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Proximate Composition and Sensory Evaluation of Tofu Products Made from Soybean (*Glycine max)* and Lime *(*Citrus aurantifolia) as Coagulant

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Abstract

The study assessed the proximate and sensory evaluation of tofu products made from soybeans (Glycine max) with lime (Citrus aurantifolia) as a coagulant. The study aimed to determine the proximate composition (moisture, protein, carbohydrate, fat, crude fibre, and ash) and the sensory attributes of the products (colour, flavour, taste, texture/viscosity, and degree of acceptability). Quasi-experimental design was employed for the study. Chemical analysis was conducted to determine the proximate composition, while sensory evaluation was performed using a 9-point hedonic scale to assess the degree of acceptability of various tofu products. The samples were tofu pie, tofu roll, tofu orange drink, and tofu pineapple drink. Data obtained from proximate and sensory evaluations were analyzed statistically using the mean, standard deviation, and t-test. Results obtained on the proximate composition showed that the snacks had a low moisture content (tofu pie: 37.71%, tofu roll: 23.47%). There was high protein content in tofu pie (14.60%), high carbohydrate content in tofu roll (43.55%), and high fat content in tofu pie (21.18%) and tofu roll (21.20%). Carbohydrate was higher in tofu orange drink (9.06%) compared to tofu pineapple drink (8.41%). The results of the sensory evaluation showed that both the tofu pie and tofu roll were most generally accepted, with scores of 8.40 ± 0.52 and 8.40 ± 0.52, respectively. The tofu orange drink was the most generally accepted of the two drinks. Based on the findings, it was concluded that pastries and drinks made from tofu are nutritionally suitable for individuals who desire a healthy lifestyle. It was recommended that food manufacturers adopt lime as a coagulant in tofu production, nutritionists and health personnel promote its wider use, and consumers consider tofu as a viable alternative to beef in their culinary choices.

Keywords: proximate composition, soybean, sensory evaluation, food blends, lime, tofu

Introduction

Tofu, also known as bean curd, is a food produced by coagulating soy milk and compressing the resulting curds into blocks that range from soft to extra-firm. It is made from soybean curds due to the coagulation of protein, and it has low calories, contains no cholesterol, and is an excellent source of protein, iron, and calcium, among other nutrients (Hosie, 2019; Ramages, 2016). Commercially, soy milk is coagulated with salt coagulants,

such as sulphates, calcium chlorides, and magnesium chlorides, as well as acid coagulants, including citric acid or glucono delta-lactone. Geng et al. (2024) further noted various coagulants, including salt coagulants, enzyme coagulants, polysaccharide additives, acid coagulants, novel coagulants, and different formulations.

Nutritionally, tofu is a good source of protein, containing 6-8% protein, as well as an adequate amount of calcium, potassium, and iron (Rogers, 2025). A 100g serving of firm tofu provides 144 kcal, 17g protein, 3g carbohydrate, 2g fibre, and 9g fat. It also contributes significantly to daily nutrient values: 53% calcium, 51% manganese, 42% copper, 32% selenium, 15% phosphorus, 15% iron, 14% magnesium, 14% zinc, and 18% vitamin A (Petre, 2023). Tofu has long been a staple in Asian cuisine and is widely recognized as a versatile meat substitute. Soy-based meat alternatives, also known as analogs, closely resemble animal meat in terms of taste, texture, and appearance, making them popular among vegetarians and vegans (Takeuchi et al., 2024). While soy may fall short in certain aspects when compared to animal flesh, it could also be more advantageous in others, making it a solid protein option to add to any diet (Pamplona-Roger, 2013; Parsons, 2020; Thomson, 2021).

Unlike most plant proteins, tofu contains all the essential amino acids required in the human diet (Hosie, 2019), which is significant because the human body cannot synthesise these amino acids on its own. Furthermore, the World Health Organization (2014) has found that soybeans are beneficial for several conditions, including diabetes, high blood pressure, and various related diseases. Research (e.g., Mitchell, 2011; Olumati, 2023; Okunowo, 2024) suggests that plant-based diets can reduce the risk of type 2 diabetes, obesity, heart disease, and certain types of cancer, as they are characterized by a low glycemic index (GI). Consuming a low GI diet can help regulate blood sugar levels, enhance insulin sensitivity, and reduce the risk of type 2 diabetes. This makes tofu an excellent option for a low-GI diet, as its soy-based composition provides a protein-rich alternative that supports blood sugar regulation while offering versatility in meal preparation (Nguyen et al., 2017).

Tofu production begins with hot, boiled soy milk, into which a coagulant is introduced to form curds. The firmness of the resulting tofu depends on the type being made (Thomson, 2021). However, Rekha and Vijayalakshmi (2013) noted that the tofu production procedure progresses from the soaking of soybeans, grinding, filtering, boiling, coagulating, stirring, moulding, and seasoning. Flavourings and spices are often added to enhance sensory qualities (Parsons, 2020). Some soy products may contain eggs or dairy to more closely replicate the taste, texture, and appearance of meat (Parsons, 2020). Tofu itself has a mild, slightly beany flavour but readily absorbs marinades, making it highly adaptable (Thomson, 2021). This flavour adaptability is essential because the production process, as described by Ezeama and Dobson (2019), often requires the use of an acidic coagulant, such as lime (*Citrus aurantifolia*).

Limes, a citrus fruit, are typically round, sour like lemons, but greener and smaller in size. Limes are rich in antioxidants, and their consumption in any form may aid in iron absorption, improve immunity, enhance digestion,

lower blood sugar levels, fight infections, reduce inflammation, and promote healthy skin (Healthline, 2016). Lime, a readily available, affordable, natural, and food-safe coagulant, is comparable to commercial coagulants (Sitanggang et al., 2020), particularly when addressing issues related to diabetes. Additionally, lime adds trace minerals and vitamin C, which can enhance the nutritional profile of tofu. For diabetic patients, vitamin C may support antioxidant activity and help reduce oxidative stress (Anderson, 2025). The diverse nutritional and functional benefits of combining soybeans and lime in tofu production provided the rationale for this study, which evaluates the proximate composition and sensory characteristics of innovative snack and beverage products derived from tofu. These formulations are designed to offer both health benefits and consumer acceptability, particularly for individuals managing diabetes. This highlights the need for functional snack formulations that not only meet consumer preferences but also provide enhanced nutritional value.

Since most snacks are enjoyable to eat but low in nutritional value, Anyakoha (2016) suggested that snacks with high protein and fibre content should be developed as a supplementary diet. According to Spritzler (2019), snacks can be either solid or liquid food; hence, snacking means eating or drinking something between meals. Often, snacks are poor sources of protein; therefore, the use of tofu in the preparation of snacks and drinks enhances the nutritional quality of the pastry and drinks. However, while incorporating tofu can improve the nutritional profile of snacks and beverages, its acceptance ultimately depends on how well these enhanced products meet consumer expectations. Acceptance of food products depends on whether they meet consumers' needs and the degree of satisfaction the product provides. Organoleptic evaluation utilizes human senses to measure the acceptability of food products based on attributes such as colour, texture, shape, appearance, taste, and aroma/flavour, assessing the effectiveness of the product (Julian, 2018; Asouzu, 2013; Eze & Njoku, 2018). According to Eze and Njoku (2018) and Asouzu (2013), the appearance of food initiates a favourable response, although taste and flavour determine the acceptance or rejection of food products. While visual appeal and sensory attributes drive initial acceptance, incorporating nutrient-rich ingredients like tofu into snack production ensures that these products not only satisfy consumer preferences but also support health-focused dietary needs.

Tofu with lime coagulant is rich in minerals, vitamins, and phytonutrients, making its use in snack production vital for a healthy diet, particularly for individuals with diabetes. According to Goodson (2020), people with diabetes should consume foods rich in vitamins, minerals, and antioxidants, especially those derived from plant-based sources, such as soybeans. The production of snacks made from tofu, a product derived from soybeans, using lime as a coagulant, is motivated by the fact that many people in contemporary Nigeria have limited access to protein-rich foods from animal sources, which are often costly (Lilly & Omoku, 2014). It is important to note that home-made or locally made tofu is good because Ramages (2016) advised that consumers should use tofu that has undergone minimal processing. Therefore, building upon the work of

other researchers, such as Sitanggang et al. (2020), Cheng et al. (2024), Ezegbe et al. (2024), and Takeuchi et al. (2024), this study aimed to assess the proximate and sensory evaluation of tofu products derived from soybeans and lime juice as a coagulant.

Specific objectives of the Study

The specific objectives of the study are to:

1. determine the proximate compositions (moisture, crude ash, crude protein, crude fat, crude fibre and carbohydrate) of tofu products (snacks and drinks).
2. evaluate the sensory attributes (colour, texture, taste, flavour, and general acceptability) of tofu products (snacks and drinks).

Materials and Methods

Research Design: The study adopted a quasi-experimental research design. According to Kpolovie (2010), quasi-experimental research refers to investigations that use designs suitable for approximating the conditions of an actual experiment in situations that do not permit the control and manipulation of all relevant variables.

Procurement of raw materials: 25kg of Soybeans was procured in the Onitsha main market in Anambra State. Lime (2kg), other ingredients (3kg flour, 1.5kg margarine, 40 oranges, two large pineapples, eight green peppers, eight red peppers, two packets of almond milk, two tins of coconut milk, and condiments) were purchased at Omoku main market.

Sample Preparation Procedure

The preparation of soymilk, tofu, snacks, and drinks was conducted for both laboratory analyses at the Central Laboratory Services of the Nigerian Stored Products Research Institute (NSPRI), Port Harcourt, and sensory evaluation by 10 panellists in the Food and Nutrition Laboratory of the Home Economics Department, Federal College of Education (Technical), Omoku.

Soymilk production: Soy milk for tofu processing was prepared according to the method described by Eze and Njoku (2018). The soybeans (*Glycine max*) were thoroughly sorted by removing dirt and other unwanted substances, such as stones, sticks, and rotten soybeans. It was washed, soaked overnight, dehusked (if desired), drained, and wet-milled. Water was added to the milled paste, drained, boiled, and strained again to get milk. Tofu production began with milk processing and the removal of scum. After removing all the scum, it was removed from the heat and allowed to cool slightly at room temperature. At this point, the soymilk is thicker than the drained milk.

Tofu production: Soymilk was first boiled until it reached a thick consistency. The soymilk was left warm before the introduction of the coagulant to ensure faster curdling. Clean, fresh, prime-ripe lime juice was then introduced as the coagulant to induce protein coagulation, which took between 45 minutes. The coagulation process was observed progressively, with occasional stirring, and tested for curdling to ensure that the tofu does not over-curdle, become drier or crumblier. Once the curds formed, they were transferred into a muslin cloth placed in a colander, with condiments added at this stage to enhance flavour. The muslin cloth was folded over and tightened, or placed in an airtight cotton bag, to allow the curds to set into a solid block. After solidification, the tofu was

removed, sliced, and either baked or fried for use in snack production or blended with other ingredients to prepare beverages. The tofu produced was used to prepare two snacks (tofu pies and tofu rolls) and two drinks (tofu orange drink and tofu pineapple drink).

Production of Tofu Snacks and Tofu Drinks

Tables 1a to 1c present the recipes for tofu processing from soybeans and the subsequent production of snacks and drinks.

Table 1a: Recipe for Tofu made from Soymilk

Ingredients	Quantity	Method
Soybean	2kg	Sorting of soybean; soaking overnight; wet-milling; addition of water; strain; boil and remove scum; strain while hot; allow to cool slightly; add lime liquid; put curds in muslin cloth placed over a colander or cotton bag; add condiments; remove when solid; slice, bake or fry and use in dishes or blend with other things for drink; and package in containers.
Lime	200ml	
Condiments	50g	
Vegetable oil	500ml	

Table 1b: Recipe for Snacks made with Tofu

Ingredients	Quantity	Methods
Whole wheat flour	2kg	a) Tofu pie: Mix pie crush dough from flour, margarine, and milk carefully into a light stiff dough and refrigerate for 30 minutes; prepare sauce for filling from onions, green pepper, red pepper, oil, sauce cube and salt and allow to cool; roll pastry and cut in circles, fill each circle by half to form a half-moon shape, seal the borders and place in slightly greased oven tray and bake for 20 minutes; serve with drink.
Margarine	1kg	
Non-diary milk	200 ml	
Tofu	1kg	
Onions	4 medium sizes	
Green pepper	4 big	
Red pepper	4 big	
Oil	2 cooking spoons	
Salt	1 level teaspoon	
Sauce cube	A pinch	
	1 (double) cube	b) Tofu rolls: Roll pie crust into a long shape, and place marinated tofu along one end and roll over, place the joint point at the base, and cut into even sizes and bake as per tofu pie.

Table 1c: Recipe for Drinks made with Tofu

Ingredients	Quantity	Methods
Fresh Orange juice	10 cups	Orange and pineapple drink: Combine all ingredients in a blender and blend until smooth. Refrigerate and serve with a snack.
Fresh Pineapple juice	10 cups	
Tofu	5 or 50g cubes	
Almond milk	5 cups	
Coconut milk	5 cups	

Chemical Analysis

The Association of Official Analytical Chemists (AOAC, 2019) procedure was applied to determine parameters of moisture content, protein, carbohydrate, fat, crude fibre and ash. This is determined by the automatic micro Kjeldahl method of AOAC. Materials and equipment

include a 500 mL Kjeldahl flask, 250 mL Erlenmeyer flasks, and glass beads. All analyses performed were in triplicate. The proximate determinations were carried out in the Central Laboratory Services of the Nigerian Stored Product Research, Port Harcourt, for the study samples as stipulated by AOAC (2019).

Sensory evaluation of the tofu products: A nine-point Hedonic scale, where 9 was the highest score and one the lowest, was used to assess the products based on likes and dislikes. A panel of 10 judges participated in the sensory evaluation. The evaluation was conducted at the Food and Nutrition Laboratory of the Home Economics Education Department at the Federal College of Education (Technical), Omoku. The coded products, including the Tpie (tofu pie) and TOD (tofu orange drink), were served first with water. To prevent carry-over effect, the panelists rinsed their mouths and drank water before the second pair of Troll (tofu roll), and TPD (tofu pineapple drink) were presented to them. The panelists were conveniently selected from the senior teaching and non-teaching staff of the College in Campus 2.

Data Analysis: Data was entered into Microsoft Excel for analysis. Mean, standard deviation, and t-test were used for the analysis. The criterion point for accepting the product is a mean score of 4.5 or above, and P-values greater than 0.05 are considered significant.

Results

Proximate composition of tofu snacks and drinks

The data in Table 2 show the proximate composition of snacks and drinks, respectively. The tofu pie's moisture content was 31.71%, while the tofu roll's was 23.47%. The protein content was higher in tofu pie (14.60%), compared to tofu roll (9.90%), while carbohydrate was higher in tofu roll (43.55%) compared to tofu pie (30.72%). Moisture content was higher in tofu pineapple drink (87.07%) compared to tofu orange drink (86.85%), while carbohydrate was higher in tofu orange drink (9.06%) compared to tofu pineapple drink (8.41%). The parameters for all variables are present, except for fibre in the tofu orange drink and the tofu pineapple drink.

Table 2: Proximate composition of Tofu Snacks and Tofu Drinks

Nutrients 100g/Sample	Tpie %	Troll %	TOD %	TPD %
Moisture	31.71	23.47	86.85	87.07
Protein	14.60	9.90	2.36	2.40
Carbohydrate	30.72	43.55	9.06	8.41
Fat	21.18	21.20	1.22	1.43
Crude fiber	0.54	0.74	0.00	0.00
Ash	1.25	1.14	0.51	0.69

N=4; Tpie=Tofu pie; Troll=Tofu roll; Tod=Tofu orange drink: Tpd=Tofu pineapple drink

Sensory evaluation of Tofu Snacks and Tofu Drinks

Table 3 reveals the organoleptic characteristics of tofu snacks and tofu drinks. The mean and standard deviation of the sensory evaluation results show that all tofu-based products were well accepted by the panelists (mean cut-off of 4.5 and above). In respect of Colour, Tofu pie (8.10 ± 0.57) was rated lower than Tofu

roll (8.30 ± 0.67), while Tofu orange drink (8.30 ± 0.82) was rated lower than Tofu pineapple drink (8.40 ± 0.70). For flavour, Tofu pie (8.10 ± 0.99) was rated slightly lower than Tofu roll (8.20 ± 0.63), while Tofu orange drink (7.90 ± 0.88) was rated lower than Tofu pineapple drink (8.40 ± 0.70). For taste, Tofu pie (8.70 ± 0.48) scored higher than Tofu roll (8.20 ± 0.79), and Tofu orange drink (7.90 ± 0.74) was rated lower than Tofu pineapple drink (8.10 ± 0.74). Regarding texture, the Tofu pie (8.00 ± 0.47) was rated slightly lower than the Tofu roll (8.30 ± 0.67). In terms of viscosity, Tofu orange drink (7.20 ± 1.69) scored lower than Tofu pineapple drink (7.60 ± 1.51). For overall acceptability, Tofu pie and Tofu roll had equal ratings (8.40 ± 0.52), while Tofu orange drink (7.90 ± 0.74) rated lower than Tofu pineapple drink (8.30 ± 1.25). At $p < 0.05$, the t-test analysis revealed no significant differences in mean organoleptic scores between the snacks and drinks.

Table 3: Sensory Evaluation of Snacks and Drinks made from Tofu

Parameter	Tpie	Troll	P-Values	Tod	Tpd	P-Values
Colour	8.10 ± 0.57	8.30 ± 0.67	-0.719	8.30 ± 0.82	8.40 ± 0.70	-0.293
Flavour	8.10 ± 0.99	8.20 ± 0.63	-0.270	7.90 ± 0.88	8.40 ± 0.70	-1.406
Taste	8.70 ± 0.48	8.20 ± 0.79	1.710	7.90 ± 0.74	8.10 ± 0.74	-1.910
Texture/Viscosity	8.00 ± 0.47	8.30 ± 0.67	-1.159	7.20 ± 1.69	7.60 ± 1.51	-1.258
Degree of Acceptability	8.40 ± 0.52	8.40 ± 0.52	0	7.90 ± 0.74	8.30 ± 1.25	-8.71

N=4; Values of Mean ± SD of Samples; P<0.05 = 2.101; Texture – Snacks: Viscosity – Drinks

Discussion of Findings

This study evaluated the proximate and sensory characteristics of tofu products made from soybeans (*Glycine max*) and lime (*Citrus aurantifolia*) as a coagulant. The study revealed that tofu pie contained higher levels of moisture and protein, whereas tofu roll was richer in carbohydrates. This distinction suggests that tofu pie may be more suitable for consumers seeking protein-rich, nutrient-dense snacks. In contrast, tofu roll could serve as an energy-providing option due to its higher carbohydrate content. The high protein values are attributable to the filling and stuffing with tofu enriched with phytonutrient vegetables. This finding aligns with the assertions of Takeuchi et al. (2024) that soy meat alternatives, also known as meat analogs, are comparable to meat on many fronts and are widely consumed by vegans and vegetarians. Snacks with high protein and fibre should be developed (Anyakoha, 2016), and tofu pie can be marketed as a protein-enhanced, health-oriented option appealing to individuals managing weight or seeking plant-based protein sources. According to Attah and Eze (2022), a high-protein diet has been linked to improved clinical outcomes, with proteins recommended to provide 10–35% of total energy intake. The high carbohydrate levels in the tofu snacks could be attributed to the pastry crust, which is composed of more flour. This makes it suitable for consumers requiring quick energy, such as children or active individuals. The high ash content in the snacks indicates they are good sources of minerals, as Ezegbe et al. (2024) noted that ash represents the non-organic compounds containing minerals in food.

Tofu contains all the essential amino acids required in a balanced diet (Hosie, 2019). Findings showed that the Tofu pineapple drink contained higher levels of moisture, protein, fat, and ash compared to the tofu orange drink, while the orange drink had higher levels of carbohydrates. The implication is that the tofu pineapple drink is nutritionally richer than the tofu orange drink, whereas the tofu orange is comparatively more energy-dense. This finding conforms to the assertion of Ejimofor et al. (2023) that pineapple drink has a higher nutrient profile than orange drink due to their elemental compositions. Our finding that the tofu pineapple drink had more protein and the tofu orange drink had more carbohydrates contrasts with that of Yacoubian (2023), which showed that the pineapple drink has more calories and other nutrients than the orange drink, while the orange drink has more protein. This discrepancy may be explained by the incorporation of tofu, where pineapple's protein contributions appear to synergize with soy's nutrient profile, resulting in the higher protein values observed in this study.

Organoleptic evaluation utilises the human senses to measure the acceptability of food products based on attributes such as colour, texture, flavour, and appearance, among others, to determine product acceptance (Julian, 2018). The results of the study show no significant difference ($p < 0.05$) in the organoleptic properties of the tofu pie and rolls. However, the findings showed that the tofu pie received higher ratings for colour, flavour, and texture, whereas the tofu roll was rated more favourably for taste. Nevertheless, both products achieved similar scores for general acceptability, highlighting their complementary strengths in consumer perception. This could be attributed to the rich sauce filling for the pastries. This finding suggests that Tofu pie excels in visual and textural appeal, while the tofu roll is preferred for taste; yet both share equal overall acceptability, highlighting opportunities for product diversification, with pies positioned for premium sensory appeal and rolls for flavour-driven markets. Equal general acceptability scores indicate that both products are viable plant-based alternatives, supporting broader adoption in the bakery and snack industries. Supporting these findings, Studies such as Yang et al. (2024) and Joo et al. (2023) confirm that tofu's sensory attributes vary significantly with formulation and processing, directly influencing consumer ratings. The distinct sensory strengths of tofu pie and tofu roll suggest that both can be marketed to different consumer segments, pies as visually and texturally appealing products, and rolls as flavour-focused options.

The acceptance of food products depends on whether they meet consumer needs and the degree of satisfaction they provide (Eze & Njoku, 2018). Although no significant difference existed between the organoleptic properties of the tofu orange and pineapple drinks, the mean findings showed that the Tofu pineapple was rated more favourably than the tofu orange drink in terms of colour, flavour, taste, viscosity and general acceptability. This suggests that pineapple may be a more suitable fruit base for enhancing the acceptability of tofu beverages, which could be attributed to the unique aroma of pineapple. Similarly, a study by Sabino et al. (2023) found that pineapple beverages had good sensory acceptance and high commercial potential for consumer consumption. According to Yusufali et al. (2024), the rising consumption of

pineapple juice is driven by its refreshing flavour, great taste, the growing awareness of its health benefits, and its ability to mask bitterness and other undesirable taste qualities. The implication is that pineapple is a suitable choice for tofu drinks and a viable option for broader use and commercial development.

Overall, the degree of acceptability, based on colour, flavour, taste, texture for snacks, and viscosity for drinks, is higher for the snacks than for the drinks. This is mainly because the appearance of food evokes initial perception. This finding agrees with Eze and Njoku (2018) and Asouzu (2013), who stated that the appearance of food initiates a favourable response, although taste and flavour determine the acceptance or rejection of food products. The findings also align with Parsons (2020), who notes that flavour and spices are typically added to tofu to enhance sensory qualities, aiming to replicate the taste, texture, colour, and form of meat products. Essentially, the findings from this research would serve as a helpful guide for the formulation of tofu production using lime as a coagulant.

Conclusion

This study assessed the proximate and sensory evaluation of tofu products made from soybean (*Glycine max*) and lime (*Citrus aurantifolia*) as a coagulant. According to the findings, the tofu pie and roll had the same degree of acceptability, while the tofu pineapple drink was more acceptable than the tofu orange drink. Although there is no significant difference between the two snacks and the two drinks, the tofu products were generally rich in protein, carbohydrates, fat, and ash. The study, therefore, concludes that incorporating tofu into conventional snack and drink production improved their nutrient content and was acceptable to consumers. The implication is that this study has the potential to inform the development of tofu-based snacks and drinks that could contribute to improved nutritional health and support the management of conditions such as diabetes, high blood pressure, and related chronic diseases. Based on the findings, the study concludes that snacks and drinks made from tofu, a byproduct of soybeans, are nutritious and acceptable to consumers.

Recommendations

The following recommendations were made based on the study's findings.

1. Food manufacturers and bakery industries should adopt the processing of soymilk using lime juice as a coagulant, utilizing the resulting tofu curds as a sustainable meat alternative in the production of pies, rolls, and other pastry products.
2. Nutritionists, dietitians, and public health personnel should promote household preparation of tofu-based pastries and conduct nutrition sensitisation campaigns, particularly during soybean harvest seasons, to encourage wider consumption of protein-rich, plant-based foods.
3. Food science researchers and academic institutions should undertake comparative studies on the use of lemon versus lime as coagulants in soy milk, evaluating differences in proximate composition and sensory attributes to guide best practices in tofu production.

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