, hardness, and fibrous appearance increases. The intensity of brown-ebony color on the combination tempe of velvet bean and soybean will increase along with the increase of fermented aroma and grey-ebony color. Conversely, the intensity of the brown -ebony will be perceived to decrease if the intensity of the characteristic whiteness, yellow-white dan softness increases. In fried tempe samples, the intensity of gray-ebony characteristics is perceived to increase if the intensity of brown-ebony, hardness and fibrous appearance increases. Conversely, the intensity of the nutty characteristic will be perceived to decrease if the intensity of the fermented increases.

The attribute of rancid aroma comes from the activity of the lipase enzyme which causes fat hydrolysis resulting in the production of short fatty acids which ome through chemical esterification to produce these acids (Gunawan-Puteri *et al*., 2015). Furthermore, Jeleǹ *et al.* (2013), reported that processing using heat such as frying contributes to an increase in aldehydes in fried tempe after 24 hrs of fermentation. This compound contributes to the oily and rancid taste, where the increase in the amount of aldehydes is related to the use of oil in the frying process as a source of aldehydes formed during the autooxidation process. On the other hand, Ben-Harb *et al*. (2022), there was an increase in the concentration of 1-penten-3-one, 1-octen-3-one, and 3-octen-2-one which contributed to the mushroom aroma of processed fermented products.

The attributes of aroma (beany), color (whiteness, gray-white, golden-yellow, and yellow-brown), taste (nutty, and savory/umami) of the optimal combination fried tempe were significantly higher than fried velvet bean tempe. A beany aroma is commonly found in soy-based fermented products. This aroma appears to be caused by a mixture of volatile compounds in the form of methyl-1-butanol, hexanal, 2,4-decadienal, dimethyl disulfide (Ben-Harb *et al*., 2022).

The addition of 60 to 70% soybeans was able to increase the panelists' assessment of the intensity of color attributes in fried tempe. The resulting color attributes are in line with research by Kustyawati *et al.* (2017), panelists described the color attributes yellow-white, white, gray-white, dense, compact and integrated texture as the dominant attributes in modified tempe with the addition of Saccharomyces serevisiae using the free-choice profiling method. Furthermore, Hemmler *et al.* (2018), the amino acid content in the form of glutamic acid, lysine, isoleucine and glycine is reactive and contributes to the Maillard reaction. The relatively high intensity of the reaction of free amino acids with reducing sugars in tempe produces a yellow-brown color with the highest intensity felt by the panelists (Starowicz and Zieliński, 2019; Dahlan *et al.,* 2022).

The fermentation process can increase the savory/umami taste attribute which is grouped as monosodium glutamate and is used as an umami seasoning. A greater increase in umami taste occurs when the amino acid groups glutamate and aspartate are mixed with umami nucleotides (Kawai *et al*., 2009)

Fresh tempe from a combination of velvet bean and soybean had dominant characteristics of aroma (sweetness, fermented and mushroom) and color (yellow -ebony, brown-ebony and gray-ebony). In fried tempe samples, panelists perceived tempe made from 100% soybean as having goden-yellow color, savory-umami aroma, softness, integrated texture and beany taste. Fried tempe made from 100% velvet bean was perceived to have dominant characteristics of mushroom, sweetness, rancid, fermented, oily, bitter dan sourness. Meanwhile, tempe from the combination of velvet bean and soybean was perceived to have dominant characteristics of brown -ebony, gray-ebony, hardness, dan fibrous appearance.

Preference mapping is an analysis in the form of a contour plot with various colors that explains the percentage of panelists' preferences for the product being tested (Adawiyah *et al*., 2020). The red area shows the highest level of panelist preference (80-100%), followed by the yellow area (60-80%), green (40-60%), light blue (20-40%), and dark blue (0-20 %). Apart from that, the overlay on the contour plot of the PCA biplot graphic illustrates the correlation between panelists' preferences and types of fresh tempe which have certain characteristics, so that information about these characteristics can be useful in product development.

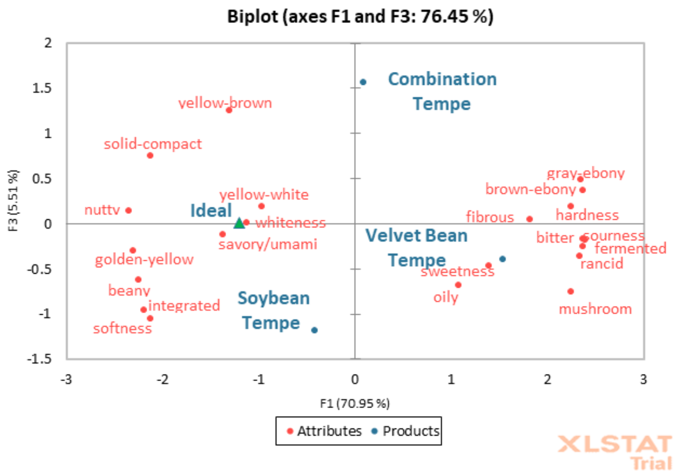

Figure 4. Biplot of characteristics of fried tempe with 100% velvet bean, velvet bean-soybean combination, and 100% soybean as raw materials.

The preferences mapping of the three types of tempe products based on panelists' perceptions (Figure 4), it can be showed that the tendency of panelists' preferences for ideal tempe products and the optimal combination tempe of velvet bean and soybean is in the red area, indicating that panelists' preferences reach 80-100%. Fresh soybean tempe and fresh velvet bean tempe are in the yellow area, indicating that the panelists' preference for these two products reached 60-80%. The distribution of each type of fresh tempe is also in different quadrants. Based on the preference map, it is clear that the ideal product, the optimal combination of velvet bean and soybean and 100% soybean tempe are in the same quadrant, even though the panelists' preferences show areas in different colors.

The preference mapping not only shows the panelists' preferences for the products they like, but also shows the panelists' preferences for their sensory attributes. The solid–compact appearance attribute is in the red area, which means that the panelists' liking for this attribute is 80-100% and this attribute point is in the same quadrant as the ideal product, fresh optimal combination tempe and fresh soybean tempe. The yellow -white attribute is in the yellow area with a panelist preference of 60-80%, followed by the beany and softness attributes which are in the green area with a panelist preference of 40-60%. Attributes located in the light blue area are mushroom, hardness, rancid, fermented, brown-ebony, gray-ebony, golden-yellow, whiteness, and integrated, have a panelist preference of 20-40%. The attributes that are most disliked are yellow-ebony, sweetness, and fibrous appearance.

The panelists' preference mapping was obtained from the XLSTAT 2023 software. The results of the analysis are displayed in the form of a contour plot graph (liking map). Based on the preferences mapping of fried tempe and ideal tempe products (Figure 5), shown that the ideal tempe is in the red area, which means that the panelists gave a preference value of 80-100%, fried soybean tempe and the optimal combination tempe of velvet bean and soybean are in the yellow area, indicating the panelists' preferences of 60-80%, while velvet bean tempe in the green area, which means the panelists gave a quite favorable rating of 40-60%.

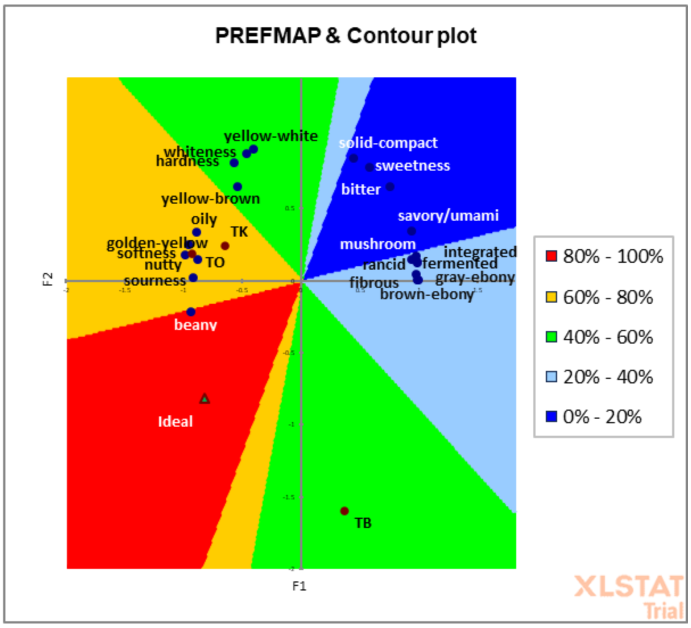

Figure 5. Preferences mapping of fried tempe attributes and ideal products based on panelists' perceptions. TB: velvet bean tempe, TO: Optimal Combination Tempe, TK: Soybean Tempe.

Based on the distribution of attributes in the contour plot (Figure 5), the attributes that had quite higher intensity by the panelists were beany aroma, golden-yellow color, yellow-brown, whiteness, yellow-white, texture, hardness, softness, and nutty, oily, sourness. The aroma (sweetness, rancid, mushroom, and fermented), color (brown-ebony and gray-ebony) texture (integrated), taste (savory-umami and bitter), and solid-compact, fibrous appearance has somewhat like by the panelist.

4. Conclusion

Optimization of tempe formula using mixture experiment influences the protein content and hardness value. The optimum tempe formula of velvet and soybean combination is 30.62% velvet and 69.37% soybean as determined through experimental method. The optimum formula has an overall score of 5.64 on fresh tempe and 5.48 on fried tempe which means that panelists rated the interest from somewhat like to like. Based on the RATA test, the combined tempe formula of velvet and fried soybean has dominant characteristics of color (brown-ebony, gray-ebony), texture (hardness) and fibrous appearance. Fresh tempe has the intensity of aroma characteristics (mushroom, sweetness and fermented) and color (yellow-ebony and brown-ebony). The recommended optimal formula also meets the requirements in accordance with the Indonesian National Standard (SNI 3144:2015) on tempe products.

Conflict of interest

The authors declare no conflict of interest.

Acknowledgements

The authors are very grateful for financial support from the Directorate General of Higher Education, Research, and Technology; Ministry of Education, Culture, Research, and Technology of the Republic of Indonesia through the "Penelitian Dasar Kompetitif Nasional" scheme, the fiscal year 2023 under Made Astawan.

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