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Research Article

Nutritional Analysis and Survey of Malaysian Tempeh Snacks

Hasnah Haron[1*], Siti Masyitah Ahmad Khairul Anam[1], Law Chai Jia[1], Erni Sofia Murtini[2], Nurul Huda[3]

[1]Nutritional Sciences Programme, Centre of Health Ageing and Wellness, Faculty of Health Sciences, Universiti Kebangsaan Malaysia, 50300 Kuala Lumpur, Malaysia
[2]Faculty of Agricultural Technology, Universitas Brawijaya, Malang 65145, Indonesia
[3]Faculty of Agroindustrial and Biosystems Technology, Universitas Brawijaya, Malang 65145, Indonesia

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***Corresponding Author:**
tel: +60133996594
email: hasnaharon@ukm.edu.my

ABSTRACT

This study surveyed tempeh-based snack varieties in the Malaysian market and analysed the nutrient content of selected products using a cross-sectional approach comprising market survey, proximate and mineral analysis, and consumer survey. The market survey covered online platforms (Shopee, Temu and Lazada) and physical stores in Kuala Lumpur and Selangor. Proximate and mineral analyses were conducted on the five most available tempeh snack products, while the consumer survey involved 179 respondents exploring awareness and preferences. Tempeh chips dominated the market with Shopee as the leading platform. Sambal-flavored chips had the highest moisture (7.94±0.87) and ash (2.97±0.11) content, while salty chips recorded the highest protein protein (27.88±0.72), Cu (0.69±0.06), Mn (1.52±0.23), Fe (3.03±0.30), Mg (80.92±5.95), and K (344.18±29.17) levels. Sambal chips had the highest Na (729.99±76.26). Pb and Cd levels were within regulatory thresholds, except Pb in sambal tempeh. Most consumers were aware of tempeh's health benefits and preferred crispy, spicy, affordable snacks priced at RM5.00-RM9.99 (USD1.2−2.4). This study contributes nutritional data to Malaysia's Food Composition Database (MyFCD) and provides recommendations for diversifying tempeh snack products.

INTRODUCTION

Food and Agriculture Organization and World Health Organization (FAO/WHO 2017) describe tempeh as a dense, white, non-crumbly fermented food with a texture and flavour resembling meat and mushrooms. It is produced mainly from soybeans fermented with *Rhizopus sp.* mould, using rice or wheat-based materials like inoculants. In Indonesia, tempeh production is regulated under SNI 3144:2009 by the National Standardization Agency of Indonesia, which sets detailed requirements for hygiene, processing, packaging and labelling. Malaysia does not yet have specific nutritional standards for tempeh, but it is classified as a fermented soybean product under the Food Regulation 1985. According to the regulation, fermented soy bean product defined as whole or ground soy bean that fermented with harmless microorganism and may contain permitted preservative, colouring substance and flavour enhancer and other wholesome foods.

Tempeh's unique taste makes it versatile for inclusion in various diets, whether as a simple dish or as an ingredient in more complex recipes. Tempeh has a short shelf life, even under vacuum packaging and refrigeration, which limits its storage and distribution (Astawan *et al.* 2016; Djunaidi *et al.* 2017). As a result, the tempeh industry, which is largely dominated by small-scale rural enterprises, has adopted product diversification strategies by converting fresh tempeh into value-added snack products to minimize post-harvest losses and enhance marketability (Purwadaria *et al.* 2016). In Malaysia, existing research has primarily focused on the diversity and macronutrient composition of raw tempeh, with limited investigation into value-added products (Wu & Hasnah 2018; Law *et al.* 2024). Consequently, comprehensive evaluations of the chemical and nutritional properties of commercially available tempeh-based snack products remain scarce, highlighting a clear research gap.

Therefore, the objectives of this study were to: 1) To identify the variety of tempeh-based snack products available in the local market, 2) To determine the macronutrient and micronutrient content of selected tempeh-based snack products through proximate and mineral analysis, 3) To gather consumer opinions on tempeh-based products available in the local market through a conducted survey. The result of this study could provide nutritional data for Malaysia's Food Composition Database (MyFCD) and recommendations for diversifying tempeh snack products to meet consumer demands.

METHODS

Design, location, and time

This cross-sectional study (June 2024–August 2025) examined the diversity, nutritional composition, and consumer perception of Malaysian tempeh-based snacks via market survey, proximate and mineral analysis, and consumer survey. Market data were collected from online platforms (Shopee, Lazada and Temu) and physical stores in Kuala Lumpur and Selangor through convenience sampling. Nutrient composition, including proximate parameters and minerals (Cr, Cd, Pb, Cu, Mn, Fe, Zn, Mg, Na, Ca, and K) was determined at the Food Composition Analysis Laboratory, Universiti Kebangsaan Malaysia with ethic approval code JEP-2024-628.

Sampling

Based on the market survey findings, the five most available tempeh-based snack products without nutritional labels were selected from both online and physical stores. Each product type was photographed, weighed, homogenized, and refrigerated until analysis. Macronutrients and minerals were determined in triplicate and duplicate, respectively. Subjects for the consumer survey were selected using convenience sampling based on specific inclusion criteria: i) Individuals who have consumed tempeh. before; ii) Malaysian citizens.

Data collection

Market survey. The market survey aimed to identify the diversity of tempeh-based products available in the Malaysian market. Key product information was recorded including product type, selling price, price per 100 g, ingredients list, manufacturer details, nutritional labels and sales platforms.

Moisture content. Moisture content was determined by the oven drying method (Law *et al.* 2024). Nickel crucibles were pre-dried overnight at 150°C and cooled in a desiccator for 30 minutes before weighing. Five grams of each sample (W1) were dried overnight at 150°C, then cooled for 45 minutes and reweighed until a constant weight (W2) was obtained. Analyses were performed in triplicate, and moisture content was calculated using the formula. Calculation formula:

$$\text{Moisture (\%)} = \frac{W_1 - W_2}{W_1} \times 100\%$$

Where;
W_1=sample weight before the drying process
W_2= sample weight after drying process

Ash content. Ash content was determined using the dry ashing method with a muffle furnace maintained at 450–550°C. Porcelain crucibles with lids were pre-dried overnight at 450–550°C. 5g of homogenized samples (W1) were added to the crucibles in triplicate. Samples were ashed overnight in the muffle furnace at 450–550°C. After ashing, crucibles were cooled in a desiccator to room temperature and reweighed (W2). The ash content was calculated using the formula:

Total weight of ash = W2 (weight of porcelain crucibles + ash) – W1 (weight of porcelain crucibles).

$$\text{Total ash content (\%)} = \frac{\text{Total weight of ash (g)}}{\text{Sample weight (g)}} \times 100\%$$

Crude fat content. Crude fat content was determined using the Soxhlet method (Abdullah *et al.* 2021). Samples of 3.000±0.001 g (W1) were transferred into clean, dry thimbles in triplicate. Pre-dried extraction cups were weighed (W2) and loaded with 70 mL of petroleum ether (40–60%). The thimbles and extraction cups were placed into the Soxtec unit and subjected to sequential boiling (25 minutes), rinsing (40 minutes), and solvent recovery (3 minutes). Extraction cups were dried on the heating plate for 2 minutes, then oven-dried at 100°C for 15 minutes. Cups were reweighed (W3), and crude fat content (%) was calculated using the formula. Crude fat percentage (%):

$$\frac{W_3 - W_2}{W_1} \times 100\%$$

Where :
W_1= Sample weight (g)
W_2= Extraction cup weight (g)
W_3= Extraction cup weight with fat (g)

Crude protein content. Crude protein content was determined using the Kjeldahl method in triplicate. Samples of 2.000±0.001 g were transferred into digestion tube along with a catalyst mixture (7 g K_2SO_4 and 0.8 g $CuSO_4$) and 12 mL of concentrated H_2SO_4. A reagent blank was prepared simultaneously. The mixture was digested at 60 minutes until a clear green color was obtained, then cooled for 15 minutes. For distillation, 75 mL of distilled water was added to the digestion tube, and 25 mL of 4% boric acid in an Erlenmeyer flask was used as the receiving solution in a Tecator Kjeltec Distilling Unit. The distillate was titrated against 0.2 M HCl until the indicator returned to its original color. A blank was titrated under the same conditions. The crude protein content was calculated based on the nitrogen content in the sample using the Kjeldahl formula:

$$\text{Nitrogen content (\%)} = \frac{\text{mL HCl (sample} - \text{blank)} \times \text{NHCl} \times 14.007}{\text{Sample weight}} \times \frac{100}{1000}$$

Crude protein percentage (%) = Nitrogen content (%)×5.71

Carbohydrate content. The carbohydrate content was determined by using the traditional method, where the method was determined by the difference based on the formula:

Total carbohydrate (%) = 100 - (weight in gram [protein + fat + moisture + ash + alcohol] in 100 g)

Mineral analysis. Mineral analysis (Cr, Cd, Pb, Cu, Mn, Fe, Zn, Mg, Na, Ca, and K) was performed using Inductively Coupled Plasma-Optical Emission Spectrometry (ICP-OES) following Wikandari *et al.* (2020). Samples of 1.0 g were digested with 10 mL HNO_3 in a sealed vessel using microwave digestion, then diluted with distilled water in a volumetric flask and filtered prior to analysis. ICP-OES was operated with plasma, auxiliary, and nebulizer gas flow rates of 10, 0.5 and 0.6 L/min, respectively.

Consumer survey. Consumer opinions on tempeh-based products were gathered via an online questionnaire distributed through social media platforms (WhatsApp, Telegram, and Instagram), adapted from Mat Amin *et al.* (2017) with approval from the original researcher. Pilot testing was conducted on 15 subjects meeting the inclusion criteria, who were subsequently excluded from the main survey. The questionnaire demonstrated good reliability with a Cronbach's Alpha of 0.834, exceeding the acceptable threshold of 0.70. Informed consent was obtained from all participants.

Data analysis

Data were analysed using IBM SPSS version 29. Descriptive analysis was conducted for market and consumer survey data, with findings presented in tables. Proximate and mineral analysis results were expressed as mean±SD. Differences in nutrient content across samples were assessed using one-way ANOVA for homogenous variance or Welch-ANOVA for heterogenous variance, with significance set at $p<0.05$.

RESULTS AND DISCUSSION

The total sales of tempeh-based snack products across selected sales platforms have been recorded. According to the survey, Shopee was the platform with the highest number of tempeh-based snack products sold, accounting for 65.3%. This suggests that most sellers in Malaysia are shifting to e-commerce, likely to reduce store rental costs and stay competitive by offering lower prices (Amit *et al.* 2013). Interestingly, no tempeh-based products were found on the Temu platform.

A total of 98 tempeh-based snacks were classified into tempeh chips (87), tempeh sago snacks (6), tempeh crackers (3) and others (2) with tempeh chips dominating the market (88.8%) which consistent with Cempaka *et al.* (2018). Tempeh chips were thinly sliced and deep-fried while sago snacks were a combination of tempeh with sago starch. Tempeh crackers were made from tempeh-flour blends, and the "others" category included tempeh mixed with potatoes, anchovies, or dried vegetables.

Five tempeh chips varieties (salty, spicy, spiced, sambal, and original) were selected based on their high market availability, with proximate analysis results presented in Table 1. Salty tempeh chips are salt-seasoned deep-fried tempeh while spicy are chilli-coated and spiced incorporate mixed spices such as cumin, turmeric, and

Table 1. Macronutrient content in five tempeh chip samples

Macronutrient	Type of tempeh chips				
	Salty (g/100 g)	Spicy (g/100 g)	Spice (g/100 g)	Sambal (g/100 g)	Original (g/100 g)
Moisture	1.51±0.22^{b}	2.65±0.20^{b}	1.75±0.03^{b}	7.94±0.87^{a}	1.97±0.07^{b}
Total ash	2.84±0.05^{a}	2.02±0.18^{b}	1.70±0.04^{b}	2.97±0.11^{a}	2.16±0.30^{b}
Crude fat	36.23±0.45^{a}	40.77±1.98^{a}	41.10±0.74^{a}	29.28±0.45^{b}	38.07±1.49^{a}
Crude protein	27.88±0.72^{a}	13.96±1.27^{b}	27.88±0.72^{a}	15.02±2.19^{b}	18.68±2.81^{ab}
Total carbohydrate	31.55±0.76^{a}	40.61±3.19^{a}	32.25±0.79^{a}	38.05±5.04^{a}	39.12±4.22^{a}

Values are reported as the mean standard deviation from three replicates; ^{a,b,ab}: Means followed by different superscript letters in the same row, differ significantly at p<0.05. Means sharing the same letter(s) in the same row are not significantly different based on the ANOVA test (post-hoc Turkey)

coriander. Sambal tempeh chips are mixed with separately cooked sambal and original are plain, lightly seasoned fried or baked tempeh (Tan *et al.* 2024)

Sambal-flavoured tempeh chips had significantly higher moisture content (7.94±0.87) than all other flavours. This was likely due to the preparation method of mixing fried tempeh with separately cooked moist sambal, unlike other varieties coated with dry seasoning powders. All samples met the BSN (2018) SNI 260:2018 maximum moisture standard of 4%, except sambal-flavoured. The elevated moisture content of sambal tempeh chips likely contributes to their distinct texture, as crispy texture is achieved when moisture drops to approximately 5%, with hardness further influenced by slice thickness and cooking temperature (Jamaluddin *et al.* 2019; Abong *et al.* 2011). Additionally, lower moisture content is associated with extended shelf life (Sakač *et al.* 2016), suggesting sambal-flavoured may have a comparatively shorter shelf life than other varieties.

According to the study, sambal flavoured tempeh chips had significantly highest average ash content (2.97±0.11) compared to the spicy (2.02±0.18), spiced (1.70±0.04) and original (2.16±0.30). However, there was no significant difference in ash content between sambal and salty (2.84±0.05). This indicates that sambal and salty tempeh chips have significantly higher mineral content compared to spicy, spiced and original flavours (Afify *et al.* 2017). Based on the Desta *et al.* (2021), fermentation duration of raw tempeh used might affect the ash content in which as the fermentation duration decreases, the ash content would increase. In addition, as soybean serves as the raw material for tempeh production, variation in soybean composition may contribute to differences in ash content in tempeh. Differences in mineral content in soybean can be attributed to the genetic variation, growing environment, for example the soil mineral composition, climate and fertilization practices as well as genotype-environment interactions (Ateye *et al.* 2025).

Sambal-flavoured tempeh chips had significantly the lowest fat content (29.28±0.45) compared to salty (36.23±0.45), spicy (40.77±1.98), spiced (41.10±0.74), and original (38.07±1.49) varieties. This difference could not be explained by ingredient lists, as none of the sambal products included detailed labelling. Based on preparation method alone, higher fat content would be expected in sambal chips. The fat content across all varieties is likely attributed to the deep-frying process, where moisture evaporation creates porous structures that facilitate oil absorption (Vujadinović *et al.* 2014). Additionally, operational parameters including frying fat-to-chip ratio, temperature control, post-frying oil drainage, and systematic equipment cleaning and oil replenishment may further influence the final fat content (Mehta & Swinburn 2001).

Salty and spiced tempeh chips had the highest crude protein content (27.88±0.72), followed by original (18.68±2.81), sambal (15.02±2.19), and spicy (13.96±1.27) varieties. Spicy and sambal had significantly lower protein than salty and spiced varieties, while original showed no significant difference from any variety. The high protein in salty tempeh chips is likely attributed to the use of plain soybean tempeh without flour admixture as the primary ingredient. Additionally, packaging material may influence protein content. Tempeh wrapped in natural leaves exhibits higher soluble protein than plastic-packaged tempeh due to enhanced oxygen diffusion and humidity regulation that promotes *Rhizopus* growth and protein hydrolysis during fermentation (Sayuti 2015). Fermentation conditions including duration, temperature, and humidity may further affect protein content (Handoyo & Morita 2006).

In terms of carbohydrate content, spicy tempeh chips had the highest amount

(40.61±3.19), followed by original (39.12±4.22), sambal flavoured (38.05±5.04), spiced (32.25±0.79) and salty (31.55±0.76). However, these differences were not statistically significant. Based on the ingredient listed on the products, the use of flours, such as tapioca and potato flour, in the production of tempeh chips contributed to the carbohydrate content in these products.

Furthermore, heavy metal and mineral content (Fe, Zn, Mg, Na, Ca, K) across all tempeh chip varieties are presented in Table 2. Cr was highest in original (0.033±0.002) and lowest in salty (0.021±0.005) tempeh chips, with no significant differences between flavors. Cd was highest in spiced (0.010±0.0008) and lowest in salty (0.007±0.0002), with all samples below the maximum permitted level (0.02 mg/100 g) by BSN (2009).

Pb was detected only in sambal (0.044±0.0006) and spicy (0.025±0.007) varieties, with sambal exceeding the BSN (2009) maximum permitted level. Both Cd and Pb levels were higher than those reported for Indonesian soybean tempeh (Widyastuti *et al.* 2022). Heavy metal contamination may arise from polluted soils, excessive fertilizer use, and processing equipment or water (Scutarasu & Trincă 2023).

Careful monitoring and quality control are essential to minimize the risk of heavy metal exposure, as the long-term intake of foods contaminated with heavy metals can adversely affect human health, contributing to chronic kidney disease, cardiovascular disorders, asthma, neurodegenerative conditions such as Alzheimer's disease, and gastrointestinal tract problems (Scutarasu & Trincă 2023; Andrade *et al.* 2023). Besides, salty tempeh had significantly higher Cu level (0.69±0.06) than all the other flavours, except spiced flavoured tempeh chips (0.53±0.01). Furthermore, Mn content was significantly highest in salty (1.52±0.23), compared to other samples.

Additionally, salty tempeh chips had the highest Fe (3.03±0.30), followed by original (2.49±0.06), with salty significantly higher than all flavours except original, while sambal had the lowest (1.96±0.05). Although non-heme iron in plant-based foods has lower bioavailability than heme iron (Wilson *et al.* 2024), fermentation enhances iron bioavailability by increasing iron(II) while reducing iron(III) and complexed forms (Ahnan-Winarno *et al.* 2021). Zn was highest in original chips (2.83±0.22) and lowest in spiced (0.99±0.02), with no significant differences. Mg was highest in salty (80.92 mg/100 g) and lowest in spiced (15.91 mg/100 g), both significantly different from all other flavours. For Na, sambal had the highest content (729.99±76.26), followed by spiced (377.86±0.73), salty (368.01±37.80), original (344.35±32.76), and spicy (268.59±6.46), with all flavours substantially exceeding MyFCD (7 mg/100 g) and USDA (14 mg/100 g) reference values. The sharp Na increase is concerning, as excessive sodium intake is associated with hypertension and cardiovascular disease (Mente *et al.* 2021; Jaques *et al.* 2021).

Ca content was highest in salty (130.62±21.05) and lowest in sambal-flavoured tempeh chips (73.04±4.95), with a significant

Table 2. Mineral content in five tempeh chip samples

Macronutrient	Type of tempeh chips				
	Salty (mg/100 g)	Spicy (mg/100 g)	Spice (mg/100 g)	Sambal (mg/100 g)	Original (mg/100 g)
Chromium (Cr)	0.021±0.005^{a}	0.026±0.002^{a}	0.028±0.001^{a}	0.024±0.001^{a}	0.033±0.002^{a}
Cadmium (Cd)	0.007±0.0002^{a}	0.009±0.001^{a}	0.010±0.0008^{a}	0.009±0.0005^{a}	0.009±0.0003^{a}
Lead (Pb)	ND	0.025±0.007^{a}	ND	0.044±0.0006^{a}	ND
Copper (Cu)	0.69±0.06^{a}	0.37±0.04^{b}	0.53±0.01^{ab}	0.52±0.01^{b}	0.52±0.01^{b}
Manganese (Mn)	1.52±0.23^{a}	0.69±0.02^{b}	0.25±0.04^{c}	0.44±0.01^{c}	0.70±0.02^{b}
Iron (Fe)	3.03±0.30^{a}	2.05±0.02^{bc}	2.03±0.02^{bc}	1.96±0.05^{b}	2.49±0.06^{ac}
Zinc (Zn)	2.33±0.12^{a}	1.24±0.02^{b}	0.99±0.02^{c}	1.35±0.20^{abc}	2.83±0.22^{abc}
Magnesium (Mg)	80.92±5.95^{a}	39.32±1.52^{b}	15.91±0.01^{c}	49.38±2.98^{b}	46.68±3.79^{b}
Sodium (Na)	368.01±37.80^{a}	268.59±6.4^{6b}	377.86±0.73^{ab}	729.99±76.26^{ab}	344.35±32.76^{ab}
Calcium (Ca)	130.62±21.05^{a}	88.16±1.66^{ab}	82.55±0.75^{ab}	73.04±4.95^{b}	118.27±12.13^{ab}
Potassium (K)	344.18±29.17^{a}	158.52±2.30^{bc}	30.15±0.23^{d}	225.68±16.78b	145.72±2.84c

Values are reported as the mean standard deviation from two replicates; $^{a, b, c, ab, bc, ac, abc}$: Means followed by different superscript letters, differ significantly at $p<0.05$. Means sharing the same letter(s) are not significantly different based on the ANOVA test (post hoc Tukey test for homogeneous variances and Games–Howell test for heterogeneous variances); Differences in Pb levels were determined using an independent t-test; ND: Not Detected difference between them. All tempeh chip varieties exceeded the Ca content of unprocessed tempeh in MyFCD (69 mg/100 g), while only salty and original surpassed the USDA value for cooked tempeh (96 mg/100 g). Adequate Ca intake is essential for bone health and osteoporosis prevention (Voulgaridou *et al.* 2023), and calcium in tempeh flour has been shown to have comparable absorption and retention to casein (Astawan *et al.* 2020), suggesting tempeh as a viable plant-based calcium source, particularly for lactose-intolerant individuals. Salty chips also recorded the highest K level (344.18±29.17), while spiced chips had the lowest (30.15±0.23), with both significantly different from other varieties.

Original-flavoured tempeh chips demonstrated a nutritionally balanced profile, with fat, protein, and carbohydrate contents all ranking in the intermediate range among all samples. Protein content showed no significant difference from any other variety. Heavy metals (Cr, Cd, and Pb) were either below safety thresholds or undetected, while essential mineral contents ranked from intermediate to among the highest across samples. Overall, original-flavoured tempeh chips represent an appropriate option, providing a moderate and balanced contribution of macronutrients and minerals without excessive or insufficient levels of any single component.

In terms of consumer survey on tempeh-based products, Table 3 shows the sociodemographic characteristics. There were 179 participants completed the customer survey. Most participants were Malaysian citizens aged 18−24 years (32.4%), In terms of ethnicity, 96.1% of participants were Malay, 2.2% were Chinese, 0.6% were Indian, and 1.1% were from other ethnic groups. For gender distribution, the majority were women (86%). Regarding education level, 93.9% of participants had attained university-level education or higher, followed by 6.1% who completed secondary. In terms of occupation, 49.7% of participants worked in the government sector, 25.1% were students, 14.5% worked in the private sector, 7.8% were unemployed and 2.8% were self-employed. Lastly, monthly income varied among participants, with the largest percentage (29.6%) earning RM6,001 and above (>USD1,446), followed by those with no income (26.3%).

Table 4 presents participants' perceptions of tempeh-based snack products. Awareness of tempeh's health benefits was high, with 91.1% of participants acknowledging its benefits and only 8.9% unaware. This is attributed to tempeh's well-established nutraceutical properties as a plant-based soybean product rich in essential amino acids, folic acid, isoflavones, and saponins (Teoh *et al.* 2024). Additionally, soybeans are recognised as high-protein legumes and alternatives to animal protein (NCCFN 2017), and are included in the protein category of the Malaysian Food Pyramid 2020. Additionally, social media was the most chosen source of information about the health benefits of tempeh (76.5%). These findings supported Stellefson *et al.* (2020), who stated media provides a platform for effectively promoting health information strategies and disseminating data. Users not only benefit from the information themselves but can also create

Table 3. Sociodemographic characteristics of the participants

Sociodemographic characteristics	n=179 n (%)
Age (years)	
18–24	58 (32.4)
25–34	25(14.0)
35–44	31 (17.3)
45–54	35 (19.6)
≥55	30 (16.8)
Ethnicity	
Malay	172 (96.1)
Chinese	4 (2.2)
Indian	1 (0.6)
Others	2 (1.1)
Gender	
Men	25 (14.0)
Women	154 (86.0)
Education level	
Primary school	0 (0.0)
Secondary school	11 (6.1)
University-level or higher	168 (93.9)
Occupation	
Government sector	89 (49.7)
Student	45 (25.1)
Private sector	26 (14.5)
Unemployed	14 (7.8)
Self-employed	5 (2.8)
Monthly income*	
No income	47 (26.3)
RM0–RM1,500 (USD0–362)	11 (6.1)
RM1,501–RM3,000 (USD362–723)	27 (15.1)
RM3,001– RM4,500 (USD723–1,085)	18 (10.1)
RM4,501–RM6,000 (USD1,085–1,446)	23 (12.8)
RM6,001 and above (≥USD1,446)	53 (29.6)

*USD[1]:RM4.15; RM: Ringgit Malaysia; USD: US Dollar

Table 4. Participants' perceptions toward tempeh-based snack products

Perceptions	n=179 n (%)
Awareness and perceptions	
Aware of the health benefits of tempeh	
Yes	163 (91.1)
No	16 (8.9)
Source of information about the health benefits of tempeh**	
Social media	137 (76.5)
Friends and family	118 (65.9)
Print media	92 (51.4)
Electronic media	69 (38.5)
Talks, exhibitions and seminars	34 (19.0)
Others	1(0.6)
Ever tried tempeh-based snack products	
Yes	157 (87.7)
No	22 (12.3)
Think that the information about tempeh-based snack products is widely disseminated	
Yes	74 (41.3)
No	105 (58.7)
Aware of variety of tempeh-based snack products	
Yes	107 (59.8)
No	72 (40.2)
Source of information about the variety of tempeh-snack products**	
Social media	92 (51.4)
Friends and family	82(45.8)
Print media	49 (27.4)
Electronic media	48 (26.8)
Talks, seminars and exhibitions	32 (17.9)
Others	4 (2.2)
Product preferences	
Preferred texture	
Dry and crispy	159 (88.8)
Soft and moist	20 (11.2)
Preferred size	
Large	106 (59.2)
Small	73 (40.8)
Preferred flavour	
Spiced	49 (27.4)
Original	45 (25.1)
Salty	20 (11.2)
Spicy	64 (35.8)
Sweet	1 (0.6)
Preferred shape**	
Round	89 (49.7)
Stick-shaped	43 (24.0)
Square	38 (21.2)
Diced	11 (6.1)
Others	2 (1.1)
Price willing to pay for 100 g*	
Less than RM4.99 (<USD1.2)	48 (26.8)
RM5.00–RM9.99 (USD1.2–2.4)	107 (59.8)
RM10.00–RM14.99 (USD2.4–3.6)	24 (13.4)
>RM15.00 (>USD3.6)	0 (0.0)

Continue from Table 4

*USD1:RM4.15; **: Can choose more than one option; RM: Ringgit Malaysia; USD: US Dollar

and share it with others. Moreover, using social media for advocacy and communication in promoting health offers a broader reach, higher efficiency and lower costs. Health campaigns and advocacy efforts can be easily delivered to a wide range of audiences (Stellefson *et al.* 2020).

Most participants (87.7%) have tried tempeh-based snack products, while only 12.3% have never tried them. This is because tempeh is a well-known traditional food commonly consumed in Malaysia, despite its origins in Indonesia. Tempeh is a nutrient-dense source of protein, sold at an affordable price, making it accessible to all Malaysians and a staple food for the local community (Astuti *et al.* 2000).

Although many participants have tried tempeh-based snack products, the majority (58.7%) believe that information about these products in Malaysia is still not widely disseminated. Meanwhile, 41.3% feel that such information is already well-distributed. This is likely because the tempeh industry is primarily run by small-scale rural producers (Purwadaria *et al.* 2009). These are classified as Small and Medium Enterprises (SMEs) based on annual revenue and the number of full-time employees (LHDN 2024). The key challenge for SMEs is their inability to adapt to changes such as shifting from traditional marketing to more structured and entrepreneurial promotional strategies. This has contributed to the limited dissemination of information about tempeh-based innovative products, such as tempeh snacks.

The majority of the participants preferred dry and crispy texture (88.8%) and larger sizes (59.2%), which consistent with previous findings that crispiness is a key sensory quality of fried snacks (Ramesh *et al.* 2018; Kocaman 2018). Spicy was the most preferred flavor (35.8%), followed by spiced (27.4%), original (25.1%), salty (11.2%), and sweet (0.6%), which contradicting Aris *et al.* (2022), who reported that young Malay adults prefer traditional snacks retaining natural taste without excessive flavouring. Additionally, round shape was the most preferred (49.2%), aligning with Yuliana and Taufik (2022) and Ayub (2016), who attributed this preference to ease of one-bite consumption, minimal crumbs, and visual appeal associated with chips.

Most consumers are willing to pay RM5.00−RM9.99 (USD1.2–2.4) for 100 g of tempeh-based smacks (59.8%), However, none were willing to pay more than RM15.00 (USD3.6) for the same quantity. These findings different from findings by Reis *et al.* (2022) who reported that the most chosen price for similar snacks was Rp7,000 (approximately RM1.94/ USD0.47) per product.

CONCLUSION

The study identified four main classifications of tempeh-based snack products: tempeh chips, tempeh crackers, sago tempeh and others. Tempeh chips are the most popular products, with Shopee being the leading platform for selling tempeh-based snacks. Most of these products are sold at affordable prices, less than RM4.99 (USD1.2). However, many of these products lack ingredient lists and nutritional labels on their packaging. Nutritional proximate and mineral analysis revealed that plain-flavoured tempeh chips are the most recommended option for the consumers due to their good nutritional content and minimal use of ingredients compared to other tempeh chip varieties. Furthermore, the findings show that most consumers are aware of the health benefits of tempeh and have tried tempeh-based snack products. Based on consumer preferences, the most favoured characteristics of tempeh-based snacks are dry and crispy texture, large size, spicy flavour, round shape and priced between RM5.00 and RM9.00 (USD1.2–2.4).

Based on these findings, the recommendations for the future product development of tempeh-based snack products is to prioritise original-flavoured tempeh chips as a healthier option. However, attention should be given on their fat, protein and lead content to ensure a healthy but readily acceptable tempeh chips. Besides, optimising the texture, shape and size based on the consumer preference is necessary to enhance the consumer acceptance and market competitiveness.

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DECLARATION OF CONFLICT OF INTEREST

The authors have no conflict of interest

DECLARATION OF GENERATIVE AI IN SCIENTIFIC WRITING

During the preparation of this work, the authors used ChatGPT (OpenAI) and SciSpace to improve the language and readability of the manuscript. After using these tools, the authors reviewed and edited the content as needed and take full responsibility for the content of the publication.

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