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Reduction of Unpleasant Perceptive Intensity and Primary School Lunch Vegetable Waste by Sauce Flavoring

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Abstract High school lunch waste, vegetable most, is a global issue. Vegetable species and preparation methods affected their acceptance and plate waste. Thermal process was demonstrated to reduce bitterness contents and seasoning to mask perception intensity, and thus improve vegetable consumption. In this study, the effect of culinary practice (blanching and seasoning addition) of broccoli, a common vegetable served in school lunch, on sensory characteristics (acceptance and perception intensity of astringency, bitterness, grassy smell and sweetness) was determined first. Moreover, the contribution of culinary practice application on vegetable waste in a primary school was assayed. Broccoli was prepared: raw (C), blanched (B), blanched and flavored with Japanese style sauce (Flavor-1), with cheese (Flavor-2), and with Chinese style sauce (Flavor-3). Our results showed raw materials exert the strongest perception intensity of grassy smell, bitterness and astringency but the least intensity of sweetness. Blanching and seasoning addition masked perception intensity and thus enhanced likeness of odor, flavor and overall acceptance. Blanching treatment, overall acceptance was significantly negatively correlated to intensity of grassy smell. While seasoning incorporation, overall acceptance was positively correlated to sweetness intensity and negatively correlated to astringency intensity. Application of culinary practice improved palatability and thus reduced vegetable rejection. The aggregated vegetable wastes for 4 consecutive semesters from July, 2020 to June, 2021 (87±3 day/semester) were as low as 6.5% per day.

Keywords: *vegetable waste, school lunch, flavoring sauces, perception intensity, sensory acceptance*

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1. Introduction

High plate waste at school lunch is a global issue. In the USA and European, around 9 to 45% of food was wasted in primary school [1,2,3,4]; while in Asia, about 21~25% of total food served were wasted in China, Taiwan, and Viet Nam schools [5,6,7]. Among food categories served, vegetables are the most wasted due to unsatisfied preference and palatability [8,9,10]. However, fruit and vegetable (F&V) waste at school lunch significantly reduced intake of certain nutrients including dietary fiber, folate, and Vitamin A, B1, B3, B6, B12 and C [2,11]. Higher fruit and vegetable intake has been associated to prevent the risks of chronic diseases such as obesity, diabetes, hypertension, high cholesterol, and nutrient deficiency [12].

The presence of teachers during meal-time, meal policies, time for eating, preference of vegetables, and palatability of food were reported to affect school lunch waste [13,14]. Moreover, dish variety, dining environment, hygiene, freshness, and cooking skills determine school lunch satisfaction [15]. Among affecting factors, poor preference and palatability were the major responsible reasons for vegetable waste [8,10]. Cooking and flavoring approaches were proposed to modify characteristics of vegetables and thus ameliorate preference and palatability [16,17]. Cooking in hot water for 3 min significantly reduced 55% bitter content and thus improved preference of cauliflower [18,19]. Various cooking methods (boiling, steaming, cooking in the combined oven, microwaving, and steaming with microwave) affected texture preference of vegetables [20]. They found boiling was the most acceptable cooking method for broccoli. Cook reduced color characteristics (brightness, redness, yellowness, color saturation and h°) of carrot but improved consumers' preference [21]. However, undercooked, cold-served and oily vegetables were dissatisfied by students [7]. Furthermore, loss of attractive appearance and flavor resulted from overcooking reduced palatability and acceptability of vegetables [22].

Aroma and flavor of foods are key parameters for consumers' acceptance. Taste qualities including sweet, salty, sour, bitterness and umami, affected food preference and consumption [23]. Unpalatability from bitter taste of vegetables is a key deterrent for consumption, which led to only 7% children and 25% adults met daily recommended intakes of vegetables [24]. Bakke et al. [24] found masking bitter perception by salt and sucrose incorporation promoted vegetable preference. Flavor enhancement via addition of spices and herbs was an alternative skill to overcome undesirable taste and improve palatability and consumption of vegetables [17]. However, studies related to incorporation effect of common used sauces (Japanese or Chinese style sauce, cheese) at home or school lunch on vegetable intakes was lack. Thus, the objective of this study is to evidence the retarded effect of thermal treatment and seasoning addition on the perception intensity (bitterness, astringency and grassy smell) and sensory acceptance of broccoli, a common served vegetable in school. Additionally, the application of thermal treatment and Chinese style seasoning addition for reducing vegetable wastes in school lunch was investigated.

2. Materials and Methods

2.1. Broccoli Preparation

Broccoli (*Brassica olearacea* L. *italica*) was purchased from the Xiluo Fruit and Vegetable Wholesale Market (Yunlin, Taiwan). Broccoli was cleaned and chopped into 4-5 cm. Japanese style sauce (composed of soy sauce, sugar, vinegar and olive oil) was from Japanese dressing (UNI-President China Store Co., Taiwan), Mozzarell cheese from Kirkland Signature, Costco Wholesale Inc. (Settle, WA, USA), and Chinese style sauce was composed of fried shallot (I-Mei Foods Co., Ltd. Taoyuan) and soy sauce (Yamaki Mentsuyu Soy Sauce, Costco Wholesale Inc., Settle, WA, USA).

While the untreated raw broccoli served as the control (C), other broccoli samples were prepared by different culinary practices in combination with seasonings. Blanched sample: broccoli heated in boiling water for 3 min; Flavor-1 sample: broccoli heated in boiling water for 3 min and mixed with 1% Japanese style sauce; Flavor-2 sample: broccoli heated in boiling water for 3 min and mixed with 1% Mozzarell cheese; Flavor-3 sample: broccoli heated in boiling water for 3 min and mixed with 1% Chinese style sauce.

2.2. Sensory Evaluation

Sensory characteristics including preference and perception intensity were evaluated according to the Quantitative Sensory Testing described by Tao et al. [25] with slight modification. After a series of instructive sessions, 20 panelists (9 male and 11 female graduate students or staffs from the Department of Food Science, National Chiayi University) were served five samples (control, blanched, Flavor-1, Flavor-2 and Flavor-3) based on random 3-digital number. Bottle water was provided to clear taste between each sample. Preference attributes including color, odor, flavor and overall acceptance were descriptively evaluated using a 9-poing hedonic scale (1-highly undesirable, 9- highly desirable). Perception intensities of bitterness, astringency, grassy smell and sweetness of sample were also scored using a 9-point scale (1-highly undetectable, 9- highly detectable).

2.3. School Lunch Program and Vegetable Waste

In Taiwan, primary school students eat lunch at school during school days. Families pay for meal expenses while local and central governments support labor, overheads, and facilities [14]. The menus including energy and nutrients from food served must follow the national guidelines from the Health Promotion Administration, Ministry of Health and Welfare (HPA). School lunch menu generally includes: a main carbohydrate source (rice or noodle); a main protein source (meat or fish); 2 dishes vegetables (one meat blended with vegetable and one vegetable only); a soup (blended with vegetables); fruit (2-3 times per week).

Our early study demonstrated the combination of thermal process and seasoning addition reduced bitterness contents and masked perception intensity of broccoli, which may eventually improve palatability and reduce waste of vegetables. This culinary practice (blanching and 1% Chinese style sauce) was further applied to monitor vegetable wastes at school lunch. The study was conducted in a primary school in Yulin (Taiwan) over 4 consecutive semesters from July, 2020 to June, 2021 (87±3 day/semester). Participants were students (n = 1082±50) in Grades 1–6 (aged 6–12 years). Lunch is served between 12:00 and 1:00 PM.

The frequencies of vegetables species served were recorded. Energy and nutrient contents (fiber, vitamin A, vitamin C, thiamin, niacin, vitamin B6, folate, calcium, sodium, potassium and iron) in those vegetables were estimated using the data base provided by the Taiwan Food and Drug Administration (consumer.fda.gov.tw /Food/TFND.aspx).

Vegetable waste was collected every day (5 days a week for 4 semesters). After lunch, students dumped all leftover vegetables (in 2 dishes and soup) into waste bins. Vegetable waste was daily weighted after water was drained. Percentage of vegetable waste was calculated by the ratio of aggregated vegetable discarded per total served to students.

2.4. Statistical Analysis

Data were expressed as mean ± SD. Principle component analysis (PCA) was performed to find out the contribution of blanching and various seasonings to sensory acceptances and perception intensity. Cluster analysis was conducted to cluster treatment and sensory characteristics. While AMOS structure analysis was performed to establish a linear structure mode to find out the correlation between sensory intensities and overall acceptance. All the statistical analysis was carried out using SPSS Statistics, version 21.0 (IBM Corp., Armonk, NY, USA).

3. Results and Discussion

Poor preference and palatability were the major reasons for vegetable waste. In this study, sensory preference including color, odor, flavor and overall acceptance of broccoli were evaluated and shown in Figure 1. Compared to raw and flavored broccoli, blanching significantly enhanced color preference of broccoli; while seasoning addition improved odor and flavor preference of broccoli. Overall preference declined in the order of seasonings > blanching > raw broccoli (Figure 1D). High color preference score (in the range of 6 to 7) indicated color was acceptable (Figure 1A); while low odor (score in the range of 2-3 only) and flavor (score about 4) preference for raw broccoli indicated unacceptable (Figure 1B and 1C, respectively). Blanching enhanced the preference scores from 4 to 5-6 and seasoning with Japanese or Chinese sauces further increased to the level of likeness (6-7).

Principal Component Analysis (PCA) model grouped the scores of sensory acceptance (color, flavor, taste and overall acceptance) into two main (PC1 and PC2) components. Kaiser-Meyer-Olkin (KMO) value and Bartlett's test were conducted to evaluate the appropriateness of PCA model [26]. In this study, the KMO values for raw, blanching and three seasoning additions (Flavor-1, Flavor-2 and Flavor-3) were 0.606, 0.639, 0.699, 0.670 and 0.744, respectively; while the values of Bartlett's test were $p < 0.05$ (Table 1). Those data supported PCA model is suitable to distinguish sensory preference. Eigenvalue of PC1 and PC2 was 2.3-3.1 and around 1, respectively; while percentage of variance for PC1 and PC2 was in the range of 53-68% and 25-29%, respectively. Cumulative variance contribution rate was 82-96%. Load factor, calculated from PCA model, is an indicator of correlation between sensory parameters and the scores of principle components, 1 and 0 representing strong or no correlation between factor and principal component, respectively. High load factors of PC1 in the ranges of 0.628-0.919, 0.916-0.971 and 0.924-0.974 for odor, flavor and overall acceptance, respectively, indicated strong correlation (Table 2). While high load factor of PC2 for color (in the ranges of 0.956-0.995) but low load factor of PC2 for odor, flavor and overall acceptance were found.

PC1 and PC2 scores of samples estimated from % of variance (Table 1) and load factor (Table 2) were shown in Figure 2A and B, respectively; while PC overall score was calculated according the equation below and shown in Figure 2C.

$$PC\ overall\ score = PC1score * \frac{\%\ of\ variance\ PC1}{\%\ of\ variance(PC1+PC2)} + PC2\ score * \frac{\%\ of\ variance\ PC2}{\%\ of\ variance(PC1+PC2)}$$

Seasoning additions significantly raised PC1 scores in the order: raw (4-5), blanched (10) and flavored (13-14) broccoli, but did not affect PC2 scores, relatively low scores of 2-4 for all samples. Moreover, significant effect of seasonings on PC overall scores (around 10) was found, much higher than blanched (8) and raw broccoli (5).

The perception intensity including bitterness, astringency, grassy smell and sweetness of sample was graded using a 9-point scale (1-highly undetectable, 9-highly detectable) and illustrated in Figure 3. Compared to the control, blanching and seasonings decreased perception intensity of grassy smell, bitterness and astringency; while perception intensity of sweetness and overall acceptance were increased.

Generally, bitterness, astringency and grassy flavor of vegetables are repulsive by human, while sweet and salty are preferred [27,28]. Phenols, flavonoids and glucosinolates in plants were considered as the sources of bitter, acidity or astringent tastes [29]. Glucosinolates has been identified as the determinant of cauliflower bitterness to obstruct its consumption [29,30]. Study of van Doorn et al. [31] found glucosinolate contents in 16 varieties of Brussels sprouts correlated to perception intensity of bitterness. Abundant glucosinolate and its hydrolysate in broccoli were the most sensory deterrent for its preference [16,19,29]. Wieczorek et al. [32] investigated the correlation between phytochemical compositions (glucosinolates, isothiocyanates, phenolics and polysaccharides) and sensory traits of 3 cultivars of broccoli, 5 of Brussels sprout, 3 of cauliflower, and 4 of kohlrabi, both raw and cooked. Data of PCA indicated bitter components negatively correlated to sensory acceptability. Another PCA data released the correlation between acceptance and perception of ten vegetables (cauliflower, broccoli, leek, carrot, onion, red bell pepper, French beans, tomato, cucumber and iceberg lettuce) prepared by raw, cooked, mashed, juice and cold mash also showed bitterness is the easily distinguish factor (66.91% weight ratio). Acceptance was negatively correlated to bitterness ($r= -0.35$, $p < 0.05$) but positively correlated to sweetness ($r= 0.43$, $p < 0.05$) [27].

Preparation methods including raw, cooked, mashed and cold pressed juice significantly altered texture, odor as well as flavor, and eventually influenced consumption and acceptance of vegetables [27,33]. Compared to preparation by mashed, stir-fried, grilled and deep-fried, participants preferred carrots and French beans prepared by steamed and boiled [34]. Cooking technique might increase the contents of phenolics and polysaccharides but decrease glucosinolates content and thus positively correlated to desirability and consumption of vegetables [18,19,35].

Moreover, masking of bitterness and astringent taste by flavoring was an alternative approach for improving of vegetable consumption. Polysaccharides can mask bitterness perception and enrich taste acceptance [36]. Sucrose (1%) or salt (0.2%) was reported to reduce bitter component content and taste in puree of broccoli, spinach and kale without affecting texture and aroma properties. Similarly, 2% sucrose addition significantly improved acceptance of cucumber and green capsicum purees [37]. Flavoring with spices and herbs enhanced desirability of broccoli, cauliflower, carrot and green beans [38]. Fritts et al. [39] also found herbs and spices increased liking and preference for vegetables among rural high school students aged from 14 to 18 yr. Moreover, light dressing enhanced raw broccoli intake among bitter sensitivity children [40]. While Torri et al. [41] showed both green salad blended with balsamic vinegar and vegetable mixed with cheese promoted vegetable intake. Pork gravy with 5% fat over broccoli and cauliflower significantly masked bitter taste and thus increased palatability [42]. In conclusion, incorporation of sugar, salt, spice, dressing and gravy had the potential for vegetable consumption [43,44].

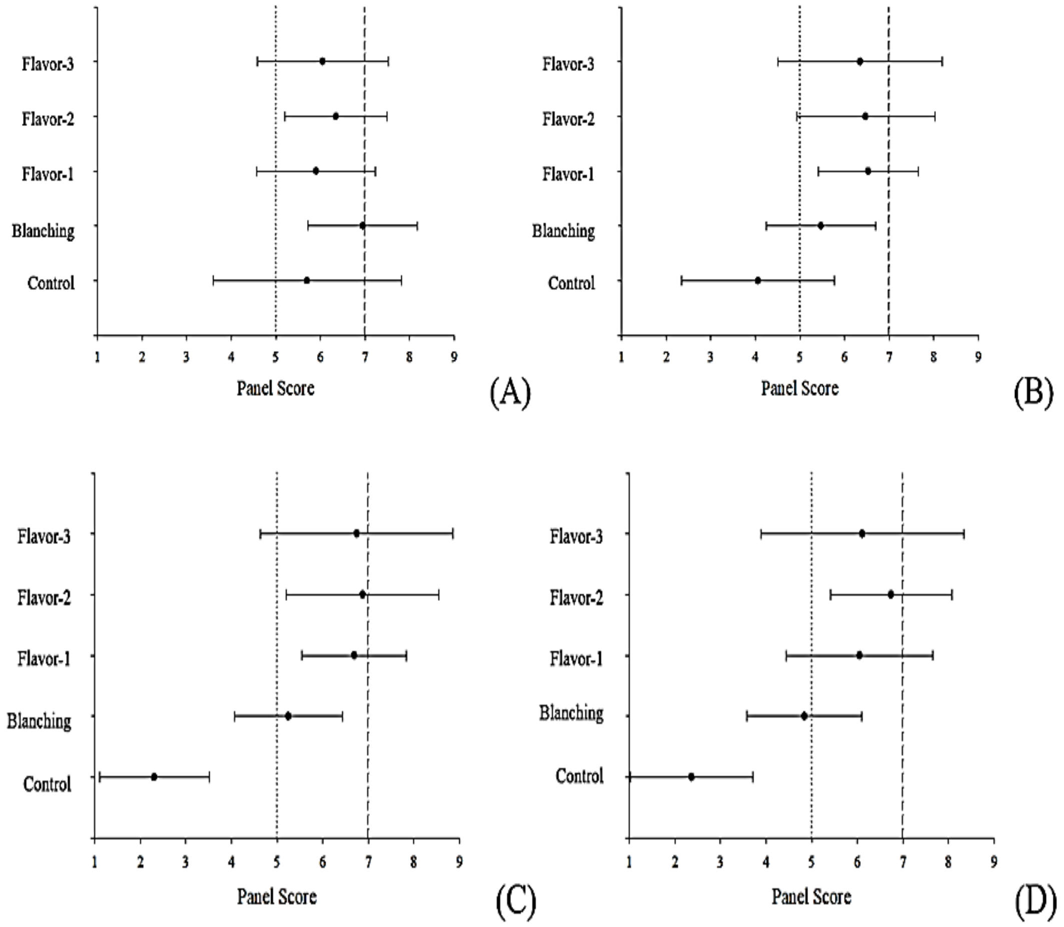


Figure 1. Sensory scores for (A) color (B) odor (C) flavor and (D) overall acceptance of raw, blanched, and flavored broccoli

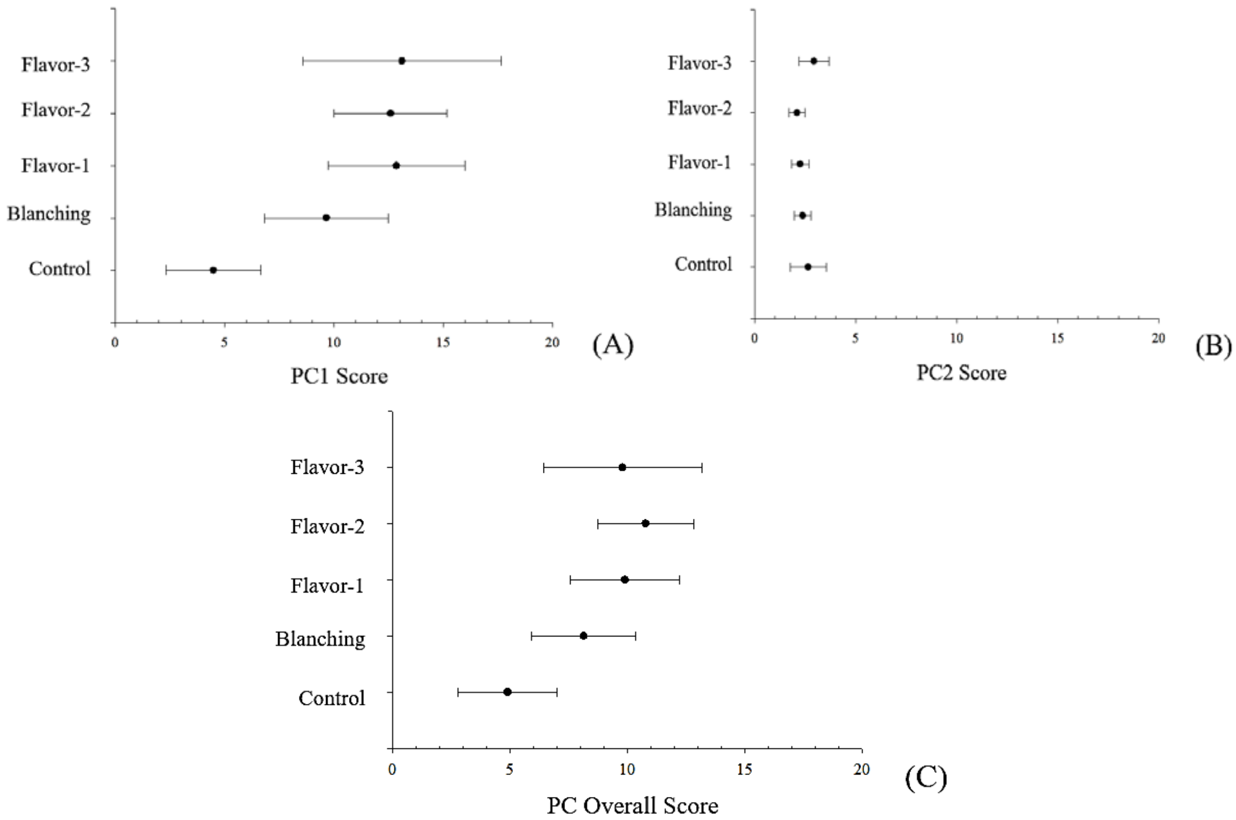


Figure 2. (A) PC1 (B) PC2 and (C) PCA scores for raw, blanched, and flavored broccoli

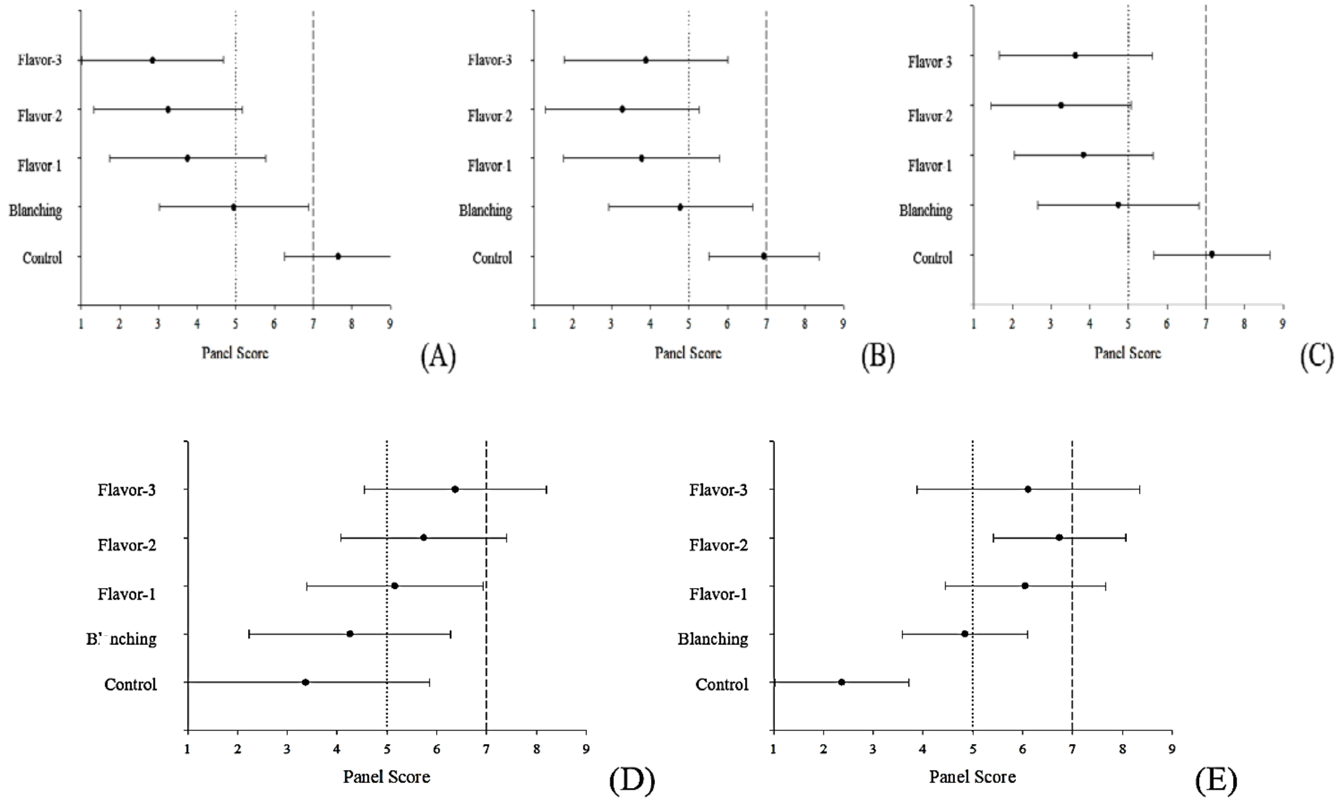


Figure 3. Perception intensity of (A) grassy smell (B) bitterness (C) astringency (D) sweetness and (E) overall acceptance for raw, blanched, and flavored broccoli

Table 1. PCA data (Eigenvalue and % of variance) of raw, blanched and flavored broccoli

	Control	Blanching	Flavor-1	Flavor-2	Flavor-3
Eigenvalue					
1	2.312	2.532	2.779	2.480	3.131
2	0.982	0.978	0.930	1.082	0.727
3	0.548	0.384	0.240	0.258	0.108
4	0.158	0.106	0.051	0.180	0.034
% of variance					
PC1	53.164	61.922	66.682	61.885	68.455
PC2	29.181	25.837	26.031	27.160	27.988
KMO	0.606	0.639	0.699	0.670	0.744

Table 2. PC1, PC2 and PC overall scores of raw, blanched and flavored broccoli

	Control		Blanching		Flavor-1		Flavor-2		Flavor-3	
	PC1	PC2	PC1	PC2	PC1	PC2	PC1	PC2	PC1	PC2
Color	0.051	0.956	0.081	0.995	0.116	0.991	0.000	0.987	0.233	0.972
Odor	0.628	0.469	0.845	0.115	0.886	0.225	0.869	0.298	0.919	0.284
Flavor	0.935	-0.050	0.934	0.168	0.959	0.053	0.916	-0.146	0.971	0.158
Overall acceptance	0.924	0.176	0.941	-0.049	0.974	0.078	0.939	-0.049	0.947	0.263

In this study, blanching and particular flavorings significantly reduced perception intensity of grassy smell, bitterness, and astringency and enhanced sweetness perception and overall acceptance (Figure 3). Ward's Minimum Variance Clustering Method and Euclidean distance were conducted to evidence the perception intensity of grassy small, bitterness, astringency and sweetness and overall acceptance of broccoli and shown in Figure 4. Euclidean distances 5 as the survey line showed that perception intensities of grassy smell, bitterness and astringency from raw and blanched broccoli were classified into different subgroups. High intensity of grassy smell, bitterness and astringency deterred raw broccoli preference (overall acceptance about 2.5). The perception intensity of grassy smell, bitterness, astringency and sweetness were similar for various seasoning incorporations. Seasoning incorporation significantly reduced the intensity of grassy smell, bitterness and astringency and enhanced sweetness intensity and thus improved overall acceptance (panels' score > 6).

Analysis of moment structure (AMOS) was conducted to establish a linear structure model to find out the correlation between perception intensities of sensory characteristics (grassy smell, bitterness, astringency and sweetness) and overall acceptance and the correlation coefficient (r) was shown in Figure 5. Compared to raw broccoli, blanching destroyed the components of grassy smell and enhanced the components of sweetness; thus, overall acceptances were enhanced (r= -0.691 and 0.261 for grassy smell and sweetness, respectively, $p < 0.01$) (Figure 5A). However, de-bitterness and de-astringency by blanching didn't affect overall acceptance, r= -0.104 and -0.021 for bitterness and astringency, respectively (Figure 5A). While seasoning incorporation, grassy smell and bitter became undetectable and thus overall acceptance was improved (r= 0.016 and -0.082 for grassy smell and bitterness, respectively) (Figure 5B). While the perception intensity of astringency and sweetness was significantly correlated well with overall acceptance (r= 0.294 and -0.511, respectively, $p < 0.05$). In a previous study of Dinehert et al. [30], the liking scores of Brusses sprouts and kale were significantly affected by the levels of sweet and bitter taste, r= 0.34 and -0.22 respectively ($p<0.01$). Our results also showed blanching removed bitterness and all the tested seasonings (vinegar/olive oil, cheese, or fried shallot/soy sauces) masked the perception of grassy smell and astringency and increased sweet perception; thus improved overall acceptance. The correlation coefficients for blanching and seasoning addition and sensory acceptance were r= 0.746 and 0.905, respectively. The overall acceptance improved from dis-likeness (2.37) for raw broccoli to dislikeness-likeness (around 5) for blanched and then to likeness (6.05-6.74) levels (Figure 3E) for blanched associated with seasoning incorporation.

Unpleasant taste from astringency and grassy taste of vegetables hindered acceptance. Schonhof et al. [45] found glucosinolates of cauliflower substantially lost (60%) by blanching and cooking. Beside bitter components removal, cooking may cause starch converting into simple sugars and thus enhance sweet taste and mask bitter taste. Flavoring incorporation into cooked cauliflower is an alternative approach to promote likeness of consumers [46]. In this study, blanching and then seasoning addition were shown to reduce the taste of astringent and improve the sensory acceptance (color, odor and flavor) and might enhance vegetables intake. Blanching and seasoning addition are simple culinary practices for preparation in large quantities such as at school lunch. In this study, blanching and seasoning addition were applied to prepare vegetables at school lunch. Our results showed school lunch provided 163±10g vegetable daily. The frequencies of 15 vegetables types served was in the order of Green cabbage, onion, Brassica rapa, Muchrooms-harore, Chinese cabbage, carrot, Pak choy, broccoli, radishes, Bok choy, sweet potato, fresh bamboo, Osaka komatsuna, sweet corn, green onion. The nutrient contents of those vegetables were clustering evaluated and shown in Figure 6. The fiber contents in vegetables were in the descending order: sweet corn and green onion (4.0~4.7g/100g), carrot, broccoli and mushrooms-harore (2.6~3.1g/100g) and others (0.9~2.2 g/100g) (Figure 6A). High vitamin A content was found in carrot (Figure 6B); while compared to other vegetables, Brassica rapa, carrot and Osaka komatsuna contain higher calcium and potassium (Figure 6D).

Figure 7 showed the provided amount of 15 vegetables: green cabbage (19-20 g/meal); onion, Brassica rapa, mushrooms-harore (10~14 g/meal); Chinese cabbage, carrot, pak choy, broccoli and radishes (7~10g/meal); others (4~7g/meal) (Figure 7A). The DV (%) of 15 vegetables served at school lunch were 10% for fiber, 38% for vitamin A, 28% for vitamin C, 12% for vitamin B6, 10% for folate, 6.3% for niacin, 5.6% for thiamin, 10% for potassium, 6% for Iron, 5% for calcium and 2% for sodium (Figure 7B). The accumulated vegetable wastes were 6.6, 5.9, 6.3 and 6.9% per day for every semester from 2020 to 2021, respectively (Figure 7C).

School lunch program is an important strategy in the world to prevent under nutrition of children [47]. However, high vegetable waste of school lunch is a serious topic in the world. Vegetable species and preparation methods (fresh, whole, cut, cooked or processed) affected acceptance and plate waste. Marlette et al. [48] found categories and preparation method of food were the key determination factor for plate wastes. About 26, 33 and 34% of vegetable in salad, boiled corn and French-fried potatoes were discarded, respectively.

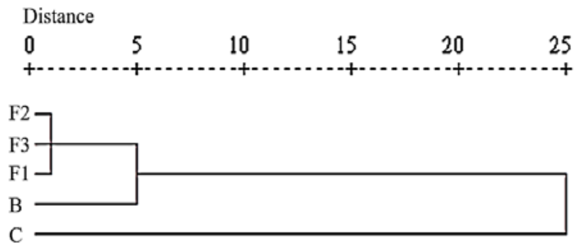


Figure 4. Dendrogram of hierarchical cluster analysis of perception intensities and overall acceptance for raw, blanched, and flavored broccoli Sample codes- C: raw broccoli as control; B: blanched; F1: Japanese style sauce; F2: cheese; F3: Chinese style sauce

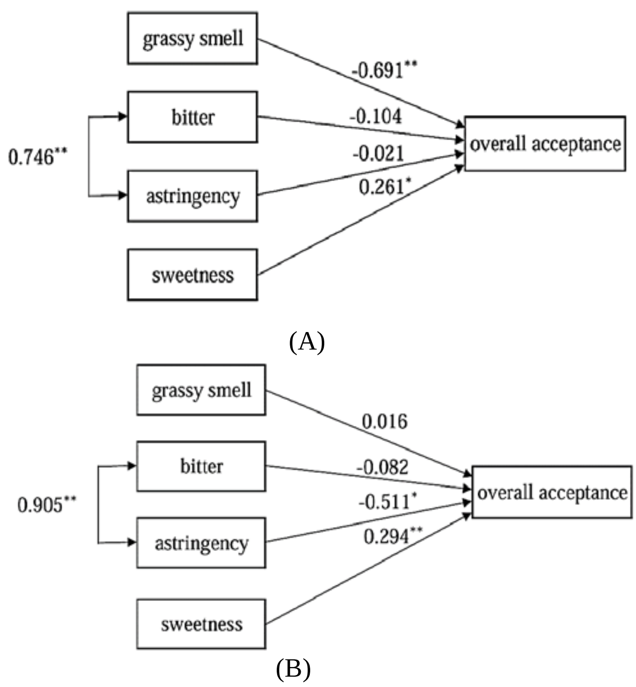


Figure 5. Linear structural model of determinants of perception intensity and overall acceptance for (A) blanching and (B) seasoning addition of broccoli

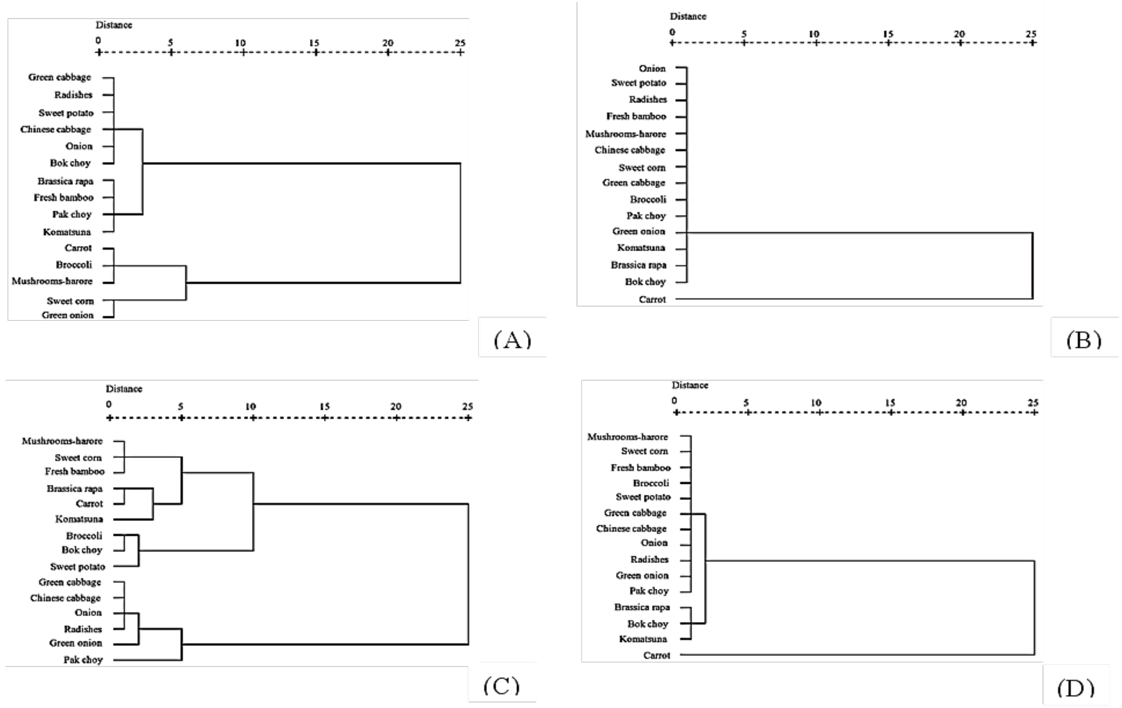
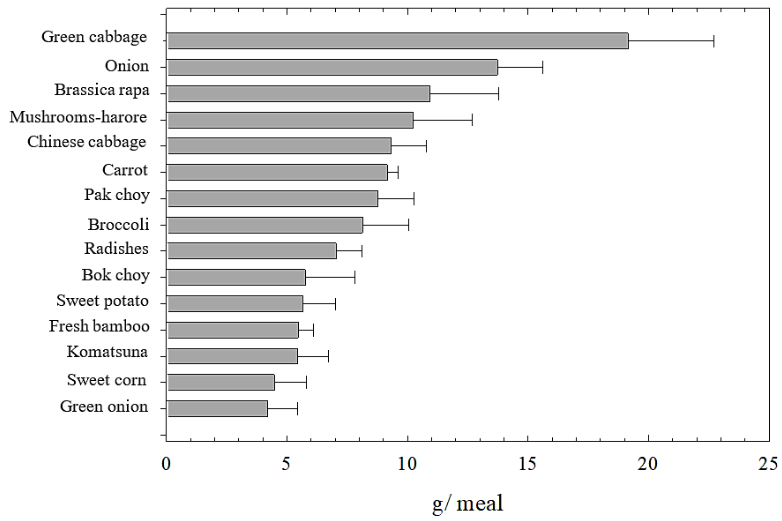
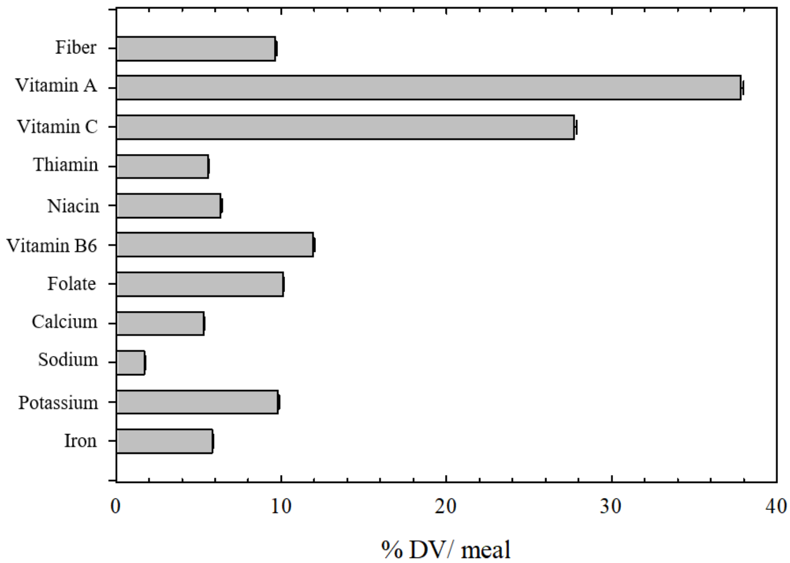


Figure 6. Dendrogram of hierarchical cluster analysis of (A) fiber (B) vitamin A (C) vitamin C (D) minerals for vegetables served





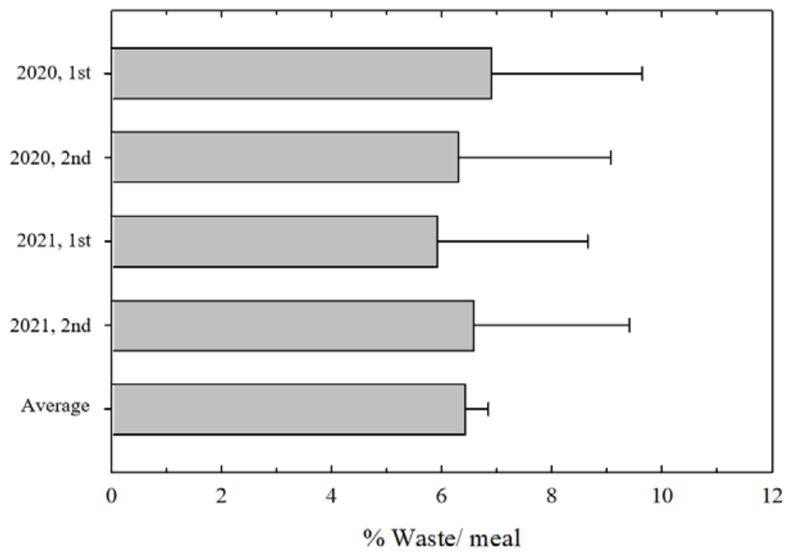


Figure 7. (A) Intake (B) % DV/meal (C) waste/meal for vegetables served

The waste percentages for boiled and mashed potato were 52 and 19%, respectively. In southern Thailand, the analyzed lunch wastes were: 7-33% rice, 9-22% meat, 7-65% vegetable, 1-19% fruit and 3-14% egg [49]. In Finland and Italy, about 5.7 and 15% were discarded, respectively, particularly 25% proportion of vegetable and salad in side-dish [50,51]. In Beijing of China, 21% plate lunch and 42% vegetable in proportion were discarded [5]. In USA, a waste investigation (from 1978 to 2015) of school lunch showed 32-58% vegetables were discarded [52]. High vegetable waste (67-75%) was also found by Cohen et al. [53] in school lunch (1030 students) from 2011-2012. In this study, blanching and seasoning addition improved palatability of vegetable in side-dishes and thus significantly reduced the waste to the level of 6.5%. Our results may provide a strategy to school and government for reducing vegetable waste.

4. Conclusion

Vegetable intake can prevent the risks of chronic diseases. However, vegetables are the most wasted due to poor preference and palatability at school lunch. Cooking and flavoring approaches were proposed to modify characteristics of vegetables and thus ameliorate preference and palatability. This study demonstrated culinary practices (blanching and seasoning incorporation) reduced perception intensity of grassy smell, bitterness and astringency and enhanced sweetness intensity. Application of this culinary practices to school lunch improved palatability and thus reduced vegetable rejection, aggregated vegetable waste as low as 6.5% per day.

Conflicts of Interest

The authors declare that they have no conflicts of interest to disclose with respect to this article.

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