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Consumer liking of steamed green Chinese cabbage (*Brassica rapa* ssp. *chinensis*) cultivated in formulated vegetable waste-based organic hydroponic solutions

Erika Pardede[1]*, Ferlist Siahaan[1], Rita Hayati[2]

[1]Universitas HKBP Nommensen, Medan, Indonesia.
[2]Universitas Syah Kuala, Banda Aceh, Indonesia.
*Corresponding author, e-mail: erikapardede@uhn.ac.id

Abstract

Chinese cabbage or pak choy (*Brassica rapa* ssp. *chinensis*) is often consumed because of its high nutritional content and several health advantages. Due to their promotion as being healthier and more ecologically friendly, hydroponic vegetables have seen a recent spike in consumer interest. The production of Chinese cabbage involved the processing of the vegetable waste to create various hydroponic solution formulations (F1 = banana peels, eggshells, and bean sprouts; F2 = banana humps, onion peels, bean sprouts, and moringa leaves; F3 = moringa leaves, onion peels, and bean sprouts; and F4 = AB Mix solution). They were applied at concentrations of 600, 900, 1,200, and 1,500 parts per million. The aim of this study was to investigate the relationship between the type of hydroponic growth solutions and Chinese cabbage customer acceptance. As a result, using a hedonic test of consumer liking, a panel of 32 untrained individuals was asked to show their liking score on sensory attributes of Chinese cabbage. There was a significant difference in the color liking of Chinese cabbage as an effect of hydroponic solution formulation. However, both organic vegetable waste-based formulations did not statistically substantially affect consumer acceptance, which includes color, taste, flavor, texture, and overall liking. Ultimately, vegetable waste-based organic formulations can be used to produce Chinese cabbage that is as acceptable to customers as those prepared with inorganic AB-Mix solution.

Keywords: organoleptic, organic, vegetables waste

Introduction

Chinese cabbage (*Brassica rapa* ssp. *chinensis*), like other species of Brassica, is consumed frequently due to its rich nutritional value and significant health benefits (Cox et al., 2012; Jideani et al., 2021). It can be consumed stir-fried, cooked, or uncooked. When the plants are young, they make a great salad.

Hydroponic produce has experienced a recent upsurge in consumer interest because it has been promoted as being healthier and more environmentally friendly (Sousa et al., 2024). Hydroponics is a modern technique of cultivating plants without soil using mineral-nutrient solutions in water. It offers a controlled environment for optimized crop growth and minimizes the risk of diseases and pests. Several hydroponic formulations are commonly used in vegetable production. Deep water culture, sometimes called floating root system, is one of the methods. It entails immersing the plant roots in a nutrient-rich water solution, with the remaining portion of the plant being supported above water level by materials like wood, cork bark, or polystyrene (Velazquez-Gonzalez et al., 2022).

Vegetables are used for food mostly based on their quality attributes, which include both nutritional and sensory aspects. Sensory quality, other than nutritional values, is a significant factor that determines consumer acceptance of a food product, such as a sensory attribute, i.e., appearance, texture, and flavor (Gong et al., 2016).

There is a connection between these chemicals and the nutritional and sensory aspects of vegetables. In *Brassica* crops, total glucosinolate concentrations and the products of their breakdown were linked to sensory characteristics (Chen et al, 2019; Nor et al, 2020). Many foods and drinks have an astringent and bitter taste because of phenolic chemicals. Among cruciferous

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vegetables (broccoli, cauliflower, kale, turnips, collards, Brussels sprouts, cabbage, Chinese cabbage, and bok choy), aldehydes and ketones seemed to be the most discriminatory, which explains their distinctive aroma. They also contain organosulfur compounds that range from 0.5 to 1 g/g. *B. rapa*, like all *Brassica* species, includes secondary plant metabolites, primarily glucosinolates and phenolic compounds such as flavonoids and hydroxycinnamic acids. Due to these compounds' advantageous health effects, their inclusion in diets has grown (Neugart et al., 2018).

In our previous research, we examined the effects of several hydroponic solutions that contained waste from different vegetables on yield and agronomic characteristics (Siahaan et al., 2023). This study aimed to compare the consumer's liking for Chinese cabbage (*Brassica rapa* var. chinensis) grown in vegetables waste-based organic solutions with varying types of vegetable waste and concentrations grown hydroponically under natural light. The novelty of this study lies in the manipulation of vegetable waste to achieve high acceptance of *B. rapa* for potential optimal marketing.

Material and Methods

Preparation of nutrient solutions

In this research, three nutrient solutions (F1, F2, and F3) were formulated using different types of vegetable waste: banana peels, moringa leaves, onion peels, bean sprouts, banana humps, and one was added with eggshells (**Table 1**). AB mix solution (F0), a normally inorganic solution used for hydroponic culture systems, which contains macro and micro nutrients needed by plants was used as control.

The vegetable waste-based organic solution was prepared as described by Siahaan et al. (2023). With the exception of eggshells, each piece of vegetable waste was washed, dried, and broken up into smaller pieces. Eggshells are powdered after being dried and cleaned. Each of the vegetables, as well as the eggshell, had a weight of 0.5 kg. After mixing the formulation as directed, 50 mL of molasses and water were added to make four liters in a container, thoroughly mixed, and sealed. The mixture was left to ferment anaerobically at room temperature. After ten days, the fermented liquid was ready to use upon filtering.

Seedlings preparation and plant growing

This study was conducted from September to November 2022 at an experimental site at Glugur Darat, Medan, Indonesia. Chinese cabbage seeds were sown on a 2.5×2.5×2.5 cm^3 rockwool medium. Rockwool was first soaked in water, drained, and placed on a plastic tray. A planting hole was made at the top of the rockwool. One seed is inserted into the planting hole on rockwool, then the plastic tray is covered with black plastic and placed in the shade. After two days, transfer to an unshaded condition.

After 14 days of sowing, at the seedling stage with three to four true leaves, the seedlings were transferred to the floating culture system by being inserted into the pipe supported by the media rockwool in the greenhouse. The cabbages were planted in a randomized block design with two factors. The first factor was the waste-based organic-formulated solution. The second factor was the concentrations (600, 900, 1.200, and 1.500 ppm).

The control (F0) and vegetables waste-based organic formulation (F1, F2, and F3) are dissolved in water according to treatments. The nutrient solution was inserted into a holding container of four liters and delivered by pumping to the closed pipe irrigation system, where the plant nutrient solution was circulated in the closed pipe. The pH of the solution was checked every three days. The nutrient solution was renewed every ten days by pumping two liters of nutrient solution according to treatments. Chinese cabbage plants are harvested approximately 30 days after planting with the criteria of green leaves, large size, health, and freshness.

Sensoric evaluation using hedonic scale

To evaluate and compare consumer liking among different hydroponic formulations for Chinese cabbage, a sensory evaluation was conducted. To determinate how the consumers liked or dislike the Chinese cabbage samples, the acceptance test was carried out using a hedonic scale structured in 9-points (1 = dislike extremely and 9 = like extremely) regarding color, taste, flavor, texture, and overall liking (Wichchukit and O'Mahony, 2014). Thirty-two untrained adult volunteers (n=32) were recruited among students and staff of the Faculty of Agriculture, University of HKBP Nommensen, North Sumatera, Indonesia. The participants were 18 females and 14 males. The test was performed in the

Table 1: Type of waste used for each nutrient solution

Formulation	Banana peels	Moringa leaves	Onion peels	Bean sprout	Banana humps	Eggshells
F1	√			√		√
F2		√	√	√	√	
F3		√	√	√		

Food Analytical Laboratory of the Faculty of Agriculture.

The cabbage was transported directly to the laboratory within two hours of harvesting. The samples selected for study were those without defects. The root of the plant was removed, the leaves and stalks were rinsed thoroughly with tap water, drained, and then steamed for five minutes just before evaluation took place. Steaming the broccoli retains more flavor, texture, and nutrients than the boiling method (Bongoni et al., 2014; Tangkam, 2019). Samples were labeled with arbitrary three-digit codes and served to the panelists on foam plates. The samples were served in random order to the participants. The respondent had to rate their liking of the Chinese cabbage from 1 as extremely dislike to 9 as extremely like, using a 90-mm structured line scale (anchored from dislike extremely to like extremely) regarding color, taste, flavor, texture, and overall liking. Obtained data than convert to 9-scale of hedonic. Between samples, respondents were instructed to rest for 60 seconds and given water and plain crackers to cleanse their palates.

Data analysis

A two-way analysis of variance (ANOVA) of consumer liking was performed on the interaction of the main treatment effect. Means were separated using Tukey's pair-wise comparison in SAS. Statistical significance was obtained at a 95% confidence level (alpha = 0.05).

Results and Discussion

The sensory experience of consuming Chinese cabbage significantly impacts consumer preferences. Consumer liking for Chinese cabbage is influenced by various sensory attributes, including taste, texture, and color (Zhao et al., 2007). Therefore, it is essential to evaluate how different hydroponic solutions affect these sensory attributes.

Table 2 shows the mean scores of liking score of Chinese cabbages grown in different formulated vegetable waste-based hydroponic solution. Statistically, the acceptance of Chinese cabbage's organoleptic qualities, in terms of taste, flavor, texture, and overall liking, was not statistically significantly impacted by the hydroponic solution's formulation. However, the formulation affected the liking on the color of cabbage.

Color.

Color is an important aspect, among others, that plays a vital role, perhaps the most important, in consumer liking (Schifferstein, 2019). Color and appearance are the initial quality attributes that draw people to a food product; they are regarded as indicators of the inherent good quality, which is associated with the acceptability of food (Spence, 2015; Vadiveloo et al., 2018). The leaves of Chinese cabbage grown using different hydroponic systems can vary in color intensity and vibrancy. These variations in color can impact perceived freshness and overall visual appeal, influencing consumer preferences

In this study, the differences in the color liking are statistically significant. The liking score on color was affected significantly by the type of solution formulation. In general, the liking score of the color was above 5 (score 5 = neither like nor dislike), with one exemption of ones grown in banana pells/bean sprout/eggshells formulation at 1500 ppm (F1C4), with score of 4.87±1.8. Only three samples had a liking score above 6 (score 6 = slightly liked; score 7 = moderately light), i.e., ones grown in banana pells/bean sprout/eggshells formulation at 1200 ppm (F1C3), in moringa leaves/onion peels/bean sprouts at 1.200 ppm (F3C3), and AB-Mix solution at 600 ppm (F0C1), with scores of 6.11±1.6, 6.55±1.5, and 6.58±1.7, respectively. The results indicated that the Chinese cabbage grown with AB-Mix solution at 600 ppm (F0C1) and grown with solution made from moringa leaves/onion peels/bean sprouts at 1.200 ppm (F3C3) were found to be the most accepted among the treatments in terms of color. Both were not significantly different from the rest, but better than grown in banana pells/bean sprout/eggshells formulation at 600 ppm (F1C1) and at 1500 ppm (F1C4). In general, the color of Chinese cabbage grown in tested waste-based organic solutions was accepted by the panelists just as well as those grown in inorganic solutions.

The color of Chinese cabbage was dominated by the presence of chlorophyll as a photosynthetic pigment; thus, it represents the intensity of green (Samec et al., 2021). Our previous study revealed that all tested solution formulations did not show any significant effect on concentrations of either chlorophyll-a or chlorophyll-b (Siahaan et al., 2023). Our current finding indicated that the liking for the color of pak choy was not only affected by the greenness of the leaves and stalk.

Taste.

This study reveals that the acceptability of the taste of Chinese cabbages was not affected by the formulation of the hydroponic solution. Only cabbage grown in banana pells/bean sprout/eggshells formulation at 1200 ppm F3C1 (score = 6.08±1.7) was scored as slightly liked (score = 6), while the rest of the of the cabbage was scored under 6, including ones produced at AB-Mix solution. The only sample rated below 5 was cabbage grown with AB-Mix solution at 1.200 ppm (F0C3), which scored 4.69±2.4.

Table 2. Mean score for acceptability attributes of Chinese cabbages using 9-hedonic scale[a] (n=32)

Chinese Cabbage samples	Color	Taste	Flavour	Texture	Overall Acceptability
F0C1	6.58±1.7c	5.65±1.9ns	6.45±1.7ns	6.46±2.0ns	6.41±2.0ns
F0C2	5.47±1.8abc	5.56±2.0ns	5.93±2.0ns	6.15±1.8ns	6.06±1.8ns
F0C3	5.96±1.5abc	4.69±2.4ns	5.33±1.8ns	5.55±2.0ns	5.53±2.0ns
F0C4	5.57±1.6abc	5.80±1.5ns	5.94±1.6ns	6.05±1.4ns	6.08±1.4ns
F1C1	5.25±1.5ab	5.22±1.2ns	5.16±1.5ns	5.61±1.2ns	5.49±1.2ns
F1C2	5.87±1.5abc	5.36±1.6ns	5.55±1.6ns	5.84±1.4ns	5.72±1.4ns
F1C3	6.11±1.6abc	5.85±1.8ns	5.96±1.7ns	6.06±1.7ns	6.16±1.7ns
F1C4	4.87±1.8a	5.59±1.9ns	5.37±1.5ns	5.88±1.6ns	5.88±1.6ns
F2C1	5.66±1.9abc	5.24±1.9ns	5.91±1.6ns	5.76±1.7ns	5.66±1.7ns
F2C2	5.88±1.4abc	5.25±1.9ns	5.63±1.7ns	5.30±1.9ns	5.78±1.9ns
F2C3	5.72±1.4abc	5.22±1.3ns	5.70±1.1ns	5.44±1.4ns	5.80±1.4ns
F2C4	5.34±1.3abc	5.30±1.9ns	5.46±1.2ns	5.57±1.7ns	5.44±1.7ns
F3C1	5.99±1.7abc	6.08±1.7ns	6.00±1.5ns	5.98±1.4ns	6.34±1.4ns
F3C2	5.50±1.6abc	5.33±2.1ns	5.79±1.8ns	5.69±1.9ns	5.57±1.9ns
F3C3	6.55±1.5c	5.19±2.1ns	5.68±1.5ns	5.73±1.7ns	5.65±1.7ns
F3C4	5.33±1.8abc	5.78±1.8ns	5.45±1.7ns	5.51±1.6ns	5.76±1.6ns

[a]Score 1= Extremely disliked; Score 2= Very much disliked; Score 3= Moderately disliked; Score 4= Slightly disliked; Score 5= Neither like nor dislike; Score 6= Slightly liked; Score 7= Moderately liked; Score 8= Very much liked; Score 9= Extremely liked. [b]Different letters within the same column indicate significant difference at P<0.05, mean±standard deviation. [c]ns= non-significant

Chinese cabbage has a sharp and bitter taste. Phenolic compounds are responsible for the bitterness and astringency of many plant-based food (Wieczorek et al., 2017). Chinese cabbage contains total phenolics ranging from 3.87 to 14.66 ppm, and they were not affected by the formulation made from vegetable waste (Siahaan et al., 2023). Brassica is also rich with sulphur-containing glucosinolate compounds, which, among other compounds, are partly responsible for the taste characteristic of Brassica vegetables (Bhandari et al., 2015). Sinigrin, gluconapin, progoitrin, and neoglucobrassicin have been associated with bitter taste (Nor et al., 2020).

Our previous study revealed no significant effect of treatment on nitrate, flavonoids, or fibre (Siahaan et al., 2023). Sweetness has the greatest effect on cooked quality of Chinese cabbage (Gong et al., 2016). It was in in agreement with Duffy et al. (2017) who revealed that bitterness decreased vegetable liking, while sweetness increased liking. This current research indicated that all hydroponic solution formulas from selected waste vegetables had no effect on the compound responsible for taste, and bitterness determined the liking for cabbage.

Flavor.

This study reveals that the acceptability of the flavor, which refers to the unique smell and taste (Song et al., 2023), of Chinese cabbages was not affected by the tested formulation of the hydroponic solution. Score 6 (slightly like) was only achieved by cabbage grown at AB-Mix solution at 600 ppm (F0C1), which produced the highest liking score of 6.45±1.7, and it was only comparable to one produced using solution made from moringa leaves, onion peels, and bean sprouts at 600 ppm (F3C1), which scored as high as 6.00±1.5.

It is believed that glucosinolates and their breakdown products—isothiocyanates—are responsible for the characteristic taste and smell of *Brassica* vegetables (Drewnowski & Gomez-Carneros, 2000). Glocosinolates participated in flavor formation, and negative perception was proven in Brussels sprouts, but no strong link was found in broccoli, cauliflower, or kohlrabi (Cano-Lamdrid et al., 2023; Wieczorek et al., 2022). In addition, Gong et al. (2016) found that cooked flavor also was one factor, among others, on cooked quality of Chinese cabbage.

Texture.

Texture is another important attribute that affects consumer liking. The white stalks are juiced and retain crunch even after cooking. All samples were rated above 5 (neither like nor dislike), and three of them were rated above 6 (slightly liked). Chinese cabbage grown at AB-Mix solution at 600 ppm (F0C1) was rated as the highest by a score of 6.46±2.0, followed by cabbage grown at AB-Mix solution at 900 ppm (F0C2) and grown in banana pells/bean sprout/eggshells formulation at 1200 ppm (F1C3) with scores of 6.15±1.8 and 6.06±1.7, respectively. Although statistically, there was no significant difference between them.

Hydroponically grown Chinese cabbage exhibits a crunchier texture due to the controlled nutrient supply, resulting in improved texture and mouthfeel compared to traditionally grown cabbage. Texture plays a significant role in determining the overall quality and sensory experience of a food product. Softness, firmness and juiceness were factor, among others, on cooked quality of Chinese cabbage (Bongoni et al, 2014; Gong et al., 2016).

Overall liking

The overall liking score was statistically affected significantly by the type of solution formulation; however, it was not strong enough to reveal differences among each treatment.

Chinese cabbages cultivated in an AB-Mix solution at 600 ppm (F0C1) was rated as the best (6.41±2.0) based on overall liking test (**Figure 1**). Their performance was better (scored > 6) in terms of flavor, texture, and color than those cabbages receiving other treatments. The F0C1 had a somewhat lower taste rating (5.65±1.9), although statistically was not significantly differ from the rest of the cabbages. In this case, these characteristics of flavor, texture, and color possibly contributed much to the Chinese cabbage the overall rating.

Cabbages grown in two different waste-based organic formulations perform as good as the normally AB-mix hydroponic solution were cabbage grown on moringa leaves/onion peels/bean sprout formulation at 600 ppm (F3C1) and ones grown at banana peels/bean sprout/egg shells formulation at 1.800 ppm (F1C3), which rated as the second and third highest overall acceptability.

The second highest overall acceptability was for cabbage grown on moringa leaves, onion peels, or bean sprout formulation at 600 ppm (F3C1), with a score of 6.34±1.4. Their performance was slightly liked (scored = 6) in terms of taste (6.08±1.7), flavor (6.00±1.5), color (5.99±1.7), and texture (5.98±1.4). It is followed by the third rank, i.e., the cabbage grown at banana peels, bean sprouts, and egg shells formulation at 1.800 ppm (F1C3), which has a hedonic score of overall (6.16±1.7) and is slightly liked in terms of color (6.11±1.6), texture (6.06±1.7), taste (5.85±1.8), and flavor (5.96±1.7).

Generally concluded that panelists liked the Chinese cabbage grown in tested vegetables waste-based organic solutions just as much as those grown in inorganic solutions. This study was in line with study of Zhao et al., (2007) and Dhakal et al. (2021) where the organically and conventionally grown vegetables show no significant differences either in consumer liking or consumer-perceived sensory quality. A similar finding by Tan et al. (2021) revealed that the sensoric characteristics of *B. chinensis* L. var. *parachinensis* grown with organic fertilizer showed no significant difference from their counterparts grown with mineral fertilizer.

Through the Pearson correlation test, we found that liking on taste, flavor, and texture were positively correlated with overall liking, with r-values of 0.76, 0.79,

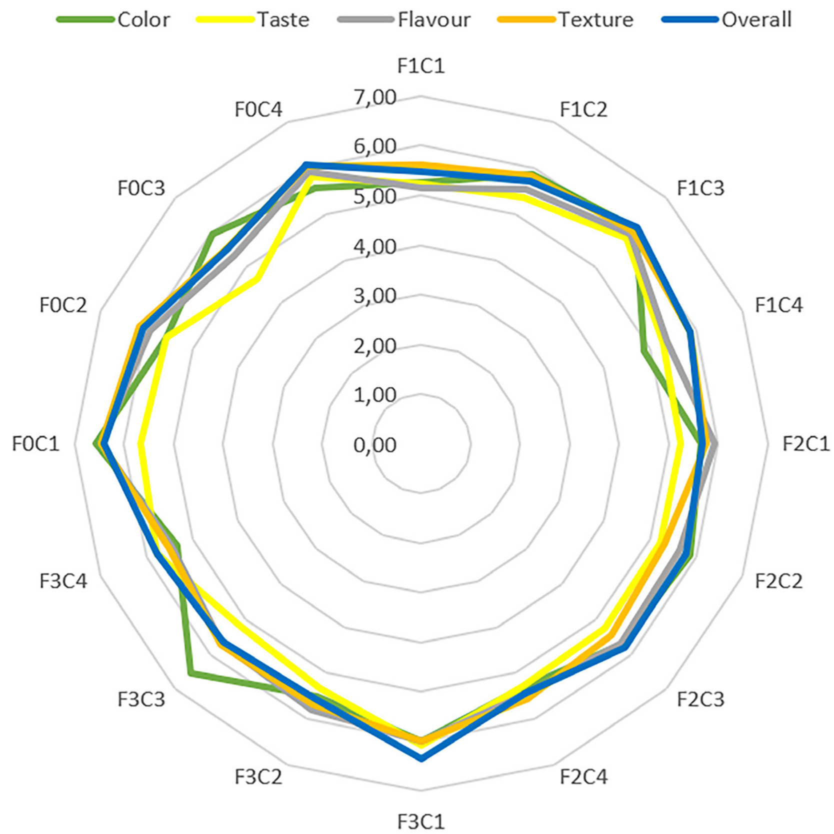

Figure 1: Chart of the hedonic analysis of Chinese cabbage

and 0.77, respectively. Meanwhile, the contribution of color was lower (r = 0,39) to the overall liking. Based on this, for Chinese cabbage, the liking on taste, flavor, and texture determined the overall liking. This is in line with the fact that Broccoli hedonics were predicted by bitterness, flavor, and sweetness (Cox et al., 2011). Moreover, food selection from consumer and marketing studies found taste, as opposed to perceived nutrition or health value, is universally the strongest determinant of food preference (Drewnowski and Gomez-Carneros, 2000).

Conclusions

In terms of color, flavor, aroma, and texture, the Chinese cabbages cultivated with formulated vegetable waste-based organic solution were found to not differ significantly from cabbage grown with a regular inorganic AB-mix solution. Understanding the different hydroponic formulations and their impact on consumer liking is crucial for the success of growers and the satisfaction of consumers. Growers can customize their hydroponic systems to enhance the total customer experience and satisfy consumer preferences by taking into account atributes like color, taste, flavor, and texture. The findings of the comparison analysis may have a big impact on hydroponics, particularly in the direction of a more environmentally friendly method. In conclusion, vegetable waste can be utilized to create nutrient solutions that consumers find to be just as enjoyable as those cultivated with AB-mix solution.

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