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UTILIZATION OF CORN *(Zea mays)* AS A COMBINATION INGREDIENT IN TOFU PRODUCTION WITH THE ADDITION OF *IE ASAM SUNTI* EXTRACT AND *IE KULOH SIRA* EXTRACT AS NATURAL COAGULANTS

Radhia Ulfa Rahmi[1*], Salmyah[1], Ratna Sari[1]
[1] Department of Chemical Engineering, State Polytechnic of Lhokseumawe
JL. Banda Aceh – Medan Km. 280.3, Buketrata, Mosque Punteut, Blang Mangat,
Lhokseumawe City, Aceh 24301, Indonesia
*Email: radhiaulfarahmi1908@gmail.com

Abstract

This study aims to examine the effect of coagulant volume and the addition of corn on the characteristics of tofu. The method used is Central Composite Design (CCD), which is part of the Response Surface Methodology (RSM), along with organoleptic testing to assess consumer acceptance. The raw material variations consist of combinations of soybean and corn in the ratios of 900 g:100 g, 800 g:200 g, 700 g:300 g, 600 g:400 g, and 500 g:500 g, as well as coagulant volumes of ie asam sunti and ie kuloh sira ranging from 100 to 300 ml. The results showed that the best combination was 700 grams of soybean and 300 grams of corn with 250 ml of ie asam sunti, producing a texture of 200 mm/second, pH 5.6, protein content of 5.6%, and a yield of 75%. Meanwhile, 250 ml of ie kuloh sira produced a texture of 240 mm/second, pH 5.8, protein content of 5.8%, and a yield of 75%. Organoleptic testing was conducted using a hedonic scale to determine consumer preference for the resulting tofu. The evaluation covered aroma, taste, and color, which are important indicators of the acceptability of corn tofu products..

***Keywords**: ie asam sunti, ie kuloh sira, soybean, corn tofu,*

PENDAHULUAN

Tofu is a solid food product made by processing soybeans *(Glycine sp.)* through protein precipitation, with or without the addition of other permitted ingredients [1]. The main ingredient in tofu production is soybean (*Glycine max),* which is rich in protein, low in saturated fat, and contains various beneficial micronutrients such as calcium and iron. Soybeans are chosen as the primary ingredient because of their ability to form a solid mass produced through the protein coagulation process in soy milk.

Along with advances in food innovation, tofu processing continues to diversify in both ingredients and production methods. One such diversification effort is the incorporation of local ingredients, such as corn (Zea mays), in tofu production.

Corn is a food ingredient rich in carbohydrates, fiber, and vitamin A, which can enhance the nutritional content of tofu while adding variation in texture and flavor. Combining soybeans and corn in tofu production is believed to create a tofu product with new and more diverse characteristics in terms of nutrition, texture, and taste [2]. The proportion of soybeans to corn in the tofu mixture plays an important role in determining the final product quality.

Because corn contains more starch, it can produce tofu with a firmer and chewier texture.

This is expected to provide an alternative for consumers seeking tofu with a more unique and appealing texture compared to conventional tofu, which tends to be soft [3]. The basic principle of tofu production is extracting soybean protein with water, followed by the use of a coagulant to precipitate the protein.

In the production of silken tofu, the coagulant commonly used is *Glucono Delta-Lactone (GDL)* [4]. In addition, several types of artificial coagulants are commonly used in tofu production, such as acetic acid and "batu tahu" (gypsum).

The addition of gypsum as a coagulant does not contribute to product preservation, making it necessary to add other substances such as salt—or even formalin, which is highly hazardous to health. Therefore, exploring eco-friendly and natural coagulant alternatives for tofu production is essential to reduce the adverse effects of conventional coagulants.One potential natural coagulant is the extract of *ie asam sunti* and *ie kuloh sira.*

Ie asam sunti is a by-product obtained from the production of asam sunti, containing a very high level of acidity, primarily *citric acid.* Meanwhile, *ie kuloh sira* is an Acehnese term referring to a salt solution used in food preparation, including tofu making. In tofu production, *ie kuloh sira* serves to enhance flavor, extend shelf life, and improve the texture of the final product.

Previous studies have shown that *ie asam sunti* can coagulate soybean protein into tofu and can also be used as a preservative [5]. However, because *ie asam sunti* has a very high citric acid content, excessive use as a coagulant can give the tofu a sour taste. Another drawback of *ie asam sunti* as a coagulant is its relatively low yield.

RESEARCH METHODOLOGY

Time and Place

The research was conducted at the Biotechnology and Food Laboratory of the Chemical Engineering Department, Politeknik Negeri Lhokseumawe, and at the Pupuk Iskandar Muda Laboratory. The study took place from January to June 2025.

Materials and Equipment

Materials

The materials used in this study were soybeans, corn**,***ie asam sunti, ie kuloh sira,* aquadest, NaOH, Indicator *methyl red*, H_2SO_4, dan H_3BO_4,

Equipment

The equipment used in this research included a blender, strainer, stirrer, and cooking pot, research included a blender, strainer, stirrer, and cooking pot, basin, stove, analytical balance, thermometer, plastic molds, texture analyzer, beakers, petri dishes, Erlenmeyer flasks, volumetric pipettes, bulb pipettes, drop pipettes, graduated cylinders, Gerber tubes, centrifuge, water bath, Kjeldahl flask, and test tubes.

Tofu Making Process

Soy milk is made using a procedure previously reviewed by researchers [7]. First, the soybeans are prepared and sorted. Then, the soybeans are thoroughly washed and soaked for 5 hours in a 3:1 water:soybean ratio. The soaking process allows the soybeans to absorb more water, softening them and making them easier to peel. Peeling the skin is done by squeezing them in water, then discarding the skin. Peeling the soybeans reduces the amount of fiber or other insoluble substances that can hinder the extraction process and improves the color of the resulting soybean extract.

Next, the soybeans are drained and washed three times. After washing, they are ground in a blender and hot water at 80°C is added at a soybean-to-water ratio of 1:5. The resulting soybean pulp is filtered and the dregs are separated.

Protein Analysis Procedure

The Kjeldahl method for analyzing protein content in tofu involves three main steps: digestion, distillation, and titration. The tofu sample is first digested with concentrated sulfuric acid and a catalyst to convert organic nitrogen to ammonium sulfate. The solution is then neutralized with NaOH, producing ammonia gas, which is then distilled and captured in a boric acid solution. The final step is titration of the capture solution with a standard acid to determine the nitrogen content, which is then converted to protein content using a factor of 6.25.

pH Analysis Procedure

Tofu acidity analysis is performed using pH paper. The first step is to prepare the pH paper. Then insert the sample into glass beaker, then dip the pH paper into the beaker containing the sample and measure the pH. Record the results obtained.

Texture Analysis Procedure

The tool used for texture analysis is a texture analyzer. The first step is to connect the power cord to the switch and press the "ON" power button. Then, attach the probe appropriate to the sample to be analyzed. Set the trigger, distance, and speed according to the sample to be analyzed. Place the sample in its place and adjust its height. Press "start." Record the results displayed on the monitor. Turn off the device by pressing the "OFF" button. Unplug the power cord. Ensure the device is always in good condition and clean.

Yield Test Procedure

Tofu yield testing is conducted to determine the efficiency of the tofu-making process from soybeans. Yield is calculated by comparing the weight of the resulting tofu to the weight of the original soybeans used. After the production process is complete, the pressed tofu is weighed.

Organoleptic Testing

Organoleptic testing was conducted using the hedonic (preference) method. The test was conducted with 25 panelists. Panelists were asked to rate silken tofu with varying coagulant types. Assessments were based on likes and dislikes, with general preference taken into account. The test included color, aroma, taste, and overall evaluation of the samples using a numerical scale.

RESULTS AND DISCUSSION

The Effect of Soybean Weight, Corn, Sunti Acid Rice, and Kuloh Sira Rice on Tofu Protein Content

The effect of the weight of soybeans, corn, namely asam sunti and ie kuloh sira on the protein content of tofu is given in Figures 1 and 2

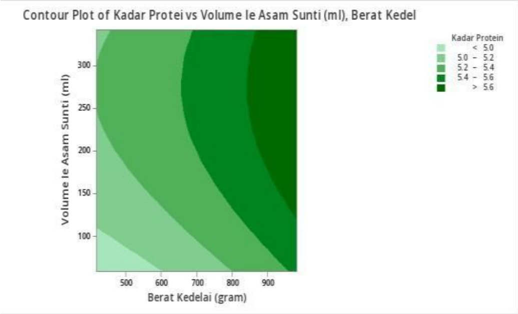
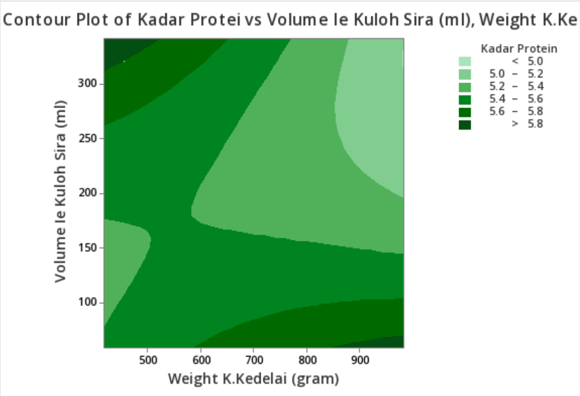


Figure 1. Contour plots of the relationship between soybeans, corn, and sunti acid on tofu protein content.

Based on the contour plot and Figure 1, tofu protein content is influenced by the volume of coagulant (i.e., sunti acid) and the weight of soybeans and corn. Coagulant volumes below 150 ml are less effective at coagulating protein, resulting in a low protein content (~5.0%). The optimal volume of 250 ml is capable of maximally coagulating protein, increasing protein content to ~5.6%. The weight of the raw material also has an impact; if the weight exceeds 800 grams without adjusting the coagulant volume, the protein content actually decreases. The best combination for the highest protein content is found with a material weight of 500–700 grams and a coagulant volume of 250 ml.

Figure 2. Contour plots of the relationship



between soybeans, corn, and dried soybeans on tofu protein content.

Figure 2 shows that tofu protein content is influenced by the combination of dried soybean volume and soybean weight. The highest protein content (5.6–5.8%) was achieved at a coagulant volume of 250–300 mL and a soybean weight of 850–900 grams, as indicated by the light green area in contour plot. This shows that the combination of high raw material and sufficient coagulant volume increases coagulation efficiency. The surface plot also indicates an optimal point, where the interaction of the two variables results in maximum protein content. If either variable is too low or too high, protein precipitation efficiency decreases, resulting in a decrease in protein content.

The Effect of the Weight of Soybeans, Corn, Ie Asam Sunti, and Ie Kuloh Sira on Tofu pH

The effect of the weight of soybeans, corn, Ie asam sunti, and Ie kuloh sira on tofu pH is shown in Figures 3 and 4.

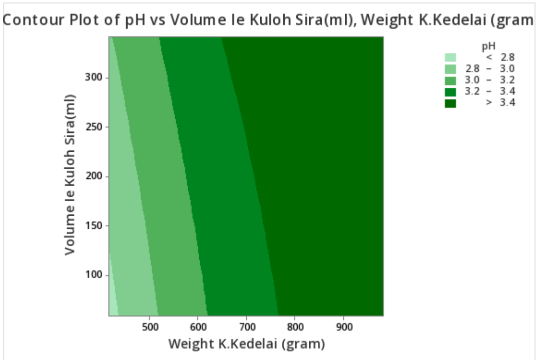


Figure 3. Contour plots of the relationship between soybeans, corn, and ie asam sunti on tofu pH.

Based on analysis using Response Surface Methodology (RSM), it was found that soybean weight and ie asam sunti volume significantly influenced tofu pH. The contour plots indicate an interaction between the two variables, where increasing both increases the pH to an optimum point, then decreases beyond the optimum level. The highest pH (3.32–3.34) was achieved with a soybean weight of 275 grams and a coagulant volume of approximately 825 ml, indicating a highly effective coagulation process. However, the best combination recommended is a soybean weight of 275 grams and a ie asam sunti volume of 250 mL, as this produces an optimal pH and is considered most suitable for tofu production with natural coagulants.

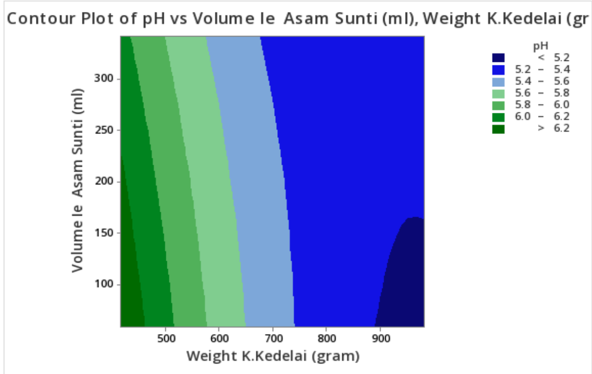


Figure 4. Contour plots of the relationship between soybeans, corn, and tofu pH.

Based on the contour plot analysis, the best combination for producing the ideal tofu pH is a coagulant volume of 200–225 ml and a soybean weight of 600–700 grams. This combination results in the tofu pH within the optimal range of 5.4–5.6, meeting quality standards, with a firm but not hard texture and without excessive sourness. The contour plot shows a yellow to light green area in this combination, indicating a pH close to neutral, which is desirable for taste and shelf life. Conversely, a coagulant volume exceeding 250 ml causes the pH to drop below 5.0, resulting in tofu that is too sour and soft.

The Effect of the Weight of Soybeans, Corn, Ie Asam Sunti, and Ie Kuloh Sira on Tofu Texture

The effect of the weight of soybeans, corn, Ie asam sunti, and Ie kuloh sira on tofu texture is shown in Figures 5 and 6.

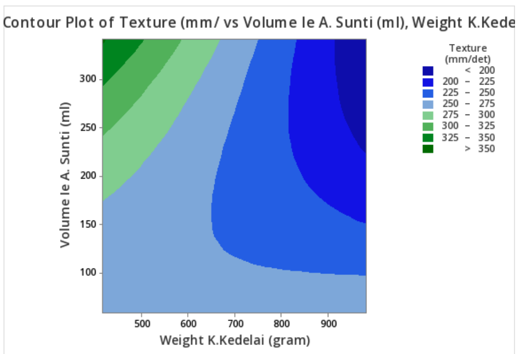


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Figure 5. Contour plots of the relationship between soybeans, corn, and sunti acid on tofu texture.

Figure 5 shows that tofu texture is influenced by the volume of sunti acid, soybean weight, and corn weight. The best combination for a firm and stable texture is found at a sunti acid volume of 100–150 ml, a soybean weight of 800–1000 grams, and a corn weight of 100–200 grams, with a penetration rate of approximately 200 mm/second. Conversely, a high coagulant volume (250–300 ml) and a low soybean weight (approximately 500 grams) result in a soft and less stable texture, characterized by a higher penetration rate.

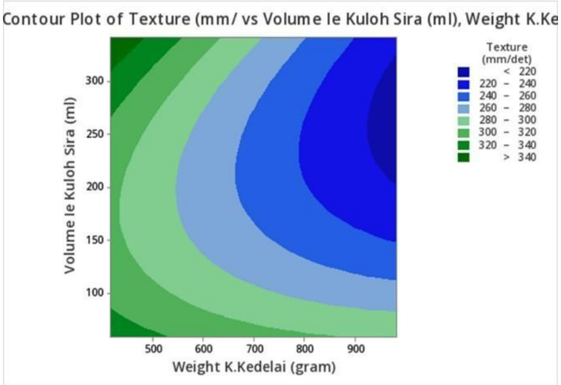

Figure 6. Contour plots on the relationship between soybeans, corn, i.e. kuloh sira and tofu texture

Figure 6 shows that tofu texture is influenced by the interaction between the volume of the coagulant, the weight of the soybeans, and the weight of the corn. The best texture value (200–240 mm/s), reflecting firm and non-crumbling tofu, was obtained with a combination of a coagulant volume of 100–200 ml, a soybean weight of 800–900 grams, and a corn weight of 100–200 grams, indicated by dark to light blue on the contour plot. Conversely, the combination of a high coagulant volume (200–300 ml), a low soybean weight (400–500 grams), and a high corn weight (500–600 grams) produced a chewy and easily crumbly texture, with a value above 320 mm/s (green). Therefore, the optimal combination for producing tofu with a firm texture is a volume of 100–200 ml, a soybean weight of 900 grams, and a corn weight of 100 grams

The Effect of the Weight of Soybeans, Corn, Sunti Acid, and Kuloh Sira on Tofu Yield

The effect of the weight of soybeans, corn, Sunti Acid, and Kuloh Sira on tofu yield is shown in Figures 7 and 8.

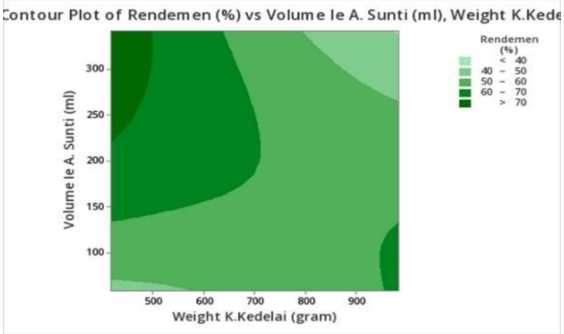

Figure 7. Contour plots of the relationship between soybeans, corn, and ie sunti acid on tofu yield.

Based on Figure 7, the combination of ie sunti acid volume and soybean weight significantly affects tofu yield (%). The highest yield (70–75%) was obtained with a high ie sunti acid volume (~300 mL) and medium to low soybean weight (500–600 grams), indicated by the light to dark green area on the contour plot. Conversely, the lowest yield (<50%) occurred with a low coagulant volume (<150 mL) and high soybean weight (800–900 grams), due to an imbalance between protein and coagulation capacity. The surface plot also shows a peak yield at the combination of a high coagulant volume and medium soybean weight, due to more optimal protein coagulation.

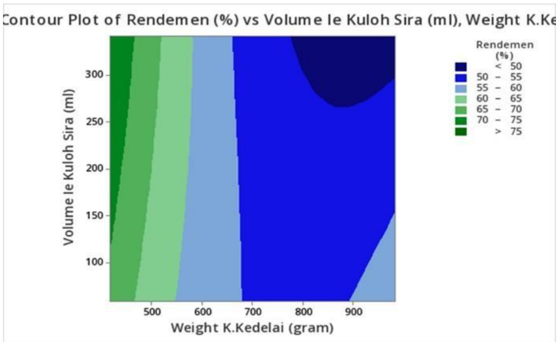

Figure 8. Contour plots on the relationship between soybeans, corn, *ie kuloh sira* and tofu yield

Based on Figure 8, the combination of coagulant volume and soybean weight significantly affects tofu yield. The highest yield (70–75%) is achieved at a coagulant volume of approximately 300 ml, a soybean weight of 900 grams, and a corn weight of 100 grams, indicated by the light to dark green area on the contour plot. Conversely, the lowest yield (<50%) occurs when the coagulant volume is low (100–150 ml), despite the high soybean weight, indicated by the blue color. This indicates that sufficient coagulant volume is crucial for optimal protein coagulation. The surface plot supports this finding by showing a peak yield at the combination of high coagulant volume and medium–high soybean weight, and a sharp decrease in yield as the coagulant volume decreases.

Organoleptic Testing of Tofu Using Ie Asam Sunti and Ie Kuloh Sira Coagulants

The organoleptic testing in this study was conducted by providing an explanation to all panelists and then providing them with a questionnaire containing instructions and scores for the color, aroma, and taste of silken tofu.To determine the most preferred preparation, an assessment was conducted by summing the panelists' scores according to the given parameters. The highest-scoring parameter was totaled and divided by the number of panelists to obtain the organoleptic test score.

Organoleptic Color Test

The hedonic organoleptic test of tofu using *ie asam sunti* showed that panelists liked the color of the tofu. Of the 25 panelists, tofu made using *ie asam sunti* coagulant received an average color score of 4.20, indicating that the color was preferred by the majority of panelists and was visually favorable.

The results of the organoleptic color test of tofu made using *ie kuloh sira* coagulant showed an average color score of 5 out of 25 panelists, indicating that the color was considered very good and highly preferred. This highest score indicates that the visual appearance of the tofu met consumer expectations in terms of cleanliness, brightness, and color uniformity.

Organoleptic Aroma Test

Aroma is a smell that arises due to chemical stimulation by the olfactory nerves in the nasal cavity [10]. Aroma is one of the added values of a product; by smelling it, panelists can determine whether a product is tasty or not. The results of the organoleptic test on the color of tofu made using coagulant *ie asam sunti* showed that out of 25 panelists, an average score of 5 was obtained for the aroma parameter. Achieving a score of 5 from all panelists also indicates that there are no unpleasant aromas such as excessive sourness, staleness, or excessively strong fermentation odors. The results of the organoleptic test on the color of tofu made using coagulant *ie kuloh sira* obtained an average score of 4 from 25 panelists. This value indicates that the aroma of tofu is considered good and liked by most panelists, although it has not reached the level of very liked or perfect.

Organoleptic Taste

Taste is the sensory response to sensory stimuli such as bitter, sweet, sour, and salty. The taste of a product is crucial for consumer acceptance.

The results of the organoleptic taste test for tofu made using the coagulant, namely asam sunti, showed that the tofu received an average taste score of 5 from 25 panelists. This score is the highest on a scale of 1 to 5, indicating that all panelists rated the tofu as very good and highly appreciated. This assessment indicates that the resulting tofu has a mild, neutral, and distinctive flavor, consistent with the characteristics of quality tofu.

The results of the organoleptic taste test for tofu made using the coagulant, namely kuloh sira, showed an average score of 5 from 25 panelists. This score is the highest score on a scale of 1–5, indicating that the tofu was highly appreciated by all panelists, with no complaints or objections to the resulting taste. The taste of tofu is considered neutral, soft and clean, in accordance with the characteristics of quality

CONCLUSION

1. The best combination of raw materials is 700 grams of soybeans and 300 grams of corn. The optimal coagulant volume for the Asam Sunti method is 250 ml, which produces a tofu texture of 200 mm/second, a pH of 5.6, a protein content of 5.6%, and a yield of 75%. Meanwhile, the best coagulant volume for the Kuloh Sira method is 250 ml, resulting in a tofu texture of 240 mm/second, a pH of 5.8, a protein content of 5.8%, and a yield of 75%.
2. The lower protein content of corn tofu compared to previous studies is due to the absence of a binder such as cornstarch and the natural lower protein content of corn compared to soybeans. However, corn remains popular with consumers for its color, aroma, and flavor.

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