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Research

Physicochemical Analysis on Tempeh Samples Available at Kuala Lumpur Supermarket and Sensory Evaluation of Tempeh Patty

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ABSTRACT

This study aimed to determine the physicochemical properties of fresh tempeh samples available in Kuala Lumpur supermarkets. The proximate composition, mineral content, and color of the fresh tempeh were assessed. One of the fresh tempeh samples was selected to create three formulations of tempeh patty, which were then subjected to sensory analysis. Seven attributes of the tempeh patty-aroma, color, appearance, texture, taste, nutty taste, and overall acceptance were evaluated by 40 panelists. The average macronutrient content of tempeh in Kuala Lumpur supermarkets was 61.47 ± 0.43% moisture, 0.84 ± 0.02% total ash, 20.10 ± 1.3% crude protein, 0.66 ± 0.30% crude fat, and 16.89 ± 1.47% total carbohydrate. The average mineral content per 100 g of tempeh was 0.11 ± 0.03 mg Fe, 3.29 ± 1.08 mg Zn, 2.38 ± 0.68 mg Na, 304.62 ± 35.98 mg Mg, and 466.40 ± 220.48 mg Ca. Color analysis revealed an average brightness (L*) of 73.8 ± 0.27, redness (a*) of 3.42 ± 0.02, and yellowness (b*) of 17.02 ± 0.07. The study found significant differences ($p<0.05$) in moisture, total ash, Mg, and color (L*, a*, b*) among the raw tempeh samples. Significant differences ($p<0.05$) were observed only in the aroma and color attributes for the three tempeh patty formulations. In conclusion, significant differences were identified in the moisture, ash, crude protein, carbohydrate, and magnesium content among the tempeh samples collected from Kuala Lumpur supermarkets. The nutrient content data obtained from this study can serve as a reference for various stakeholders, and the tempeh patty has the potential to be developed as a healthy tempeh-based dish.

Key words: Color, minerals, nutrient contents, raw tempeh, supermarkets, tempeh patty

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INTRODUCTION

Soybean (*Glycine max*) is a legume native to East Asia, belonging to the Fabaceae family. It is widely utilized in East Asian and Southeast Asian countries in both fermented and unfermented forms. Incorporating fermented soy foods into the daily diet is believed to prevent chronic diseases and enhance overall health. Although Asian populations have historically been the primary consumers of soybeans, consumption in Western countries is also increasing, consistent with the rise of vegetarian diets and the perceived benefits of daily soybean intake (Huang *et al*., 2016). Fermented soy-based foods are associated with high protein and phytonutrient content, such as isoflavones, making them a good source of nutrients and health benefits (Mukherjee *et al*., 2016).

Tempeh is a fermented soybean product. Tempeh is a staple food in Indonesia, valued as an economical, affordable, and healthy protein source (Ahnan-Winarno *et al*., 2021). Tempeh is also renowned for its appealing taste, texture, and digestibility (Puteri *et al*., 2018). It is produced through the fermentation of soybeans using starters of *Rhizopus* spp. The production of tempeh involves soaking, dehulling, washing, boiling, draining, cooling, inoculating with a starter culture, and incubating at room temperature

(30°C) (Fanny *et al*., 2019). Fresh tempeh has a short shelf life, lasting approximately three days at ambient temperature (Ahnan-Winarno *et al*., 2021).

Tempeh is recognized as a functional food, containing bioactive components that are beneficial for health. The increasing popularity of tempeh is attributed to its high content of B complex vitamins. Tempeh contains vitamin B12, typically absent in plant products (Nout & Kiers, 2005). It also includes bioactive compounds such as isoflavones and dietary fiber, and it has been shown to increase the activity of the superoxide dismutase enzyme (Harun *et al*., 2015; Haron *et al*., 2016; Ahnan-Winarno *et al*., 2021).

Tempeh contains a variety of nutrients, including bioactive components like isoflavones, which can bind to estrogen receptors and act as estrogens, thereby increasing estrogen levels when they are low. Estrogen is crucial for the health of bones, the heart, reproductive organs, blood vessels, and the brain (Astawan *et al*., 2017). Additionally, tempeh is rich in antioxidants such as beta-carotene, vitamin E, and isoflavones. It is often considered a cancer-preventive food due to its unique vitamin B12 content, which is believed to originate from the fungus that grows on tempeh (Astawan *et al*., 2017).

Tempeh patties are rich in vegetable protein derived from tempeh. Tempeh patty is an innovation in culinary applications, where tempeh can serve as a substitute for meat, catering to those who choose not to consume meat. It is a popular choice for health-conscious consumers due to its nutritional value and affordability. This approach optimizes the use of local food ingredients, promoting food diversity and offering an alternative method for processing tempeh. Tempeh patties provide a healthy, low-cost snack option that can be easily prepared at home, making them accessible to everyone, especially individuals with dietary restrictions requiring limited meat intake (Abubakar Seghosime *et al*., 2022).

This study was therefore conducted to determine the physicochemical characteristics of various tempeh samples available in Kuala Lumpur supermarkets. One selected tempeh sample was used to produce a healthy tempeh-based product, and a sensory evaluation of tempeh patties was conducted to assess consumer acceptance of tempeh-based products.

MATERIALS AND METHODS

Materials

Convenience sampling was employed to select the tempeh samples for this study. The samples comprised five brands of raw tempeh from supermarkets in Kuala Lumpur, designated as U, AB, E, B, and V. Each sample was analyzed in triplicate, resulting in a total of fifteen replicates for each analysis across the five samples.

Color determination

Color characteristics, including lightness (L*), redness (a*), and yellowness (b*), were measured using CR-400 and CR-410 spectrophotometers (Konica Minolta, Japan).

Proximate analysis

Proximate analysis was conducted to determine moisture content, total ash, crude protein, and crude fat, using AOAC methods (1997). Total carbohydrate content was calculated using the difference method. For moisture content, 5 g of homogenized samples were dried in an air oven at 105°C overnight until a constant weight was reached. Total ash content was determined by placing the sample in a crucible and heating it in a furnace at 450-550°C. Protein content was determined using the Kjeldahl method, which involves digestion, neutralization, and titration. Nitrogen content was converted into protein content using a conversion factor of 6.25. Fat content was determined using the Soxhlet method.

Mineral analysis

Ash samples prepared during ash determination were used for mineral analysis. The samples were digested with concentrated hydrochloric acid, filtered into a 100 mL volumetric flask, and mixed with deionized water to homogenize. The samples were then analyzed using an Atomic Absorption Spectrophotometer (AAS). The original solution (1000 ppm) was diluted to prepare a stock solution (100 ppm), which was then used to create standard solutions for each mineral. Standard solutions of 20 ppm, 30 ppm, 50 ppm, and 70 ppm were prepared for iron. Solutions of 0.1 ppm, 0.2 ppm, 0.3 ppm, and 0.4 ppm were prepared for magnesium. For potassium and calcium, 1 ppm, 2 ppm, 3 ppm, and 4 ppm solutions were prepared. For sodium, solutions of 0.2 ppm, 0.3 ppm, 0.5 ppm, and 0.7 ppm were prepared. Calcium, iron, sodium, magnesium, and zinc contents were analyzed using an AAS (GBC, Melbourne) with acetylene gas at a pressure of 1.0 kPa and an air compressor at a pressure of 330 kPa.

Tempeh patty preparation

Due to its high protein content, cost-effectiveness, and widespread availability, raw tempeh from brand U was used to make tempeh patties. The preparation process involved steaming, mixing, molding, packaging, and freezing. Tempeh was weighed according to the set weight, steamed for 15 min, and grounded until smooth using a blender. Additional ingredients were added and blended until combined. Three formulations, varying in the presence of additional ingredients, percentage of tempeh, and percentage of textured vegetable protein, were used to create three types of tempeh patties. The additional ingredient used was banana blossoms, which were added only in formulation 3. The percentages of tempeh in formulations 1, 2, and 3 were 60%, 50%, and 50%, respectively. Textured vegetable protein content was 21%, 31%, and 21% in formulations 1, 2, and 3, respectively. Percentages were calculated by dividing the ingredients' weight by the tempeh patty's total weight. Table 1 presents the three formulations of tempeh patties. The mixture of ground tempeh and additional ingredients was divided, weighed, and formed into 10-cm-wide patties using a mold lined with plastic coated in cooking oil. The patties were stored in a freezer at 0°C for 12 hr. They were then cooked using the frying method in a pan with cooking oil at 160°C for 5 min. Macronutrients and micronutrients of the tempeh patties were determined using Nutritionist Pro software (version 5.2, Axxya Systems-Nutritionist Pro, Stafford, TX, USA).

Table 1. Three formulations of tempeh patty

Ingredient	Formulation 1		Formulation 2		Formulation 3	
	Weight (g)	%	Weight (g)	%	Weight (g)	%
Tempeh (steamed)	200	60	170	50	170	50
Banana blossoms	0	-	0	-	33.5	10
Textured vegetable protein (TVP)	70	21	104	31	70	21
Patty premix	65	19	65	19	65	19
Total (g)	335	100	335	100	335	100

Sensory analysis

A hedonic test was conducted with 40 untrained panelists at the Faculty of Health Sciences. The panelists, comprising staff and students of Universiti Kebangsaan Malaysia Kuala Lumpur, were randomly selected and ranged in age from 18 to 59 years. Fried tempeh patty samples were served in small portions for the panelists to evaluate various attributes, including appearance, color, taste, nutty taste, aroma, texture, and overall acceptance, using a sensory form with 7-point hedonic scales.

Statistical analysis

All experiments were conducted in triplicate. The collected data were analyzed using IBM SPSS for Windows, version 26.0 (IBM Corporation, Chicago, IL, USA). Descriptive analysis was performed to obtain the average, percentage, and standard deviation of data regarding physicochemical characteristics such as color, moisture content, total ash, protein, fat, carbohydrates, and minerals in various brands of tempeh. Additionally, descriptive analysis was used to evaluate the level of consumer acceptance of the organoleptic characteristics of tempeh patty. An ANOVA test was employed to compare the physicochemical properties and consumer acceptance levels across different brands of tempeh and a menu of healthy tempeh-based dishes. A one-way ANOVA with Tukey's HSD was used to determine differences in all nutrients among the samples. Significant values were set at $p<0.05$. Finally, the macronutrient and micronutrient content of the tempeh patty was analyzed using Nutritionist Pro software (version 5.2, Axxya Systems-Nutritionist Pro, Stafford, TX, USA).

RESULTS AND DISCUSSION

Proximate analysis

Proximate analysis includes moisture, total ash, crude protein, crude fat, and total carbohydrate contents in various tempeh samples available in Kuala Lumpur supermarkets. The macronutrient content was reported as a percentage based on wet weight. Table 2 presents the moisture content of several tempeh samples from Kuala Lumpur. The average macronutrient contents in tempeh available in these supermarkets were 61.47 ± 0.43% moisture, 0.84 ± 0.02% total ash, 20.10 ± 1.30% crude protein, 0.66 ± 0.30% crude fat, and 16.89 ± 1.47% total carbohydrate. According to Table 2, the moisture content of tempeh U (64.45%) was significantly higher ($p<0.05$) compared to other tempeh samples. The average moisture content for all tempeh samples collected from Kuala Lumpur supermarkets was 61.47%. This average moisture content is lower than the moisture content (66.0%) reported in the Malaysia Food

Composition Database (MyFCD). The water content in tempeh is relatively high, which can impact its biological, organoleptic, and physicochemical qualities, as well as its durability. As moisture content increases, the durability of a product decreases (Shi *et al*., 2010). This is why tempeh has a short shelf life, lasting approximately three days at ambient temperature (Ahnan-Winarno *et al*., 2021).

Table 2. Nutrient content in samples of several brands of tempeh in Kuala Lumpur supermarkets based on wet weight

Tempeh samples	U	AB	E	B	V	Average
Moisture (%)	64.45 ± 0.92[a]	62.44 ± 0.33[b]	60.52 ± 0.47[c]	60.34 ± 0.07[cd]	59.62 ± 0.36[d]	61.47 ± 0.43
Ash (%)	0.61 ± 0.02[e]	0.95 ± 0.02[b]	1.03 ± 0.03[a]	0.87 ± 0.01[c]	0.73 ± 0.01[d]	0.84 ± 0.02
Crude protein (%)	23.7 ± 0.44[a]	19.52 ± 2.20[b]	18.44 ± 0.92[b]	20.81 ± 1.11[ab]	18.07 ± 1.89[b]	20.10 ± 1.30
Crude fat (%)	0.44 ± 0.44[a]	0.28 ± 0.09[a]	0.51 ± 0.21[a]	0.68 ± 0.21[a]	1.37 ± 1.08[a]	0.66 ± 0.30
Carbohydrate (%)	10.65 ± 0.18[b]	16.80 ± 2.56[a]	20.52 ± 1.28[a]	17.29 ± 0.95[a]	20.21± 2.80[a]	16.89 ± 1.47

[#] Values are reported as mean ± standard deviation of three replicates

[#] Values of the same alphabet in the same row indicate no significant differences (p>0.05) based on the ANOVA test (Tukey's post-hoc).

The total ash content in tempeh E (1.03%) was significantly higher ($p<0.05$) compared to other tempeh samples. Although the ash content in tempeh reported by MyFCD (0.9%) is slightly higher, it does not differ substantially from the average ash content found in this study (0.84%). Low total ash content indicates low mineral content (Ferreira *et al*., 2011). The average protein content in this study (20.1%) was higher than the crude protein content reported by MyFCD (15.9%). The total crude protein content in tempeh U (23.7%) was significantly higher ($p<0.05$) than in other tempeh samples. The crude fat content in tempeh V (1.37%) was significantly higher ($p<0.05$) compared to other samples. However, the crude fat content reported by MyFCD (7.5%) was substantially higher than the results obtained in this study. Incomplete drying of the samples may act as a physical barrier, preventing fat from dissolving into the solvent, which could lead to lower fat yields (Abubakar Seghosime *et al*., 2022). Tempeh E had the highest total carbohydrate content (20.52%) compared to other tempeh brands, although this was only significantly different from sample U. The carbohydrate content in tempeh reported by MyFCD (6.8%) was much lower than the results of this study (16.89%). The amount of carbohydrates is influenced by the content of other macronutrients, depending on the methods used. A reduction in water content can affect the results of measuring carbohydrate values, similar to its effect on other proximate values (Pratama *et al*., 2014).

Mineral contents

The mineral contents in this study are presented in Table 3. The calcium (Ca), magnesium (Mg), sodium (Na), zinc (Zn), and iron (Fe) contents in the studied samples were measured based on wet weight. The average mineral content per 100 g of tempeh was 0.11 ± 0.03 mg Fe, 3.29 ± 1.08 mg Zn, 2.38 ± 0.68 mg Na, 304.62 ± 35.98 mg Mg, and 466.40 ± 220.48 mg Ca. The iron content in tempeh AB (0.15 mg Fe/100 g) was the highest, although there was no significant difference among all tempeh samples. The Fe content of tempeh recorded in MyFCD (1.8 g/100 g)was much higher than in the tempeh samples of this study (0.11 mg Fe/100 g). As for zinc, tempeh U had the highest Zn content (5.32 mg Zn/100 g), but it was not significantly different from the other samples. The zinc content of tempeh reported in the USDA Online Database (1.14 mg/100 g) is much lower than the results of this study (3.29 mg Zn/100 g). Zn content increased slightly, and Fe levels fluctuated during germination (Shi *et al*., 2010). The sodium content in tempeh E (3.99 mg Na/100 g) was the highest, although no significant differences were observed among all tempeh samples. The sodium content of tempeh reported in MyFCD (7 mg/100 g) was higher than the average Na content in this study (2.38 mg/100 g). Tempeh generally contains more calcium, less iron, less sodium, and less sugar (Ahnan-Winarno, 2021).

The magnesium (Mg) content in tempeh AB (460.9 mg/100 g) was significantly higher ($p<0.05$) compared to other tempeh samples. The magnesium content reported in the USDA Online Database is lower (81 mg/100 g) compared to the average Mg content found in this study (304.62 mg/100 g). Regarding calcium (Ca), tempeh E had the highest Ca content (775.8 mg/100 g), although there was no significant difference among the tempeh samples. The calcium content reported in MyFCD is 69 mg/100 g, which is substantially lower than the average Ca content found in this study (466.40 mg/100 g). Differences in mineral content may be attributed to variations in soybean cultivars, soil conditions, plant environments (Huang *et al*., 2016), as well as food preparation practices (Gibson *et al*., 2000).

Table 3. Mineral contents in several brands of tempeh in Kuala Lumpur supermarkets based on wet weight

Mineral	Sample (mg/100g)					
	U	AB	E	B	V	Average
Iron (Fe)	0.10 ± 0.00[a]	0.15 ± 0.08[a]	0.14 ± 0.03[a]	0.08 ± 0.04[a]	0.10 ± 0.02[a]	0.11 ± 0.03
Zinc (Zn)	5.32 ± 1.39[a]	2.77 ± 1.52[a]	3.70 ± 0.65[a]	3.34 ± 1.17[a]	1.30 ± 0.68[a]	3.29 ± 1.08
Sodium (Na)	2.32 ± 0.21[a]	0.77 ± 0.06[a]	3.99 ± 1.97[a]	1.61 ± 0.14[a]	3.20 ± 1.00[a]	2.38 ± 0.68
Magnesium (Mg)	266.00 ± 35.49[bc]	460.90 ± 34.07[a]	113.26 ± 73.73[c]	433.70 ± 31.07[ab]	249.24 ± 5.56[c]	304.62 ± 35.98
Calcium (Ca)	232.43 ± 11.81[a]	407.53 ±457.40[a]	775.80 ± 29.70[a]	373.70 ± 330.57[a]	542.50 ± 272.9[a]	466.60 ± 220.48

[#] Values are reported as mean ± standard deviation of three replicates

[#] Values of the same alphabet in the same row indicate no significant differences (*p*>0.05) based on the ANOVA test (Tukey's post-hoc).

Colour analysis

Table 4 presents the average color analysis of brightness levels for various tempeh brands available in Kuala Lumpur supermarkets. The measurements are recorded using L, a, and b scale values. The L scale value represents the level of brightness, a denotes the level of redness, and b indicates the level of yellowness. The average values for brightness (L*), redness (a*), and yellowness (b*) were 73.8 ± 0.27, 3.42 ± 0.02, and 17.02 ± 0.07, respectively.

Table 4. Color analysis for several brands of tempeh in Kuala Lumpur supermarkets

Tempeh samples	U	AB	E	B	V	Average
Lightness *L**	82.32 ± 0.30[a]	77.91 ± 0.29[b]	69.17 ± 0.28[d]	67.18 ± 0.25[e]	72.26 ± 0.23[c]	73.80 ± 0.27
Redness *a**	0.93 ± 0.02[e]	2.50 ± 0.01[d]	5.20 ± 0.02[b]	5.58 ± 0.02[a]	2.91 ± 0.03[c]	3.42 ± 0.02
Yellowness *b**	13.34 ± 0.09[d]	13.59 ± 0.07[d]	18.59 ± 0.06[b]	24.57 ± 0.06[a]	15.00 ± 0.07[c]	17.02 ± 0.07

[#] Values are reported as mean ± standard deviation of three replicates

[#] Values of the same alphabet in the same row indicate no significant differences (p>0.05) based on the ANOVA test (Tukey's post hoc)

For brightness (L*), the average level of brightness in tempeh brand U (82.32) was significantly higher ($p<0.05$) compared to other tempeh samples. In terms of redness (a*), tempeh brand B exhibited the highest average level of redness (5.58) among all samples. Regarding yellowness (b*), tempeh from brand B also showed the highest average level of yellowness (24.57) compared to other brands. Variations in these physicochemical properties are attributed to the germination process and the additional fermentation period of tempeh (Abdurrasyid *et al*., 2023). The germination process may influence the color of tempeh by increasing the concentration of amino acids in the seeds. Consequently, during the heating process of tempeh production, the Maillard reaction involving amino acids can reduce the lightness of the tempeh (Astawan *et al*., 2023). Additionally, the extended fermentation period may alter the color due to the death phase of Rhizopus spp. and the oxidation of unsaturated fatty acids. This period may also result in the oxidation of carotenoids, further contributing to the darkening of the tempeh (Ahnan-Winarno *et al*., 2021; Astawan *et al*., 2023).

Sensory analysis

Based on Table 5, formulation 2 achieved the highest average score (3.89) for aroma, which was significantly higher ($p<0.05$) compared to the other formulations. Formulation 1 received a score of 3.48 for aroma, which was higher than Formulation 3's score of 3.13. Significant differences ($p<0.05$) were observed in the aroma scores among all three formulations. This may be attributed to the use of ingredients in formulation 2 that include spices producing herbal aromas, which may enhance the appeal of the tempeh patty. According to Abubakar Seghosime *et al*. (2022), panelists preferred tempeh snacks made with *Rhizopus oligosporus* due to their pleasant, clean, and sweet aroma.

Color is an important attribute consumers evaluate when assessing food quality (Kusuma, 2016). Formulations 1 and 2 received the same average color score (3.5), with no significant difference. However, formulation 3 had a significantly lower color score (3.03, $p<0.05$) compared to formulations 1 and 2. This lower score may be due to the darker color of the tempeh patty in formulation 3, which resulted from the heat treatment process. During this process, the Maillard reaction between amino acids and reducing sugars can produce varying flavors and colors (Tamanna & Mahmood, 2015).

Regarding appearance, formulation 2 achieved the highest average appearance score (3.53), followed by formulation 1 (3.48) and formulation 3 (3.28). No significant difference ($p>0.05$) was observed in appearance scores among the three formulations, indicating consistency in shape across all samples. Appearance, aroma, texture, and taste are crucial parameters influencing consumer acceptance (Purwandari *et al*., 2021).

Table 5. Average value of tempeh patty attribute score for three formulations

Attributes	Score		
	Formulation 1	Formulation 2	Formulation 3
Aroma	3.48 ± 1.06[ab]	3.89 ± 1.02[a]	3.13 ± 0.99[b]
Color	3.5 ± 0.88[a]	3.53 ± 1.13[a]	3.03 ± 0.97[b]
Appearance	3.48 ± 0.85[a]	3.53 ± 1.01[a]	3.28 ± 0.99[a]
Texture	3.25 ± 1.21[a]	3.45 ± 1.26[a]	2.88 ± 1.04[a]
Taste	3.40 ± 1.19[a]	3.38 ± 1.37[a]	3.23 ± 0.92[a]
Nutty taste	3.15 ± 1.12[a]	3.38 ± 1.27[a]	3.20 ± 0.94[a]
Overall acceptance	3.38 ± 1.10[a]	3.43 ± 1.34[a]	3.15 ± 1.00[a]

[#] Values are reported as mean ± standard deviation of 40 replicates

[#] Values of the same alphabet in the same row indicate no significant differences (p>0.05)

For the texture attribute score, tempeh patty formulation 2 received the highest average score (3.45), followed by formulation 1 (3.25) and formulation 3 (2.88). No significant difference (p>0.05) was found in the texture attributes among the three formulations. According to Bourne (2002), texture is assessed through the sense of touch. The lack of significant difference in texture may be attributed to the fact that all three formulations underwent the same steaming process before being ground with other ingredients.

For the taste attribute, tempeh patty formulation 1 achieved the highest average score (3.40), followed by formulation 2 (3.38) and formulation 3 (3.23). No significant difference (p>0.05) was observed across these formulations' taste attributes. This lack of significant difference may be due to the use of identical premix ingredients and spice percentages in all three formulations. Tinangon (2014) supports this observation, noting that spices generally enhance aroma and taste in food processing.

Formulation 2 also received the highest average score for nutty taste (3.38), followed by formulation 3 (3.20) and formulation 1 (3.15). However, there was no significant difference (p>0.05) in the nutty taste attribute among the three formulations. Overall, the average acceptance score was highest for formulation 2 (3.43), followed by formulation 1 (3.38), with formulation 3 having the lowest score (3.15). No significant difference (p>0.05) was noted in the overall acceptance scores for the three formulations. This suggests that the panel could not detect significant differences among the samples, possibly due to their similarities in appearance, texture, taste, and nutty taste.

CONCLUSION

In conclusion, significant differences were observed in moisture, ash, crude protein, carbohydrates, and magnesium content in some tempeh samples collected from supermarkets in Kuala Lumpur. The color readings obtained in this study were consistent with those reported in previous research. No significant differences (p>0.05) were found in the appearance, texture, taste, nutty taste, and overall acceptance among the three formulations. Formulation 2 achieved the highest average overall acceptance score in the sensory test. Future studies should involve collecting and analyzing a broader range of tempeh samples from various locations to obtain more representative data.

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ETHICAL STATEMENT

Not applicable

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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