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Sensory Attributes and Phytochemical Composition in Microgreens: Implications for Acceptability Among School Students in Selangor, Malaysia

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Abstract.
Microgreens, the young seedlings of edible plants, have gained attention for their potential health benefits and culinary applications. This newly emerging functional food crop has the potential to sustainably diversify global food systems, facilitate urbanization and climate change responses, and advance human health. However, their reception among school students remains an understudied area, particularly in the Malaysian context. In this study, five microgreens species including *ulam raja*, red amaranth, red radish, daikon, and corn were evaluated for their sensory perception and acceptability among secondary school students in Selangor, and their phytochemical compositions. Among the evaluated species, corn exhibited the highest intensity of sweetness, *ulam raja* demonstrated a strong aroma and bitterness, while red radish was notable for its astringency and heat. Red amaranth had the highest intensity of grassy taste, and all five microgreens had a low score for sourness. Corn had the highest rating on acceptability of flavor and overall eating quality, signifying its favorable impression among students. Conversely, red radish and *ulam raja* received the lowest acceptability scores in both categories. The highest total phenolic and flavonoid content and antioxidant activity was exhibited in *ulam raja*. These findings suggest the potential to leverage corn's favorable acceptability to introduce microgreens into student diets. In general, this study highlights the correlation between sensory attributes and phytochemical composition, both influencing the Malaysian students' perceptions of microgreens. By understanding their preferences, educators, policymakers, and entrepreneurs can formulate effective strategies for healthier eating habits among the youth and develop successful commercialization strategies.

Keywords: flavor, food systems, healthy diet, microgreens, student acceptance

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1. INTRODUCTION

Microgreens are miniature versions of salads, composed of vegetable or herb seedlings. It can be grown hydroponically or with organic medium like peat moss or cocopeat, with a harvest period as short as 7-14 days. This emerging specialty food products have received increasing attention due to their potential health benefits, nutritional value and culinary applications [1, 2, 3]. Additionally, it holds the potential to contribute to the sustainable diversification of global food systems, support urbanization and climate change mitigation efforts, and promote human health. It not only offers a concentrated source of essential vitamins and minerals but also exhibit a wide range of sensory attributes that can influence their acceptability among diverse consumer groups [4, 5]. Malaysia, like many other countries, is witnessing a growing interest in promoting healthier dietary choices, particularly among young individuals. The Malaysian Dietary Guidelines for Children and Adolescents encourages the children and adolescents (7-18 years old) to eat at least three servings of vegetables and two servings of fruits daily [6]. However, it has been noted that fruit and vegetable consumption among youth worldwide, including Malaysia, remains low. [7]. Several studies have found that sensory qualities such as taste, color, and texture of foods influence children's preference and intake of fruits and vegetables [8]. Integrating microgreens into the local food systems especially the diets of school students can be a promising approach to enhance their nutritional intake and foster an appreciation for fresh, locally grown produce. However, to effectively encourage the consumption of microgreens among this demographic, it is crucial to fully understand how sensory perceptions and phytochemical composition impact overall acceptance of microgreens. Several studies have been conducted to analyze the sensory qualities and consumer acceptance of various microgreens among adult consumers, with the conclusion that almost every microgreens species had excellent consumer acceptability. [4,5,9]. However, their reception among school students remains an understudied area, particularly in the Malaysian context. This study aims to investigate the sensory attributes and phytochemical composition of five different types of microgreens and explores their implications for acceptability among school students in Selangor, Malaysia.

2. MATERIALS AND METHODS

2.1. Plant Materials

Five microgreens species consisting of *Cosmos caudatus* Kunth also known as *ulam raja* in Malaysia, *Raphanus sativus* L. (red radish), *Raphanus sativus* var. *longipinnatus* (daikon), Amaranthus tricolor L. (red amaranth) and Zea mays L. (corn) were used in this study. These microgreens were purchased from the local grower in Shah Alam, Selangor as shown in Figure

1. These microgreens were selected for their distinctive flavors and health benefits, which are attributed to their role as functional foods in reducing the risk of disease [10,11]. The microgreens were grown in the mixture of cocopeat and perlite, and maintained under white LED illumination at room temperature condition. The microgreens were harvested after 7-10 days and freshly used for the sensory perception and phytochemical extraction.

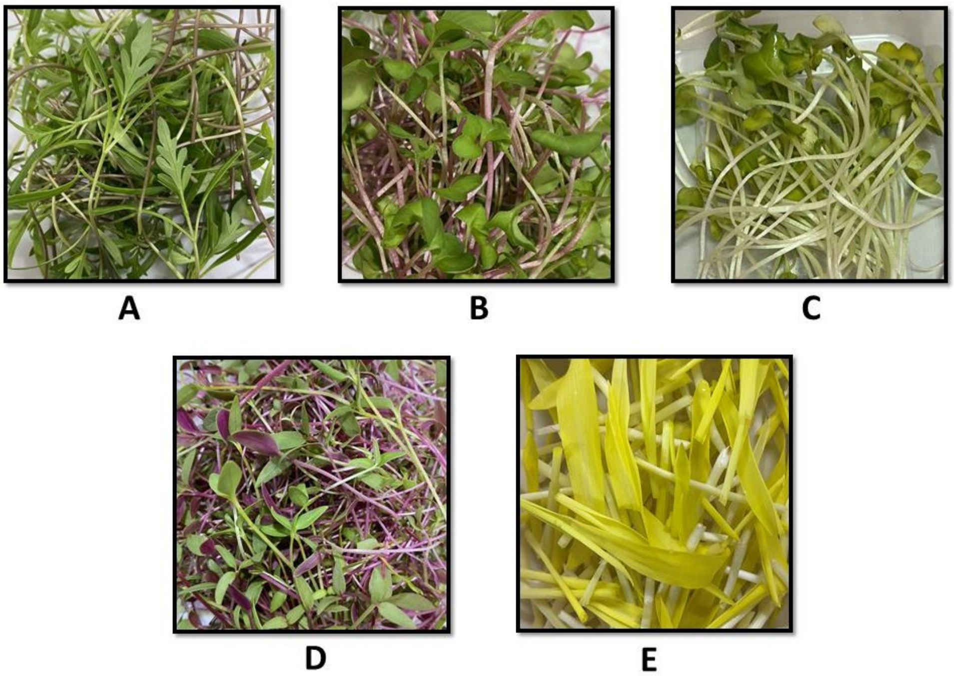

Figure 1: Image of six different microgreens used in the student's sensory attributes test: (A) *ulam raja*, (B) red radish, (C) daikon, (D) red amaranth and (E) corn.

2.2. Sensory perception and acceptance evaluation

Sensory perception and acceptance evaluations were conducted on students using twelve sensory attributes proposed by [4]. The sensory attributes and acceptability criteria as shown in Table 1 and 2 were used for the evaluation as suggested by [5]. The study assessed the perception of microgreen sensory characteristics by employing a nine-point hedonic and sensory scale ranging from score (1) to (9) as described by [5]. Printed versions of the sensory evaluation form were provided to every student, accompanied by straightforward explanations of each sensory attributes using non-technical terminology. The students consisted of volunteers from the Secondary School of Bandar Baru Sungai Buloh, Selangor, who had participated in a microgreens cultivation workshop and had no prior awareness of this research.

2.3. Preparation of Microgreens Extracts

The harvested microgreens were initially cleaned to eliminate any foreign material, dirt, and seed coats. Following this, they were dried at 50 °C for 48 hours and then ground into a powder using a pestle and mortar. Subsequently, the powdered microgreens were immersed in 80% (v/v) methanol within 100 ml Erlenmeyer flasks. They were subjected to incubation on an orbital shaker set at 110 rpm and a temperature of 25 °C for a duration of 48 hours. Following the incubation period, the extracts subjected to filtration using Whatman No. 1 filter paper, with the residue being preserved for further extraction. The filtrate that was collected underwent concentration to dryness under reduced pressure at 45 °C. The dried extracts were then dissolved in 80% (v/v) methanol to achieve a final concentration of crude methanolic extracts at 20 mg/ml. These microgreens extracts were stored at -18 °C in sterile containers until further use.

2.4. Determination of Total Phenolic Content

The total phenolic content of each microgreens extract was assessed using the Folin-Ciocalteu method [12]. The total phenolic content was quantified and expressed as milligrams of gallic acid equivalents per gram of dry extract (mg GAE/g DW).

2.5. Determination of Total Flavonoid Content

The total flavonoid content was assessed using the aluminum chloride colorimetric method [12], with quercetin used as the standard. The total flavonoid content was quantified and expressed as milligrams of quercetin equivalents per gram of dry extract (mg QE/g DW).

2.6. Determination of DPPH Radical Scavenging Activity

The assessment of the antioxidant activity in the microgreen extracts was based on their ability to scavenge radicals, which was determined using the 2,2-diphenyl-2-picrylhydrazyl (DPPH) assay [13]. The radical scavenging activity was calculated using the formula [(A0 - A1)/A0] × 100, where A0 represents the absorbance of the control, and A1 represents the absorbance of the crude extracts.

2.7. Statistical Analysis

The data were presented in the form of mean values ± standard error. To identify significant differences within the tested samples, an Analysis of Variance (ANOVA) test was conducted, followed by Tukey's Honestly Significant Difference (HSD) test at a significance level of $p \leq 0.05$. These statistical analyses were performed using IBM SPSS Statistics Version 21.

3. RESULTS AND DISCUSSIONS

3.1. Sensory perception and acceptance

The decision to use a 9-point hedonic scale in this study was based on its common application in food science for comparing responses to various food items. Additionally, the sensory version of this scale has been employed to evaluate the perceived intensities of taste qualities in various food products. Both of these scales were employed as single-attribute scales. As shown in Table 1, the results indicated that the overall acceptability of all five microgreens among the school students ranged from 5.0 to 6.0, represents neither liked nor disliked and liked slightly, respectively with no statistically significant differences ($p = 0.09$). The highest score for overall acceptability was given to corn (6.0 ± 0.3) and red amaranth (6.1 ± 0.4), while *ulam raja* received the lowest score (4.9 ± 0.4). Regarding texture, corn had the highest texture acceptability (6.0 ± 0.3), while red radish had the lowest (4.4 ± 0.4). The scores for flavor acceptability for all five microgreens were generally low, ranging from 4.0 to 5.0, represents disliked slightly and neither liked nor disliked, respectively with no statistically significant differences ($p = 0.073$). The highest score for acceptability of appearance was recorded in red-colored microgreens, specifically red radish (6.7 ± 0.3), which had bright pink-colored stems, followed by red amaranth (6.4 ± 0.3). Acceptability of appearance received high scores (> 6.0) for all microgreens except for *ulam raja* (5.2 ± 0.4). Given that the scores for overall eating quality fell within the range of 5.0 to 6.0, it can be concluded that all five microgreens were regarded as moderately acceptable.

Table 1: Overall liking scores for acceptability of microgreens samples.

Microgreens	Appearance	Flavor	Texture	Overall acceptability
Ulam raja	5.2 ± 0.4 b	4.2 ± 0.4 a	4.7 ± 0.4 ab	4.9 ± 0.4 a
Red radish	6.7 ± 0.3 a	4.1 ± 0.4 a	4.4 ± 0.4 b	5.2 ± 0.4 a
Daikon	6.0 ± 0.3 ab	4.6 ± 0.4 a	5.0 ± 0.4 ab	5.7 ± 0.4 a
Red amaranth	6.4 ± 0.3 a	5.0 ± 0.4 a	5.1 ± 0.3 ab	6.0 ± 0.3 a
Corn	5.9 ± 0.3 ab	5.4 ± 0.4 a	6.0 ± 0.3 a	6.1 ± 0.4 a

Mean ± SE (*n = 40*). Values within the same column followed by the same letter are not significantly different ($P < 0.05$) analyzed by Tukey's method.

In terms of sensory intensity ratings, all five microgreens had low scores for sourness (< 2.0) (Table 2). The average liking scores and sensory perception intensity ratings for *ulam raja*, red radish, and daikon exhibited less significant differences, with the exception of the sensation of heat, which was reported as higher for red radish (5.2) compared to daikon (3.6) and *ulam raja* (1.7). All three of these microgreens demonstrated strong astringency (> 5.0) and bitterness (> 6.0) scores with less sweetness (< 2.0). In contrast, red amaranth had the highest intensity of grassy taste (6.3) with low astringency (2.7) and bitterness (4.4) scores, while corn exhibited the highest intensity of sweetness (6.6). Both corn and red amaranth received the highest ratings for acceptability of flavor and overall eating quality, indicating a favorable impression among students. High ratings for overall acceptability of red amaranth have also been reported in previous studies [4, 5]. In general, red radish and *ulam raja* received the lowest acceptability scores in both flavor and overall eating quality categories. The presence of a high percentage of amylose (> 70%) in corn contributes to its sweetness [14]. The relatively low titratable acidity value could enhance the perception of sweetness in the microgreens [4]. Additionally, the high concentrations of secondary metabolites of glucosinolates and isothiocyanates in the Brassicaceae family, such as red radish and daikon, primarily contribute to the bitterness and heat taste in these cruciferous vegetables [15,16]. The findings from this study revealed that bitter taste and astringency appeared as the primary factors leading consumers to decline various vegetables rich in phytonutrients, eventhough these vegetables are acknowledged for their health-promoting properties [16].

Table 3 presents a comparison of mean student liking scores for the five microgreen samples based on gender. The present study found that, except for differences in the acceptability of appearance for corn and flavor for red radish, there were no significant variations between females and males in terms of the other sensory attributes

TABLE 2: Mean score for intensity of microgreen sensory attributes.

Microgreens	Sweetness	Aroma	Astringency	Bitterness	Grassy	Sourness	Heat
Ulam raja	2.0 bc	4.8 a	3.5 ab	6.1 a	5.6 ab	1.6 a	1.7 c
Red radish	2.2 bc	3.6 a	4.9 a	5.9 a	5.0 ab	2.2 a	5.2 a
Daikon	1.9 c	4.2 a	4.7 a	5.1 ab	5.4 ab	1.8 a	3.6 b
Red amaranth	3.0 b	3.7 a	2.7 b	4.4 bc	6.3 a	1.6 a	2.0 c
Corn	6.6 a	4.5 a	2.6 b	3.1 c	4.1 b	1.5 a	1.2 c

Mean (*n = 40*). Values within the same column followed by the same letter are not significantly different (P < 0.05) analyzed by Tukey's method.

of the five microgreens. Corn received a higher appearance acceptability score from female students (6.5 ± 0.4) compared to male students (5.2 ± 0.5), with a statistically significant difference (p = 0.049). Regarding flavor acceptability, there were significant differences (p = 0.011) between female and male students in their perceptions of red radish microgreens, with females rating it much lower (3.4 ± 0.4) compared to males (5.2 ± 0.5). The results of this study indicate that there is gender-based differences in chemosensory perceptions that are associated with specific acceptability and sensory characteristics of microgreens, as reported by [5].

TABLE 3: Mean score for acceptability of microgreens samples by female and male students.

Microgreens	Appearance	Flavor	Texture	Overall Acceptability
Ulam raja				
Females	5.4 ± 0.5	3.6 ± 0.5	4.3 ± 0.5	4.8 ± 0.5
Males	5.2 ± 0.6	4.7 ± 0.6	5.2 ± 0.6	5.0 ± 0.6
Red Radish				
Females	7.0 ± 0.3	3.4 ± 0.4*	4.0 ± 0.5	5.0 ± 0.4
Males	6.1 ± 0.5	5.2 ± 0.5	5.1 ± 0.6	5.7 ± 0.7
Daikon				
Females	6.2 ± 0.4	4.0 ± 0.5	4.3 ± 0.6	5.1 ± 0.5
Males	6.6 ± 0.5	5.4 ± 0.5	6.0 ± 0.6	6.5 ± 0.5
Red Amaranth				
Females	6.5 ± 0.4	4.7 ± 0.4	4.9 ± 0.4	5.9 ± 0.3
Males	6.3 ± 0.6	5.5 ± 0.6	5.4 ± 0.6	6.3 ± 0.5
Corn				
Females	6.5 ± 0.4*	5.4 ± 0.5	5.6 ± 0.5	6.0 ± 0.5
Males	5.2 ± 0.5	5.5 ± 0.5	6.3 ± 0.4	6.2 ± 0.5

Mean ± SE. *Significantly different than males (*P* < 0.05; analyzed by Tukey's method).

3.2. Total Phenolic Content

The results of the total phenolic content are presented in Table 4. The total phenolic content in the extracts of the five microgreens ranged from 11.84 ± 1.01 to 21.02 ± 0.45 mg GA/ g DW, representing an approximate two-fold variation. This study revealed that *ulam raja* had the highest total phenolic content (21.02 ± 0.45 mg GA/g DW), followed by red radish, daikon, red amaranth, and corn with values of 19.06 ± 0.34, 18.92 ± 0.74, 16.25 ± 0.41, and 11.84 ± 1.01 mg GA/g DW, respectively ($p < 0.05$). The phenolic content in fresh produce, including microgreens, can be affected by a range of internal and external factors, including genotypes, growing conditions, maturity, and post-harvest handling [17,18]. In this study, methanolic extraction was chosen due to the enhanced solubility of phenolic compounds in polar organic solvents. The findings showed that red radish and daikon microgreens had the highest phenolic content compared to red amaranth and corn. This result aligns with previous observations that microgreens from the Brassicaceae family are known for their elevated levels of phenolic compounds, establishing them as valuable sources of dietary polyphenols [19]. *Ulam raja* (*Cosmos caudatus*), a member of the Asteraceae family, is also known for its elevated total phenolic content, which is associated with a range of beneficial properties such as anti- inflammatory, antibacterial, antifungal, and anticancer activity [20]. The total phenolic content of *ulam raja* microgreens obtained in this study is relatively higher compared to mature *ulam raja*, as reported by [21]. The high phenolic content in *ulam raja*, red radish, and daikon has contributed to their bitter and astringent taste [4]. These findings demonstrated a strong correlation between the overall acceptability and sensory attributes of microgreens and their total

phenolic content.

Table 4: Total phenolic and flavonoid content, and percentage of DPPH inhibition in five microgreens.

Microgreens	**Total Phenolic Content (mg GAE/ g DW)**	**Total Flavonoid Content (mg Quer/ g DW)**	**Percentage of DPPH Inhibition (%)**
Ulam raja	21.02 ± 0.45a	21.14 ± 0.28a	68.32 ± 0.51a
Red radish	19.06 ± 0.34ab	5.53 ± 0.30d	69.38 ± 0.24a
Daikon	18.92 ± 0.74ab	5.21 ± 0.15d	65.34 ± 0.51ab
Red amaranth	16.25 ± 0.41b	8.66 ± 0.22b	49.14 ± 8.24bc
Corn	11.84 ± 1.01c	6.97 ± 0.13c	38.14 ± 0.85c

Mean (*n = 3*). Values within the same column followed by the same letter are not significantly different ($P < 0.05$) analyzed by Tukey's method.

3.3. Total Flavonoid Content

The total flavonoid content ranged from 6.97 ± 0.13 to 21.14 ± 0.28 mg QE/g DW, representing an approximate three-fold variation. *ulam raja* microgreens exhibited the highest total flavonoid content (21.14 ± 0.28 mg QE/g DW), followed by red amaranth, corn, red radish, and daikon with values of 8.66 ± 0.22, 6.97 ± 0.13, 5.53 ± 0.30, and 5.21 ± 0.15 mg QE/g DW, respectively ($p < 0.05$). Flavonoids are a significant category of plant secondary metabolites known for their diverse range of chemical and biological properties, including antioxidative, anti-inflammatory, antimutagenic, and anticarcinogenic activities [22]. *Ulam raja*, in particular, contains major flavonoids like quercitrin, catechin, and rutin, which are renowned for their antioxidant properties and therapeutic benefits [23].

3.4. DPPH Radical Scavenging Activity

The DPPH radical scavenging activities are presented in Table 4. A higher percentage of DPPH inhibition indicates stronger DPPH radical scavenging activity. The results showed that the highest percentage of inhibition was recorded in red radish microgreens (69.38 ± 0.24 %), followed by *ulam raja* (69.38 ± 0.24 %), daikon (65.34 ± 0.51 %), red amaranth (49.14 ± 8.24 %), and corn (38.14 ± 0.85 %). The DPPH assay is a simple technique frequently employed to assess the ability of crude extracts from fresh produce to scavenge radicals. The findings from this study indicated that microgreens with a limited total phenolic content such as red amaranth and corn exhibit lower antioxidant activity. This postulated the significant role of hydroxyl groups in phenolic compounds majorly found in Brassicaceae and Asteraceae species of microgreens in aiding the scavenging of free radicals [12].

4. CONCLUSION AND RECOMMENDATION

The present study has explored the sensory perception, acceptability, and phytochemical composition of five distinct microgreens species among Malaysian school students. The findings have revealed the valuable insights into the potential of microgreens as a functional sustainable food crop within this demographic. The sensory evaluation highlighted distinct attributes of each microgreen's species. Corn microgreens that were characterized by a pronounced sweetness has received the highest ratings for acceptability of flavor and overall eating quality, indicating their favorability among the student population. Conversely, red radish and *ulam raja* faced challenges in garnering acceptance, due to the bitter and astringent taste, receiving the lowest scores in both categories. The phytochemical composition unveiled notable variations among the microgreens. The higher total phenolic content contributed to the bitterness taste in microgreens. The phytochemical content could serve as crucial parameters and indicators of sensory attributes and predictive factors for consumer acceptability, including among younger individuals. The present study also revealed the potential of *ulam raja*, which has the highest total phenolic and flavonoid content, and antioxidant activity as a source of health-promoting compounds. These findings underscore the correlation between sensory attributes and phytochemical composition, providing valuable insights into how these factors influence the perceptions of microgreens among Malaysian students. By understanding their preferences, educators, policymakers and entrepreneurs can formulate effective strategies for healthier eating habits among the youth and develop successful commercialization strategies. The overall acceptability of the five microgreens in this study was moderately rated. Therefore, the results of this study emphasize the need for educational efforts aimed at informing students about the health advantages of microgreens and their potential positive effects on personal well-being and sustainability. Such initiatives could contribute to increasing the acceptance and integration of microgreens into daily diets. Additionally, further research is warranted to assess consumer acceptability and sensory perceptions in diverse populations and geographic regions across Malaysia.

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