

Physical Characteristics and Sensory Properties of Tofu Nuggets with The Addition of Cheddar Cheese and Eri Pupae Cheese

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ABSTRACT

The increasing demand for nutritious food has driven innovations such as tofu nuggets, yet their bland taste and limited sensory appeal remain a challenge. The addition of cheddar cheese can enhance flavor, while eri pupae provide high protein and sustainability benefit, making eri pupae cheese a promising ingredients to improve both sensory quality and nutritional value. This study evaluate the physical and sensory characteristics of tofu nuggets with the addition of cheddar and eri pupae cheese. Five formulations were tested, including control and combinations with 5% and 10% cheddar or eri pupae cheese. Physical parameters such as pH and water activity (aw), and sensory attributes, including color, odor, taste, texture, and overall preference, were assessed using hedonic and hedonic quality tests with 35 semi-trained panelists. Results showed that adding cheddar and eri pupae cheese significantly increased pH ($P<0.05$), while aw remained unchanged. Nuggets with 10% eri pupae cheese (P5) obtained the highest scores for color, texture, and overall liking, due to natural pigments and emulsifying properties, while taste remain unchanged. These findings suggest that combining cheddar and eri pupae cheese can enhance the sensory quality of tofu nuggets, supporting the use of alternative proteins in sustainable food innovation.

Keywords: cheddar cheese, eri pupae, sensory, tofu nugget

ABSTRAK

Permintaan akan pangan yang bergizi mendorong inovasi produk seperti nuget tahu, namun rasa hambar dan kurangnya daya tarik sensori masih menjadi tantangan. Penambahan keju cedar dapat meningkatkan cita rasa, sedangkan pupa eri meningkatkan protein dan keberlanjutan sehingga keju pupa eri menjadi bahan potensial untuk memperbaiki mutu sensori dan nilai gizi nuget tahu. Penelitian ini mengevaluasi karakteristik fisik dan sensori nuget tahu dengan penambahan keju cedar dan keju pupa eri. Lima formulasi diuji, meliputi kontrol serta kombinasi dengan keju cedar dan keju pupa eri sebanyak 5% dan 10%. Parameter fisik seperti pH dan aktivitas air (aw), serta atribut sensori meliputi warna, odor, rasa, tekstur, dan kesan keseluruhan diuji menggunakan metode hedonik dan mutu hedonik oleh 35 panelis semi-terlatih. Hasil menunjukkan bahwa penambahan keju cedar dan keju pupa eri meningkatkan nilai pH secara signifikan ($P<0.05$), sedangkan aw tidak menunjukkan perbedaan nyata. Nugget dengan 10% keju pupa eri (P5) memperoleh skor tertinggi pada warna, tekstur, dan tingkat kesukaan keseluruhan, yang diduga berasal dari pigmen alami dan sifat emulsi bahan. Rasa tidak menunjukkan perbedaan signifikan antar perlakuan. Temuan ini menunjukkan bahwa kombinasi keju cedar dan pupa eri dapat meningkatkan mutu sensori produk berbasis tahu, serta mendukung pengembangan pangan berbasis protein alternatif yang berkelanjutan.

Kata kunci: keju cedar, nuget tahu, pupa eri, sensori

INTRODUCTION

The growing demand for nutritious and sustainable food products has led to the development of innovative processed products. These products often utilize local and alternative resources to meet consumer needs while promoting environmental sustainability (Rabadan *et al.* 2021). Tofu nuggets are a plant-based food product that made and shaped to resemble chicken nugget (Rifqi *et al.* 2017). However, consumer acceptance remains a challenge, as sensory studies have reported that plant-based products generally receive lower overall scores, particularly for flavor and texture attributes due to the presence of a bland taste and beany aftertaste (Ettinger *et al.* 2022). This limitation highlights the need for formulation improvements that can enhance both sensory appeal and nutritional value. Physical parameters such as pH and water activity (a_w) are important to determinants of products stability and sensory quality (Amoah *et al.* 2023; Nunez *et al.* 2019).

Cheddar cheese is one of the most produced and consumed cheeses worldwide. It's widely recognized for its umami taste and characteristic odor. The addition of cheddar can enhance the flavor, aroma, and masking the undesirable notes and increasing palatability. The fats and protein in cheddar act as emulsifiers, improving the texture and mouthfeel (Zheng *et al.* 2021). Meanwhile, eri pupae (*Samia cynthia ricini*), a byproduct of the silk industry, have potential as a functional food and sustainable alternative ingredient, showing promise in improving the sensory profile and functionality of processed foods (Patel *et al.* 2020). Several studies have shown that eri pupae contain 55-65% protein and are rich in essential amino acids, fats, and bioactive compounds. Eri pupae can enrich tofu nuggets with micronutrients such as iron, zinc, and vitamin B12 (Zhou *et al.* 2022). Eri pupae cheese contains 33.46% more protein and 20.51% less fat than processed cheddar cheese. Eri pupae cheese has an opaque yellow color, nutty odor, and salty taste (Ramadhani 2024). The combination of these two ingredients in tofu-based nuggets represents a novel formulation approach that supports both product development and environmental sustainability.

Despite increasing interest in alternative protein sources, limited research has specifically examined the organoleptic impact of combining cheddar cheese and eri pupae in plant-based nugget formulations. Therefore, this study aims to evaluate the sensory characteristics, namely color, odor, taste, texture, and overall acceptability of tofu nuggets fortified with cheddar cheese and eri pupae cheese, with the goal of enhancing consumer appeal and supporting the advancement of sustainable foods.

MATERIALS AND METHODS

The equipment used consists of a digital scale, blender, oven, 80-mesh sieve, stove, thermometer, mold, and food processor. The ingredients used in the study consist of eri pupae, cheddar cheese, tofu, water, all-purpose flour, bread flour, and STPP (*Sodium Tripolyphosphate*). The method for making eri pupae cheese utilizes the Ramadhani (2024) method, as illustrated in Figure 1.

The procedure for making tofu nuggets is based on Asriani *et al.* (2021); Mastuti and Adrian (2021); Khatimah *et al.* (2018) with modifications. This study adds cheddar cheese and eri pupae cheese. The percentage determination is based on the research by Asriani *et al.* (2021), namely 0%, 5%, and 10%. The production of tofu nuggets begins with weighing the ingredients according to the formula and mixing them using a food processor. Once thoroughly mixed, the dough is molded into a baking tray and steamed for 15 minutes at 90 °C. Next, it is cooled for 10 minutes in the refrigerator. Then, the coating process using wet batter (all-purpose flour) and dry batter (bread flour), followed by frying at 150 °C for 3 minutes. The tofu nugget formulation is presented in Table 1.

The physical characteristics of tofu nuggets include pH value and water activity (a_w). pH measurement is performed by a pH meter IONIX pH5S made in china (AOAC 2005). The a_w value is measured using an a_w meter, Novasina MS-1, made in Switzerland (AOAC 2005).

Organoleptic testing is conducted using BSN (2006) methods namely hedonic testing and hedonic quality methods to determine panelists' preferences for taste, odor,

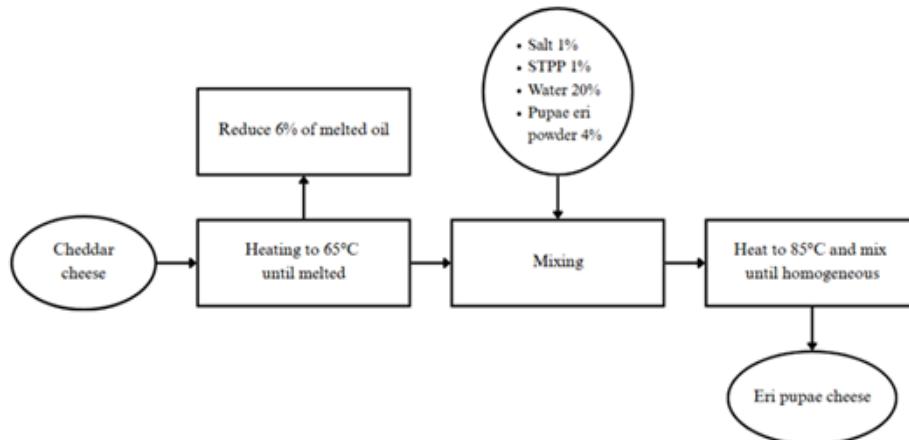


Figure 1. Flowchart of eri pupae cheese production

Table 1. Formulation for making tofu nuggets with the addition of cheddar cheese and eri pupae cheese

Ingredient	Treatment				
	P1	P2	P3	P4	P5
Tofu (g)	100	100	100	100	100
Cheddar cheese (g)	0	5	10	0	0
Eri pupae cheese (g)	0	0	0	5	10
Flour (g)	10	10	10	10	10
Garlic (g)	5	5	5	5	5
Salt (g)	1	1	1	1	1
Pepper (g)	0.5	0.5	0.5	0.5	0.5

Notes: The percentages used are based on the weight of the tofu used; P1: Tofu nuggets without cheese addition, P2: Tofu nuggets with cheddar cheese addition (5%), P3: Tofu nuggets with cheddar cheese addition (10%), P4: Tofu nuggets with eri pupae cheese addition (5%), P5: Tofu nuggets with eri pupae cheese addition (10%).

color, and texture. This testing involved 35 semi-trained panelists. The hedonic test was conducted using a four-point rating scale: 1 (dislike), 2 (somewhat like), 3 (like), and 4 (very like). The hedonic quality test was based on four main parameters: taste, odor, color, and texture. The taste parameter was assessed using a scale of 1 (not salty), 2 (slightly salty), 3 (salty), and 4 (very salty). The odor parameter was assessed using a scale of 1 (cheese odor), 2 (slight cheese odor), 3 (slight pupa odor), and 4 (pupa odor). The color parameter uses a scale of 1 (slightly yellow), 2 (yellow), 3 (slightly brown), and 4 (brown). The texture parameter uses a scale of 1 (soft), 2 (slightly soft), 3 (slightly hard), and 4 (hard).

Data analysis in this study used the Completely Randomised Design (CRD) method with treatment types as the experimental factor. Each treatment was repeated three times. Physical testing data were analyzed using Analysis of Variance (ANOVA), while organoleptic testing data were analyzed using the Kruskal-Wallis test.

RESULTS AND DISCUSSION

Physical Characteristics

The physical characteristics of tofu nuggets tested include pH and water activity (aw) parameters, both of which play crucial roles in determining food quality and safety. The results of the physical characteristics testing of the tofu nuggets are presented in Table 2.

Table 2 Analysis of the physical characteristics of tofu nuggets with cheddar cheese and eri pupae cheese

Physical characteristic	Treatment				
	P1	P2	P3	P4	P5
aw	0.852±0.02	0.850±0.02	0.842±0.03	0.854±0.02	0.844±0.03
pH	5.33±0.03a	5.45±0.01b	5.45±0.03b	5.56±0.05c	5.61±0.02c

Note: Different letters in the same row indicate significant differences ($P<0.05$). P1: Tofu nuggets without cheese addition, P2: Tofu nuggets with cheddar cheese addition (5%), P3: Tofu nuggets with cheddar cheese addition (10%), P4: Tofu nuggets with eri pupae cheese addition (5%), P5: Tofu nuggets with eri pupae cheese addition (10%).

The results of the study showed that the addition of cheddar cheese and eri pupae cheese significantly increased the pH value ($P<0.05$) compared to the control treatment (P1). The lowest pH value was found in P1 at 5.33, while the highest pH value was found in P5 at 5.61. This increase is due to the alkaline nature of cheddar cheese and eri pupae cheese compared to white tofu. Cheddar cheese has pH value around 4.8-5.4 and eri pupae cheese at 5.31 (Nunez *et al.* 2020; Ramadhani 2024). Meanwhile white tofu at 3-5 depends on the coagulant use (Indrawijaya *et al.* 2017). The addition of cheese can neutralizes some of the acidity in tofu, resulting in a more neutral-tasting tofu nugget and greater consumer acceptance.

Meanwhile, the aw values of tofu nuggets under various treatments did not show significant differences ($P>0.05$), ranging from 0.842 to 0.854. These aw values fall into the moderate category and still allow for the growth of yeast and mold, so it is important to consider the storage aspects of the product (Tapia *et al.* 2020). The composition of ingredients and processing methods, such as steaming, adding wheat flour, salt, and frying, influence the aw value of tofu nuggets (Ramadhani 2024; Simanjuntak *et al.* 2022).

Sensory Characteristics

Sensory characteristics are a method of evaluating the characteristics of a product based on the five senses, including color, odor, taste, and texture. This characteristic of tofu nuggets was measured using two methods, such as hedonic testing and hedonic quality testing. Hedonic testing measures the level of consumer liking or acceptance of a food product based on the subjective assessment of panelists (Permadi *et al.* 2018). The results of the tofu nuggets hedonic test can be seen in Figure 2.

The color of the tofu nuggets showed a significant increase ($P<0.05$) with the addition of cheddar cheese and eri pupae. The treatment with 10% eri pupa cheese (P5) obtained the highest color score of 3.05, while the control without addition (P1) had the lowest value. This indicates that the color of P5 nuggets is preferred over other treatments, especially P1. Zarli and Holinesti (2022) stated that golden yellow nuggets are the consumers' preference. The addition of cheddar cheese can enhance the yellow color of chicken nuggets (Zarli and Holinesti 2022). This color improvement in tofu nuggets is likely due to the Maillard reaction between protein and sugar during heating, as well as the fat content in eri pupae and cheddar cheese, which can influence the color intensity of the product (Amoah *et al.* 2023; Kourimska and Adamkova 2016).

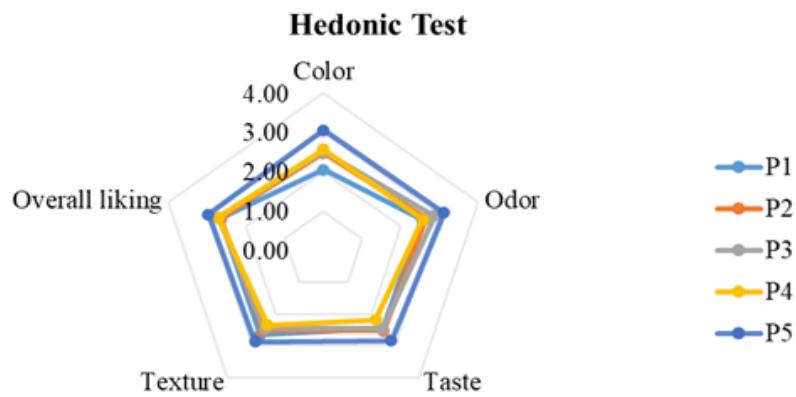


Figure 2. Hedonic testing of tofu nuggets with the addition of cheddar cheese and eri pupae cheese

The odor of the tofu nuggets did not show significant differences between treatments ($P>0.05$), meaning that all product variations had an odor acceptable to the panelists. Research by Holinesti and Zarli (2022) stated that the odor of food is determined by the quality of the ingredients used. Nuggets are expected to have a fragrant odor that comes from the chicken and seasonings used. The distinctive odor of cheddar cheese produced by fermentation provides a savory odor that is preferred (Kilcawey and O'Sullivan 2018; Sullivan *et al.* 2023). Additionally, volatile compounds from the eri pupae contribute to the product's odor, enhancing its sensory appeal (Karnjanapratum *et al.* 2022). The addition of 30-40% silkworm pupae powder can increase the odor liking score for cereal (Hirunyophat *et al.* 2020).

The taste of the tofu nuggets also did not differ significantly ($P>0.05$) between treatments, indicating that the addition of cheddar cheese and eri pupae did not significantly alter the panelists' taste preferences. Hirunyophat *et al.* (2020) found that the addition of 30-40% silkworm pupae powder increases the liking score for breakfast cereals' taste, which may be due to the unique savory taste. The addition of fermented ingredients such as cheddar cheese can enhance the complexity of the product's taste. Cheddar cheese is known to increase sweetness and creaminess due to the ripening process, which produces flavor-enhancing peptides (Gulzar *et al.* 2020). This makes the taste of the tofu nuggets more savory and appealing to consumers.

The texture of the tofu nuggets in all treatments was generally preferred and did not differ significantly ($P > 0.05$). Tofu is produced by the coagulation of soy milk, resulting in a soft, solid form which gives tofu a smooth and tender texture (Aryanti *et al.* 2016). Riandani and Irfan (2022) stated that cheddar cheese is known to enhance the softness and mouthfeel of the product, making the texture of the nuggets smoother (Riandani and Irfan 2022). Eri pupae also acts as an emulsifier that improves the texture and stability of the product (Zielinska 2022).

Overall, the treatment with 10% cheddar cheese and eri pupae (P5) received the highest score, indicating that this combination was most preferred by the panelists. These results suggest that tofu nugget products with added cheese and eri pupae are well-received by consumers. These findings are consistent with previous studies showing good

acceptance of insect-based and fermented food products (Ho *et al.* 2022; Kowalski *et al.* 2022).

Hedonic quality testing assesses specific quality attributes of food products compared to hedonic testing (Permadi *et al.* 2018). In this study, the panelists evaluated the color, odor, taste, and texture attributes of the tofu nuggets. The results of the hedonic quality testing can be seen in Figure 3.

Color is an important attribute that influences consumer preferences for food products. Tofu nuggets with added eri pupae cheese (P5) exhibited a more stable yellow color compared to nuggets without additions (P1), which tended to be brown. The yellow coloration in the product is primarily derived from natural pigments that contribute both visual appeal and nutritional value. These pigments include β -carotene and various types of carotenoids, which are abundant in cheddar cheese and responsible for its characteristic golden-yellow hue (Racette *et al.* 2024). β -carotene, in particular, is a precursor to vitamin A and is known for its antioxidant properties, offering potential health benefits in addition to its coloring function. Eri pupae also contain flavonoids and carotenoids that contribute to the yellow color (Buthkup *et al.* 2012). Carotenoids are fat-soluble pigments responsible for yellow to orange hues, while flavonoids, though primarily associated with antioxidant activity, can also influence the overall appearance of the product through pigment interactions (Anuduang *et al.* 2020).

In contrast, the brown color in P1 is caused by the Maillard reaction. The Maillard reaction is a non-enzymatic browning process that occurs between reducing sugars and amino acids during heat treatment. This reaction produces melanoidin compounds, which darken the color of food products (Aunon-Lopez *et al.* 2025; El Hosry *et al.* 2025). The absence of pigment-rich ingredients such as cheddar cheese and eri pupae may have allowed the Maillard reaction to dominate the browning process, leading to a more intense brown appearance. This finding is in line with the results reported by Saetae (2025), which showed that the incorporation of pupae protein extract into chocolate ice cream formulations with cocoa powder leads to a lighter appearance, reduces the intensity of brown coloration, and slightly alters the red and yellow color components.

The odor of tofu nuggets P5 has a stronger cheese

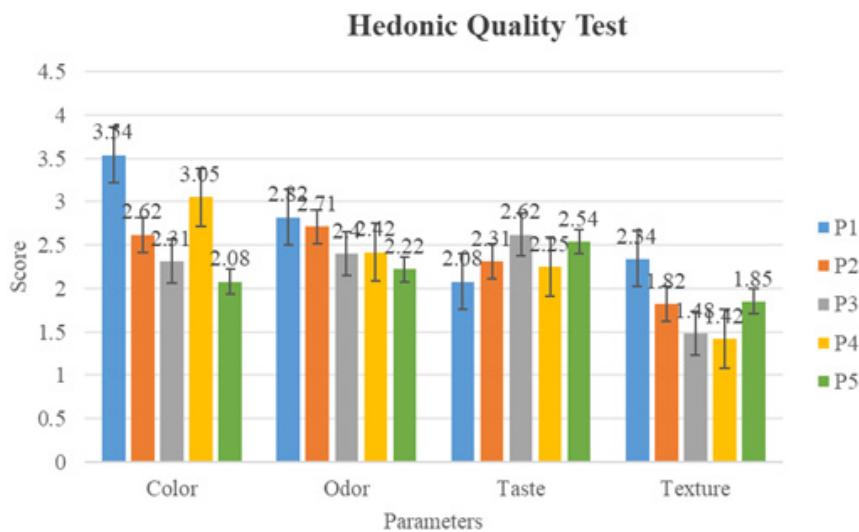


Figure 3. Hedonic quality testing of tofu nuggets with the addition of cheddar cheese and eri pupae cheese

odor compared to other treatments due to the addition of a larger amount of cheddar cheese and eri pupae. The cheese develops its characteristic odor through complex biochemical reactions in its ripening process, which produces various volatile compounds. The combination of volatile compounds from cheddar cheese, includes aldehydes and ketones. This contributes to a rich and diverse profile ranging from mild and creamy to sharp and pungent (Kilcawey and O'Sullivan 2018). Volatile compounds found in pupae of silkworm, such as alcohols, alkanes, aldehydes, esters, and ketones, show a range of intensities. In terms of sensory, eri pupae are usually described with herbal, fruity, and nutty odor notes (Mishyna *et al.* 2020). Conversely, nuggets without additions have a more neutral odor due to the minimal presence of volatile compounds (Rifqi *et al.* 2017).

The taste of tofu nuggets across all treatments showed no significant differences and generally exhibited a slightly salty flavor. The incorporation of cheddar cheese and pupa eri did not intensify the salty taste, even though eri pupae are known to possess naturally higher saltiness levels (Ramadhani, 2024). This finding aligns with research by Holinesti and Zarli (2022), who reported that adding cedar cheese to chicken nuggets did not significantly affect the savory profile. Although insects such as eri pupae contain umami compounds that can enhance flavor complexity, excessive concentrations may lead to a decline in consumer preference due to overpowering taste. The impact of formulation levels on flavor was also observed by Rifqi *et al.* (2017), who found that the addition of 70% and 80% pury flour produced tofu nuggets with a bland taste. Meanwhile, increasing the pury flour to 90% resulted in a noticeably bitter flavor, indicating a threshold for ingredient acceptability. Therefore, while functional ingredients like cheese and insect protein can improve taste, careful formulation is necessary to maintain balance and consumer acceptability.

The texture of the tofu nuggets was significantly influenced by the addition of cheddar cheese and eri pupae, with treatments P3 and P4 producing the softest texture,

while P1 was the hardest. Riandani and Irfan (2022) stated that the addition of cheddar cheese is known to enhance the softness and overall mouthfeel of food products, contributing to a smoother and more tender texture in nuggets. The fat and protein content in cheddar cheese, along with its semi-solid consistency, aids in creating a cohesive and moist structure, which positively influences the consumer's sensory experience. In addition to cheddar cheese, eri pupa has also been identified as a beneficial ingredient due to its emulsifying properties. According to Zielinska (2022), eri pupa functions as a natural emulsifier that helps bind water and fat components within the mixture, thereby improving the product's texture, consistency, and stability. The combination of cheddar cheese and eri pupa not only enhances the physical attributes of the nugget such as smoothness, softness, and uniformity but also contributes to better processing performance and extended shelf life. Together, these ingredients play a synergistic role in refining the texture and structural integrity of the final product.

CONCLUSION

This study demonstrated that the addition of cheddar cheese and eri pupae cheese significantly influenced both the physical and sensory qualities of tofu nuggets. The incorporation of cheddar and eri pupae cheese increased the pH value of tofu nuggets, while aw remained stable across treatment. The sensory evaluation revealed that the treatment with 10% eri pupae cheese (P5) produced the highest sensory scores, showing improved yellow color from natural pigments, a more favorable texture due to emulsifying properties, and a more appealing odor profile. Although no significant differences were found in taste across treatments, the addition of these ingredients contributed positively to the sensory complexity of the product. These findings imply that the use of alternative protein sources like eri pupae, combined with familiar ingredients such as cheddar cheese, can effectively improve both physical and sensory appeal of tofu nuggets. This has important implications for animal

production and food biology, as it supports the development of sustainable, nutritious, and consumer-acceptable alternatives to conventional animal-based products.

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