Malaysian Applied Biology
https://doi.org/10.55230/mabjournal.v55i1.3580

Research Article

Sensory Evaluation and Nutritional Analysis of Keropok Lekor Containing Okara

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ABSTRACT

Keropok lekor is a popular Malaysian snack made primarily from fish meat and contains very low fibre. Okara is a soy by-product from the production of soy milk and tofu, and is often discarded as food waste. However, okara is rich in nutrients, containing 55% fibre, 30% protein, 10% fat, and other bioactive components. The incorporation of okara into the production of *keropok lekor* can help to increase the nutritional content and reduce the environmental impact. This study aimed to evaluate the sensory and nutritional properties of okara-containing *keropok lekor*. Out of 16 formulations, 5 formulations, including the control, were selected for sensory evaluation: control, formulation 1 (2.7% okara), formulation 2 (5.4% okara), formulation 3 (6.7% okara), and formulation 4 (8.1% okara). The sensory evaluation revealed that formulation 1 received the highest scores for aroma, colour, and appearance and was within the acceptable range for all of these attributes, including overall acceptance. Formulation 1 showed no significant differences in colour, appearance, taste, texture, and overall acceptability compared to the control. Nutrient content of control and formulation 1 showed that fibre (3.25 ± 0.07 g/100 g vs 5.10 ± 0.14 g/100 g), fat (11.05 ± 0.21 g/100 g vs 14.10 ± 0.57 g/100 g) and energy content (289.00 ± 0.01 g/100 g vs 325.00 ± 2.83 g/100 g) increased after incorporation of okara, while moisture (37.20 ± 0.14 g/100 g vs 33.55 ± 0.07 g/100 g) and ash (4.30 ± 0.14 g/100 g vs 2.85 ± 0.21 g/100 g) decreased. In conclusion, *keropok lekor*, which contains 2.7% okara, exhibits acceptable sensory properties, suggesting that okara can be used in food development to increase dietary fibre content.

Key words: *Keropok lekor*, nutritional analysis, okara, sensory evaluation

INTRODUCTION

The soybean is a plant that belongs to the *Fabaceae* (*Leguminosae*) family (Singh, 2017). It is widely used in Western and Asian countries for the production of soymilk and tofu (Colletti *et al*., 2020; Asghar *et al*., 2023). The production of soymilk and tofu produces soy residues known as okara. Okara is a yellowish-white solid from the insoluble part of soybeans that remains in the filter bag after soymilk production (Chang *et al*., 2014). The production of 1000 litres of soymilk generates approximately 250 kg of okara. The annual global production of okara waste is estimated to reach 14 million tonnes (Li *et al*., 2012). Although okara is usually disposed of in landfills, its high nutrient and moisture content promote the growth of microorganisms, leading to unpleasant odours and leaching problems. Therefore, the disposal of okara incurs high costs, estimated at 2.5 billion USD annually (Sen *et al*., 2016). However, in some cases, okara is reused as animal feed due to its rich nutrient profile, which is a more sustainable alternative to landfill disposal.

Okara is nutrient-rich and has attracted interest from researchers and food manufacturers. On a dry weight basis, it contains 10% fat, 30% protein, and 55% fibre, of which 50% is insoluble fibre, and 5% is soluble fibre (Mateos-Aparicio *et al*., 2010). Okara also contains bioactive components such as isoflavones, phytosterols, saponins, and phytates (Mateos-Aparicio *et al*., 2010). The rich nutritional content of okara makes it a potential functional food, as dietary fibre intake is associated with positive physiological effects on digestion, blood sugar levels, and blood cholesterol levels, while reducing the risk of diseases such as constipation, diverticular disease, hypertension, diabetes, obesity, heart disease, and cancer (Barber *et al*., 2020).

In addition, the unique composition of okara, which contains cellulose, hemicellulose, and lignin, allows it to contribute to functional properties such as water-binding and oil-binding, thickening, gelling, and structuring, particularly when processed or incorporated appropriately into formulations (Wu *et al*., 2024). Okara has been successfully incorporated into various foods, including bread, cookies, pancakes, noodles, sausages, and yoghurt, mainly to improve water retention, texture, and shelf-life without adversely affecting sensory quality (Roslan *et al*., 2020; Ibrahim *et al*., 2021; Asghar *et al*., 2023). The use of okara in the food industry is widespread in Asian countries, especially in Japan, China, and Indonesia (Hu *et al*., 2022). In addition,

Article History
Accepted: 9 February 2026
First version online: 31 March 2026
Cite This Article:
Lim, S.M., Lim, J.A., Soo, S.Y. & Haron, H. 2026. Sensory evaluation and nutritional analysis of keropok lekor containing okara. Malaysian Applied Biology, 55(1): 102-112. https://doi.org/10.55230/mabjournal.v55i1.3580

several studies have investigated innovative products containing okara, such as okara beef sausages (Noriham *et al*., 2016) and okara yoghurt (Azlina *et al*., 2022) in Malaysia. The reuse and repurposing of okara in the food industry help reduce the waste generated during the production of soymilk and tofu (Azlina *et al*., 2023).

Keropok lekor is a traditional Malaysian snack that is popular on the east coast of Peninsular Malaysia, especially in Terengganu. It is made from ingredients such as fish filling (round scad or fringescale sardine), sago flour, salt, monosodium glutamate (MSG), and sugar. These ingredients are mixed, kneaded into a dough, formed into sausage-like shapes, and cooked in hot water (Che Rohani *et al*., 2013; Muhamad Rafid & Muammar, 2019). The cooked *keropok lekor* can be eaten directly or deep-fried, and is usually served with chilli sauce to enhance its flavour (Mohd Najib *et al*., 2020; Marina *et al*., 2021). In recent years, food manufacturers have introduced innovative versions of *keropok lekor,* such as cheese-filled *keropok lekor* (Nor Salasiah *et al*., 2023) and vegan *keropok lekor* (Vegan District Malaysia, 2025), to attract customers and increase sales. There are also studies on innovations in *keropok lekor* products, such as low-salt *keropok lekor* (Qurratul *et al*., 2024) and mushroom-enriched *keropok lekor* (Nor Salasiah *et al*, 2023). Traditional *keropok lekor* is generally high in starch due to the use of sago flour and contains very little dietary fibre, which may contribute to unhealthy dietary patterns when consumed frequently. These nutritional characteristics are relevant to growing concerns about diet-related non-communicable diseases (NCDs), as high refined starch intake and inadequate fibre consumption are recognised dietary risk factors.

As people become more aware of the importance of a healthy diet, they are increasingly choosing foods that support better health outcomes. This shift is relevant to *keropok lekor* because the traditional product is high in starch and very low in dietary fibre, characteristics that may contribute to unhealthy dietary patterns if consumed frequently. Improving the nutritional profile of commonly consumed traditional snacks is therefore important for supporting healthier eating habits and reducing the risk of diet-related malnutrition problems such as overweight and obesity, and non-communicable diseases including diabetes, heart disease, stroke, and cancer (WHO, 2018). Therefore, this study aimed to evaluate the sensory and nutritional properties of *keropok lekor* containing okara by utilising the nutritional value and functional properties of okara to improve the quality of *keropok lekor*.

MATERIALS AND METHODS

Materials

The ingredients for making okara-containing *keropok lekor*, including salt, MSG, sugar, and oil, were purchased from NSK supermarket in Kuala Lumpur, the fish filling (round scad) from Noorizam Hasan Enterprise, and the sago flour from Giant supermarket in Sungai Wang, Kuala Lumpur. Raw okara was sourced from Ace Canning Corporation Sdn Bhd, Shah Alam, Selangor, Malaysia.

Moisture analysis

The moisture content of okara was determined in triplicate according to the AOAC (1997) method by air drying in an oven. About 5g of okara was dried overnight in an air oven at 105°C until a constant weight was reached.

Keropok lekor containing okara preparation

The control sample of *keropok lekor* was prepared according to the recipe of Qurratul *et al*. (2024), with modifications that included the addition of an extra 5 g of oil and a reduction of 10 g of sago flour to improve the texture of the *keropok lekor*. The ingredients used for the preparation of *keropok lekor* were fish filling, sago flour, okara, salt, MSG, sugar, and oil. A total of 16 formulations were initially developed to explore the effects of incorporating okara into *keropok lekor*. Preliminary trials indicated that formulations with higher okara content often resulted in an excessively hard texture or a noticeable beany flavour, while very low okara levels had a minimal impact compared to the control. Based on trained panel discussions and evaluations, 5 formulations were selected: control, formulation 1 (2.7% okara), formulation 2 (5.4% okara), formulation 3 (6.7% okara), and formulation 4 (8.1% okara). The okara content in each formulation is expressed as a percentage of the total dough (% w/w). The fish filling was kept constant across all formulations, accounting for 67.3% (w/w) of the total dough, while the remaining ingredients were adjusted accordingly to maintain consistent dough characteristics. The preparation process consisted of four main steps: dough preparation, dough forming, cooking, and frying. First, all ingredients were mixed and kneaded until a dough was formed. The dough was formed into sausage-like shapes, measuring 1.5 cm in diameter and 7 cm in length. The formed dough was then cooked in boiling water at 100°C. As soon as the *keropok lekor* floated on the surface of the water, they were lifted out and drained. After cooling, the *keropok lekor* were deep-fried in hot oil at 180°C for 4-5 min. The nutrient content of all five formulations was analysed using Nutritionist Pro software (version 5.2, Axxya Systems-Nutritionist Pro, Stafford, TX, USA). The control and formulation 1 were sent to ALS Technichem (M) Sdn Bhd, Shah Alam, Selangor, Malaysia, for further proximate and dietary fibre analyses, based on AOAC official methods. The nutrient value for the raw *keropok lekor* was generated using Nutritionist Pro, while the food analysis was conducted on the cooked samples of control and formulation 1.

Sensory evaluation

A purposive sampling method was used for the sensory evaluation, in which panellists were selected according to specific criteria. The sensory evaluation involved 54 untrained panellists, including students and staff from Universiti Kebangsaan Malaysia, Kuala Lumpur Campus, Malaysia. It was conducted at the Sensory Room of the Faculty of Health Sciences, Universiti Kebangsaan Malaysia, Kuala Lumpur Campus. Fried *keropok lekor* containing okara and control were served to the panellists to evaluate sensory attributes such as aroma, colour, appearance, taste, texture, and overall acceptance using a sensory evaluation form with a 7-point hedonic scale. The sensory evaluation form also included a questionnaire to assess the panellists' sociodemographic characteristics and consumption habits of *keropok lekor* and okara, providing important context for interpreting sensory acceptance and potential variations in preferences. Sociodemographic information collected included age group, gender, ethnicity, religion, place of birth, highest level of education, marital status, occupation, and monthly household income. Information on consumption habits included willingness to purchase the evaluated samples, preferred sample choice, and factors influencing non-purchase decisions. In addition, panellists were asked about their experience with *keropok lekor* consumption, frequency of intake, purchasing platforms, knowledge of okara, perceptions of okara's potential as an alternative food ingredient to reduce food waste, experience with okara-containing foods, types of okara-containing foods previously consumed, and willingness to accept okara-containing products. Collectively, these data provide essential insight into the panellists' sociodemographic background and familiarity with *keropok lekor* and okara, thereby facilitating a more comprehensive interpretation of their sensory responses and overall acceptance of the tested samples. The questionnaire was adapted from a previous study by Law *et al*. (2024).

Statistical analysis

The collected data were analysed using IBM SPSS for Windows, version 29.0 (IBM Corporation, Chicago, IL, USA). Descriptive analysis was performed to calculate the mean and standard deviation for the sensory attributes, including aroma, colour, appearance, taste, texture, and overall acceptance. A one-way ANOVA test followed by *Tukey's HSD* post hoc test was performed to compare the mean values of the sensory attributes between the different formulations of the samples. An independent t-test was used to determine whether there were significant differences in nutritional analysis between the control and formulation 1. A statistically significant value was set at $p<0.05$.

RESULTS AND DISCUSSION

Moisture analysis of okara

The moisture analysis of okara was conducted to determine the moisture content and the maximum achievable dryness. The okara showed a moisture content of 84.34 ± 0.27%, which is close to the reported moisture content of okara by Vong & Liu (2016) of 70-80%. Due to the high moisture content, standard operating procedures for drying okara were developed to prevent spoilage and extend shelf life for later use in food product development. Previous studies have used different temperatures and time periods for drying okara. For example, Voss *et al*. (2018) dried okara at 80°C for 4 hr, while Tridtitanakiat *et al*. (2023) dried okara at 100°C for 2 hr. Based on these studies, an initial trial was conducted in which okara was dried at 100°C for 2 hr, but the surface of the okara showed slight burnt areas. The okara was then dried at 90°C for 4 hr, but the surface still showed burnt areas. To solve this problem, the okara was dried at 80°C for 4 hr, stirring every hr to prevent burning on the surface. The result was that the okara dried at 80°C for 4 hr had no burnt areas.

However, it is important to determine whether the okara has reached a constant weight and its maximum degree of dryness after drying at 80°C to ensure that it does not spoil easily and is ready for storage or further processing (Guimarães *et al*., 2020). To achieve this, the okara was dried at 80°C for 5, 6, and 7 hr, respectively, to determine the optimal drying temperature and duration. Table 1 shows that the okara reached a constant weight after drying at 80°C for 6 hr. The average moisture content of okara was 84.83 ± 0.76%. This result was almost identical to the moisture content obtained in the moisture content analysis (84.34%). This result indicates that okara dried in the oven at 80°C for 6 hr had reached its maximum degree of dryness. Therefore, the okara was dried in the oven at 80°C for 6 hr for further use in the production of *keropok lekor*. After drying, the okara was completely cooled, ground into powder, and stored in an airtight plastic bag. It was then placed in the freezer to maintain its freshness.

Table 1. Okara moisture content at different drying hr at 80°C

Okara	Weight of okara before drying (g)	Weight of okara after drying 4 hr, 80°C (g)	Weight of okara after drying 5 hr, 80°C (g)	Weight of okara after drying 6 hr, 80°C (g)	Weight of okara after drying 7 hr, 80°C (g)	Moisture content (%)
1	400	62	58	58	-	85.50
2	400	70	60	60	-	85.00
3	400	127	98	64	64	84.00
				Mean ± standard deviation		84.83 ± 0.76

Sociodemographic characteristics of panellists for sensory evaluation

The total number of panellists who participated in the sensory evaluation was 55. However, only 54 (98.2%) panellists were included in the analysis of the study, while one panellist (1.8%) was excluded for not completing the sensory evaluation form. Table 2 shows the sociodemographic data of the panellists, including age group, gender, ethnicity, religion, place of birth, highest level of education, marital status, occupation, and monthly household income.

The majority of panellists who participated in the sensory evaluation were in the 19-29 age range (88.9%), while 11.1% were in the 30-59 age range. In terms of gender, the majority were female (87.0%), while 13.0% were male. In terms of ethnicity, the majority of panellists were Malays (75.9%), followed by Chinese (14.8%), others (5.6%), and Indians (3.7%). The majority of panellists were Muslims (77.8%), followed by Buddhists (14.8%), Hindus (3.7%), and Christians (3.7%). The panellists came from various states in Malaysia, with the majority from Kuala Lumpur (22.2%). Other representatives came from other states, including Johor, Kedah, Kelantan, Melaka, Negeri Sembilan, Pahang, Pulau Pinang, Perak, Perlis, Sabah, Sarawak, Selangor, and Terengganu. In terms of the highest level of education, 87.0% of the panellists had completed Form 6, matriculation, or a diploma, 9.3% had a bachelor's degree, and 1.9% had completed secondary school or a master's degree. Most panellists were single (92.6%), followed by married (5.6%) and widower/widow (1.9%). In terms of occupation, most panellists were students (90.7%), while the rest worked as government employees (9.3%). In terms of monthly household income, most panellists reported a monthly household income of more than RM6500 (35.2%).

Table 2. Sociodemographic characteristics of panellists for sensory evaluation (*n*=54)

Characteristics	Total, *n* (%)
Age group (years old)	
19-29	48 (88.9)
30-59	6 (11.1)
Gender	
Male	7 (13.0)
Female	47 (87.0)
Ethnicity	
Malay	41 (75.9)
Chinese	8 (14.8)
Indian	2 (3.7)
Others[1]	3 (5.6)
Religion	
Muslim	42 (77.8)
Buddhist	8 (14.8)
Hindu	2 (3.7)
Christian	2 (3.7)
Place of birth	
Johor	3 (5.6)
Kedah	5 (9.3)
Kelantan	4 (7.4)
Kuala Lumpur	12 (22.2)
Melaka	1 (1.9)
Negeri Sembilan	3 (5.6)
Pahang	1 (1.9)
Pulau Pinang	2 (3.7)
Perak	6 (11.1)
Perlis	1 (1.9)
Sabah	2 (3.7)
Sarawak	2 (3.7)
Selangor	10 (18.5)
Terengganu	2 (3.7)
Highest level of education	
Completed secondary school	1 (1.9)
Completed form 6/ matriculation/ diploma (Pre-U)	47 (87.0)
Completed bachelor's degree	5 (9.3)
Completed master's degree	1 (1.9)
Marital status	
Single	50 (92.6)
Married	3 (5.6)
Widow/Widower	1 (1.9)
Occupation	
Government employee	5 (9.3)
Student	49 (90.7)
Monthly household income[2]	
Less than RM1500	10 (18.5)
RM 1501 – RM 2500	4 (7.4)
RM 2501 – RM 3500	8 (14.8)
RM 3501 – RM 4500	6 (11.1)
RM 4501 – RM 5500	3 (5.6)
RM 5501 – RM 6500	4 (7.4)
More than RM 6500	19 (35.2)

[1]Others include Kenyah, Murut, and Bugis.

[2]Income ranges for monthly household income are based on the Household Income and Basic Amenities Survey Report 2019 (Department of Statistics Malaysia 2020).

Sensory evaluation

Table 3 shows the mean scores for the sensory evaluation of six attributes, including aroma, colour, appearance, taste, texture, and overall acceptability. The scores were made on a scale of 1 to 7, from "dislike very much" to "like very much". A mean score between 5 and 7 was considered a well-accepted sample, as this range refers to "like" to "like very much".

Table 3. Mean scores of sensory attributes for five *keropok lekor* formulations

Attributes	Control	Formulation 1	Formulation 2	Formulation 3	Formulation 4
Aroma	4.70 ± 1.14^{ab}	5.44 ± 1.27^{c}	4.78 ± 1.21^{a}	4.17 ± 1.08^{bd}	3.94 ± 1.00^{d}
Colour	4.89 ± 1.24^{abc}	5.11 ± 1.19^{a}	4.96 ± 1.13^{ab}	4.37 ± 1.23^{bc}	4.30 ± 1.14^{c}
Appearance	4.93 ± 1.33^{ab}	5.24 ± 1.21^{a}	4.89 ± 1.02^{abc}	4.50 ± 1.34^{bc}	4.26 ± 1.20^{c}
Taste	5.13 ± 1.58^{a}	4.63 ± 1.55^{a}	4.44 ± 1.72^{ab}	3.74 ± 1.48^{bc}	3.48 ± 1.50^{c}
Texture	4.93 ± 1.44^{a}	4.72 ± 1.58^{a}	4.33 ± 1.59^{ab}	4.17 ± 1.51^{ab}	3.69 ± 1.52^{b}
Overall acceptance	5.07 ± 1.40^{a}	5.06 ± 1.34^{a}	4.43 ± 1.53^{ab}	4.06 ± 1.32^{b}	3.72 ± 1.24^{b}

Values are reported as mean ± standard deviation. A total of 54 panellists participated in the sensory evaluations.

Values of different letters in the same row indicate significant differences ($p<0.05$) based on Tukey's HSD Post Hoc test.

For the aroma attribute, formulation 1 received the highest mean score (5.44 ± 1.27) compared to the control (4.70 ± 1.14), formulation 2 (4.78 ± 1.21), formulation 3 (4.17 ± 1.08), and formulation 4 (3.94 ± 1.00). There was a significant difference (p<0.05) between formulation 1 and control, formulation 2, 3, and 4 for aroma attribute. However, the control showed no significant difference compared to formulations 2 and 3. In addition, the mean score for the aroma attribute decreased with increasing okara content from formulation 1 to 4. This may be due to okara having an unpleasant beany odour (Wang *et al*., 2022). Therefore, adding okara to the formulation may increase the intensity of the beany odour, which in turn decreases the mean score for the aroma attribute.

For the colour attribute, formulation 1 recorded the highest mean score (5.11 ± 1.19) compared to the other formulations. Formulation 1 showed no significant difference (p>0.05) compared to the control (4.89 ± 1.24) and formulation 2 (4.96 ± 1.13). There was also no significant difference (p>0.05) in the control compared to all formulations of *keropok lekor* containing okara. Thus, replacing sago flour with okara had no significant effect on the colour of *keropok lekor*. This result is consistent with the study by Grizotto *et al*. (2010), who found that the colour of a moulded sweet biscuit with 30% okara flour was not significantly different from that of the standard biscuit.

For the appearance attribute, formulation 1 also achieved the highest mean score (5.24 ± 1.21) compared to the other formulations. Formulation 1 showed no significant difference compared to the control (4.93 ± 1.33) and formulation 2 (4.89 ± 1.02). The control also showed no significant difference compared to formulations 1, 2, and 3 (4.50 ± 1.34). Only formulation 4 (4.26 ± 1.20) showed a significant difference (p<0.05) from the control. This may be because okara is a yellowish-white solid particle (Swallah *et al*., 2021). When okara was mixed into the ingredients of *keropok lekor*, the yellowish-white okara solid particles were clearly visible in the *keropok lekor*. This result supports the findings of the study by Cao *et al*. (2024), which reported that dried okara has a pale-yellow colour and can maintain its colour when combined with wheat flour in noodle production. Therefore, the presence of okara particles in *keropok lekor* affects its appearance.

For the taste attribute, the control had the highest mean score (5.13 ± 1.58) compared to the other formulations. The control showed no significant difference compared to formulations 1 (4.63 ± 1.55) and 2 (4.44 ± 1.72), but there was a significant difference (p<0.05) compared to formulations 3 (3.74 ± 1.48) and 4 (3.48 ± 1.50). This difference was due to the beany taste of okara (Azanza & Gascon, 2015). This result supports the study by Mohamad Afifi *et al*. (2024), who reported that biscuits made with okara received a lower mean score on sensory attributes due to the beany taste of okara. Therefore, increasing the okara content in *keropok lekor* affects the taste of the product and lowers the mean score for the taste attribute.

For the texture attribute, all samples, including the control, received a mean score below 5, indicating moderate acceptability among the panellists. The control received the highest mean score (4.93 ± 1.44), yet it was still slightly below the neutral point of the hedonic scale. This may be attributed to its inherent formulation-dependent texture. Traditional *keropok lekor* is inherently chewy, which may not align with the preferences of all panellists, particularly those less familiar with this snack. *Keropok lekor* is primarily made from fish and starch, and its hardness, springiness, cohesiveness, and chewiness are strongly influenced by the fish-to-starch ratio, type of starch, and water content. Previous studies have shown that higher fish content or exclusive use of sago starch increases hardness and chewiness, which can reduce consumer liking (Afifi *et al*., 2023; Che Ku Jusoh *et al*., 2023; Saeed *et al*., 2024). Additionally, minor variations in preparation, such as frying time, oil temperature, or serving conditions (e.g., freshly fried versus cooled), could have influenced texture perception. Panellist expectations and individual preferences for chewiness may also have played a role in the relatively low texture scores. Future studies should include a larger and more diverse panel, encompassing a wider range of age groups and a more balanced gender distribution, to provide more robust and representative sensory evaluation outcomes.

In this study, there was no significant difference (p>0.05) between the control and formulations 1 (4.72 ± 1.58), 2 (4.33 ± 1.59), and 3 (4.17 ± 1.51). Only formulation 4 (3.69 ± 1.52) showed a significant difference (p<0.05) compared to the control. The decrease in the mean score for the texture attribute due to the addition of okara in *keropok lekor* had increased the hardness, which may not be a favourable characteristic for *keropok lekor*. This phenomenon was also observed in the studies by Momin *et al*. (2020) and Cao *et al*. (2024), who reported that an increase in okara content led to a harder texture of the food. Therefore, replacing sago flour with okara may increase the hardness of *keropok lekor* and thus reduce the mean score for the texture attribute.

In terms of overall acceptability, the control recorded the highest mean score (5.07 ± 1.40), followed by formulation 1 (5.06 ± 1.34), formulation 2 (4.43 ± 1.53), formulation 3 (4.06 ± 1.32), and formulation 4 (3.72 ± 1.24). The control showed no significant difference from formulations 1 and 2, but there was a significant difference (p<0.05) between formulations 3 and 4. Both the control and formulation 1 received a mean score of more than 5, indicating good overall acceptance.

Overall, formulation 1 achieved the highest mean scores for aroma, colour, and appearance, while it ranked second for texture, taste, and overall acceptance. Figure 1 shows that formulation 1 was at the bottom of the radar chart for most attributes, with the exception of texture and taste. Therefore, formulation 1 (2.7% okara) was the best accepted by the panellists compared to other okara-containing *keropok lekor* formulations. The sensory evaluation also showed that formulations with higher okara content received lower scores, particularly for taste, aroma, and texture, likely due to the characteristic's beany odour and taste of okara as well as a firmer texture. A previous study has also reported that a higher okara content adversely affects the properties of the extruded snack and results in a harder, less crispy, and denser product (Aussanasuwannakul *et al*., 2022).

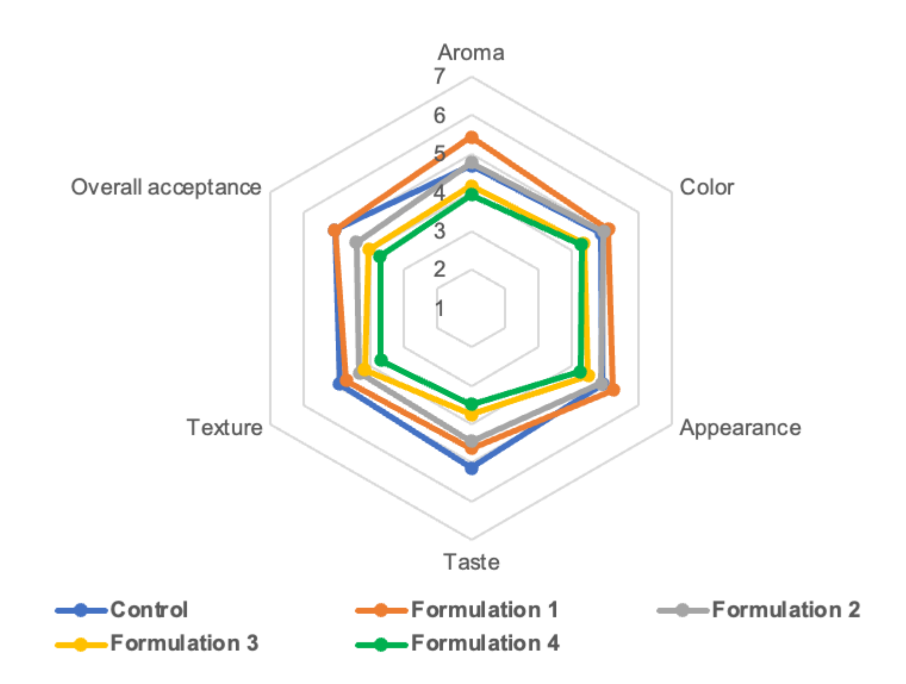

Fig. 1. The radar chart shows a comparison of the mean scores for sensory attributes across different formulations. The values are reported as mean ± standard deviation. A 7-point hedonic scale ranging from 1 (dislike very much) to 7 (like very much) was used for each attribute. Control; Formulation 1 (2.7% okara); Formulation 2 (5.4% okara); Formulation 3 (6.7% okara); Formulation 4 (8.1% okara).

Consumption habits of *keropok lekor* and okara

Table 4 shows the consumption habits of *keropok lekor* and okara by the panellists in the sensory evaluation. A total of 74.1% of the panellists indicated that they would be willing to buy the samples evaluated in the sensory evaluation, while 11.1% were not willing and 14.8% were not sure. Among the samples, control was the most preferred (28.8%), followed by formulation 1 (27.3%), formulation 2 (18.2%), formulation 3 (13.6%), and formulation 4 (12.1%). This result is consistent with the sensory analysis, where the control received the highest overall score, followed by formulations 1, 2, 3, and 4.

Regarding the factors that led them not to buy the samples, 14.3% of the panellists stated that they do not consume *keropok lekor* frequently, while 85.7% stated that the samples evaluated were less tasty or that there were better alternatives. All panellists (100%) confirmed that they had eaten *keropok lekor* before and thus met the inclusion criterion of having consumed it within the last 6 months.

The frequency of consumption of *keropok lekor* varied: once a month (40.7%), 2-3 times a month (33.3%), once a week (11.1%), once in 6 months (9.3%), 2-6 times a week (3.7%), and 2-5 times in 6 months (1.9%). Most panellists bought ready-to-eat *keropok lekor* from street stalls (62.8%), followed by frozen *keropok lekor* from supermarkets (17.9%), ready-to-eat *keropok lekor* from restaurants (9.0%), frozen *keropok lekor* through online orders (6.4%), and ready-to-eat *keropok lekor* through online orders (3.8%). These results are in line with Atiqah *et al*. (2024) and Azman *et al*. (2012), who reported that *keropok lekor* is commonly sold at street stalls and night markets.

In terms of knowledge of okara, 46.3% of the panellists were familiar with it, 40.7% were not familiar, and 13.0% were not sure. The majority of panellists (75.9%) agreed that okara has the potential to be an alternative source in food production to reduce food waste, while 24.1% disagreed. This is in line with the studies by Su *et al*. (2013) and Feng *et al*. (2021), who found that okara is partly used as a substitute for wheat flour, tapioca flour, corn flour, and soy flour in various food products, thus contributing to the reduction of food waste.

Only 3.7% of panellists had ever eaten food with okara, 46.3% had not, and 50% were not sure. One panellist reported that okara tempeh was the okara-containing food s/he had consumed. Although many of the panellists were unfamiliar with okara (40.7%) and had never eaten foods containing okara (46.3%), most panellists (74.1%) said they would accept the product, only 5.6% would not accept it, and 20.4% were not sure.

Table 4. Survey on consumption habits of *keropok lekor* and okara by the panellists in sensory evaluation (n=54)

Statement	Total, n (%)
Willingness to purchase the samples evaluated in the sensory evaluation	
Yes	40 (74.1)
No	6 (11.1)
Not sure	8 (14.8)
Sample that panellists would choose to buy[a]	
Control	19 (28.8)
Formulation 1	18 (27.3)
Formulation 2	12 (18.2)
Formulation 3	9 (13.6)
Formulation 4	8 (12.1)
Factors that led to not purchasing the samples evaluated in the sensory evaluation[b]	
Do not consume *keropok lekor* frequently	1 (14.3)
Less tasty, or there are better options	6 (85.7)
Experience of eating *keropok lekor*	
Yes	54 (100.0)
Frequency of *keropok lekor* consumption	
Once every 6 months	5 (9.3)
2-5 times in 6 months	1 (1.9)
Once a month	22 (40.7)
2 -3 times a month	18 (33.3)
Once a week	6 (11.1)
2-6 times a week	2 (3.7)
A platform to buy *keropok lekor*	
Supermarket (frozen)	14 (17.9)
Online order (frozen)	5 (6.4)
Online order (ready to eat)	3 (3.8)
Street stall (ready to eat)	49 (62.8)
Restaurant (ready to eat)	7 (9.0)
Knowledge about okara	
Yes	25 (46.3)
No	22 (40.7)
Not sure	7 (13.0)
Perception of the potential of okara as an alternative source in food production to reduce food waste	
Yes	41 (75.9)
No	13 (24.1)
Experience of eating okara-containing foods	
Yes	2 (3.7)
No	25 (46.3)
Not sure	27 (50.0)
Okara-containing foods that panellists have eaten	
Okara tempeh	1 (100.0)
Willingness to accept okara-containing foods	
Yes	40 (74.1)
No	3 (5.6)
Not sure	11 (20.4)

[a]Panellists were allowed to select more than one option

[b]Panelists who responded 'No' or 'Not sure' regarding their willingness to purchase the samples were asked to provide the reason; however, some did not provide any responses

Nutrient content through Nutritionist Pro

Table 5 shows the nutrient content of five formulations per 100 g, based on an analysis with the Nutritionist Pro software. The results show that the addition of okara reduces the energy value in the formulations. This reduction is because sago flour, a high-carbohydrate source (Huwae & Papilaya, 2014), was replaced with okara, which is high in fibre but low in carbohydrates (Li *et al*., 2012). Carbohydrates provided 4 kcal/g, while fibre provided only 2 kcal/g (Slavin & Carlson, 2014). Replacing some carbohydrates with lower-calorie dietary fibre, therefore, helped to reduce the total number of calories in *keropok lekor*.

Table 5. Nutrient content of five formulations per 100 g in raw using Nutritionist Pro

Parameters	Control	Formulation 1	Formulation 2	Formulation 3	Formulation 4
Energy (kcal/100 g)	201	194	187	184	179
Protein (g/100 g)	15.01	15.10	15.19	15.28	15.27
Carbohydrate (g/100 g)	24.05	22.05	20.05	19.12	18.05
Fat (g/100 g)	4.98	5.02	5.07	5.11	5.12
Fibre (g/100 g)	0	0.11	0.22	0.28	0.33

The addition of okara also increased the protein content in the formulations. On a dry weight basis, okara contains a high protein content of 30% (Mateos-Aparicio *et al*., 2010). This increase indicates that okara contributes to the protein content in the formulation. Therefore, replacing sago flour with okara in the formulation may increase the protein content of *keropok lekor*. The carbohydrate content decreased when the proportion of okara in the formulation was increased. This is because sago flour is rich in carbohydrates (Huwae & Papilaya, 2014), while okara has a low carbohydrate content (Li *et al*., 2012). By replacing sago flour with okara, the carbohydrate content in the formulations can be directly reduced. The fat content increased slightly with the addition of okara. This is due to the fat content of okara, which is 10% of the dry weight (Mateos-Aparicio *et al*., 2010). However, this increase in fat content was minimal.

In addition, the addition of okara significantly increased the fibre content in the formulations. Okara contains 55% dietary fibre on a dry weight basis (Mateos-Aparicio *et al*., 2010). Replacing sago flour with okara contributed to this increase. This is evident in the control, which contained no okara and had no dietary fibre content (0 g), compared to formulation 4, which had the highest okara content (8.1% okara) and a dietary fibre content of 0.33 g. This shows that replacing sago flour with okara can increase the fibre content in the *keropok lekor* formulation.

Replacing sago flour with okara has a positive effect on the nutritional profile of *keropok lekor*, especially by increasing the fibre and protein content. These results are consistent with the study by Asghar *et al*. (2023), which states that okara has the potential to be used in food production to increase fibre and protein content.

Proximate and dietary fibre content through food analysis

Since formulation 1 received the highest score for most sensory attributes and was the most accepted *keropok lekor* containing okara, it was selected for further analysis together with the control sample. Both samples were subjected to food analysis in the laboratory after frying to determine their proximate composition and dietary fibre content. The results of the nutrient content for the fried control sample and formulation 1 are presented in Table 6. The calorie content of formulation 1 (325.00 ± 2.83 kcal/100 g) was significantly higher (p<0.05) compared to the control (289.00 ± 0.01 kcal/100 g). This increase corresponds to a significantly higher fat content (p<0.05) in formulation 1 (14.10 ± 0.57 g/100 g) than in the control (11.05 ± 0.21 g/100 g), with a difference of 3.05 g/100 g. Fat provides the most calories among the macronutrients at 9 kcal/g, compared to carbohydrates and proteins, which provide 4 kcal/g each (NCCFN, 2021). Therefore, the higher fat content in formulation 1 contributed to its higher total calorie content.

Table 6. Nutrient content of control and formulation 1 per 100 g after frying by food analysis

Parameter	Control	Formulation 1
Energy (kcal/100 g)	289.00 ± 0.01[a]	325.00 ± 2.83[b]
Total dietary fibre (g/100 g)	3.25 ± 0.07[a]	5.10 ± 0.14[b]
Carbohydrate (g/100 g)	32.15 ± 0.78[a]	34.25 ± 0.78[a]
Fat (g/100 g)	11.05 ± 0.21[a]	14.10 ± 0.57[b]
Protein (g/100 g)	15.35 ± 0.35[a]	15.30 ± 0.28[a]
Moisture content (g/100 g)	37.20 ± 0.14[a]	33.55 ± 0.07[b]
Ash content (g/100 g)	4.30 ± 0.14[a]	2.85 ± 0.21[b]

Values are reported as mean ± standard deviation.

Values of different letters in the same row indicate significant differences (p<0.05) based on an independent t-test

The oil-retaining properties of okara during frying may influence mouthfeel, thereby contributing to changes in sensory perception. The fat in okara is predominantly unsaturated, with linoleic acid (C18:2, 49.76%) and oleic acid (C18:1, 27.12%) as the major fatty acids, followed by palmitic acid (C16:0, 15.34%), stearic acid (C18:0, 2.59%), and alpha-linolenic acid (C18:3, 5.14%). Compared to soybean seed oil, okara contains higher proportions of palmitic and oleic acids but lower alpha-linolenic acid (Kumar *et al*., 2016). Overall, the presence of these unsaturated fatty acids enhances the nutritional value of okara.

In addition, the carbohydrate content in formulation 1 (34.25 ± 0.78 g/100 g) was also higher than that of the control (32.15 ± 0.78 g/100 g). The dietary fibre content in formulation 1 (5.10 ± 0.14 g/100 g) was significantly higher (p<0.05) than in the control (3.25 ± 0.07 g/100 g), as formulation 1 contained 2.7% okara, which is rich in dietary fibre. Since the dietary fibre content in Formulation 1 is approximately 5 g per 100 g, exceeding the minimum of 3 g per 100 g, it is considered a “source of dietary fibre” according to the Guide to Nutrition Labelling and Claims in Malaysia (MOH, 2010). The protein content in the control was slightly higher than in formulation 1, with a minimal difference of only 0.05g/100 g, and thus did not contribute significantly to the calorie difference. The moisture content (33.55 ± 0.07 g/100 g) and ash content (2.85 ± 0.21 g/100 g) were significantly lower (p<0.05) in formulation 1 compared to the control (37.20 ± 0.14 g/100 g and 4.30 ± 0.14 g/100 g, respectively).

Comparison of nutrient values between Nutritionist Pro and food analysis

There were differences between the results of the Nutritionist Pro (Table 5) and the food analysis (Table 6). The food analysis was performed on the fried *keropok lekor*, whereas Nutritionist Pro calculated the nutritional values based on raw ingredients. This explains the variation in energy content, where formulation 1 showed higher energy in the proximate analysis but lower energy in the nutrient analysis.

Moreover, the fibre in okara is capable of retaining fat during frying, thereby reducing fat loss and contributing to increased calorie content after frying (Kumar *et al*., 2015). For fibre and fat content, both analytical methods showed higher values in formulation 1 compared to the control. However, the differences were more pronounced in the food analysis (fibre: 1.85 g/100 g; fat: 3.05 g/100 g) than in the Nutritionist Pro (fibre: 0.11 g/100 g; fat: 0.04g/100 g). For protein content, the food analysis indicated that the control was slightly higher, whereas the Nutritionist Pro showed higher protein content in formulation 1. However, theoretically, formulation 1 should contain more protein, as sago flour contains only 0.7 g/100 g of protein (Metaragakusuma *et al*., 2016), while okara contains 20-30 g/100 g of protein (Guimarães *et al*., 2020).

Okara is also rich in minerals, with an ash content of 3.7%, including potassium, sodium, calcium, magnesium, copper, zinc, and iron (Mateos-Aparicio *et al*., 2010). Nevertheless, in the food analysis, the ash content in formulation 1 was lower than in the control by 1.45 g/100 g. This reduction in protein and ash content in formulation 1 may be due to nutrient loss during the production of okara powder. According to Asghar *et al*. (2023), the pre-treatment and processing conditions of okara powder can affect its nutritional profile. Although okara is high in fibre and has good water absorption properties, the moisture content in formulation 1 was still lower than in the control by 3.65 g/100 g in the food analysis. This is likely due to the thorough drying process of the okara before use, unlike sago flour, which typically contains 14 – 17% moisture.

A limitation of this study is that the majority of the panellists in the sensory evaluation were students and staff from Universiti Kebangsaan Malaysia, Kuala Lumpur Campus, aged between 19 and 59 years old, and predominantly Malays. Therefore, the data collected does not comprehensively represent Malaysian consumers of all ages, ethnicities, and states, providing a limited and unbalanced view of consumer acceptance of *keropok lekor* containing okara. Despite this limitation, this study is the first study to report the sensory and nutritional analysis of *keropok lekor* containing okara. It serves as a basis for further research on the use of okara as a substitute for sago flour in the production of *keropok lekor*. In addition, this study contributes valuable insights into the suitability of okara for the production of *keropok lekor* and its potential to increase fibre and protein content.

CONCLUSION

Formulation 1 (2.7% okara) achieved the highest mean score for the attributes like aroma, colour, and appearance, and the second highest mean score for texture, taste, and overall acceptability. No differences were observed between formulation 1 and the control for the attributes colour, appearance, taste, texture, and overall acceptability, except for the aroma attribute. The nutrient content of the formulations for keropok lekor containing okara showed an increase in fibre. Formulation 1 offered the best balance between nutritional value and sensory acceptability among all formulations. Formulation 1 offered a healthier alternative for consumers looking for keropok lekor with a higher fibre content. Future studies should determine the shelf life of keropok lekor containing okara to determine the optimal storage time and method, while ensuring its suitability and potential for use in the food market.

ACKNOWLEDGEMENTS

The authors would like to thank the panellists who participated in the sensory evaluation and Ms. Karren Tan Ka Hong of Ace Canning Corporation Sdn Bhd, Shah Alam, Selangor, Malaysia, for arranging the raw okara used in this study.

ETHICAL STATEMENT

This study was approved by the Research Ethics Committee of Universiti Kebangsaan Malaysia, approval number JEP-2024-564.

CONFLICT OF INTEREST

Sek Yow Soo is an employee of Ace Canning Corporation Sdn Bhd. The other authors declare no conflicts of interest.

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