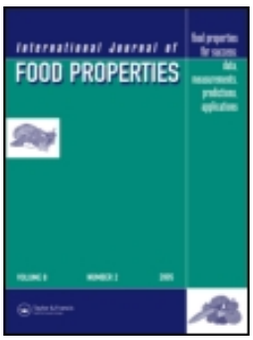

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A. Kala & Jamuna Prakash

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Nutrient Composition and Sensory Profile of Differently Cooked Green Leafy Vegetables

A. Kala and Jamuna Prakash*

Department of Studies in Food Science and Nutrition,
University of Mysore, Manasagangotri, Mysore, India

ABSTRACT

Four green leafy vegetables commonly consumed in South India were selected for the study. They were subjected to three different methods of cooking namely, conventional, pressure, and microwave cooking. Proximate composition, vitamins (ascorbic acid and β-carotene), mineral content (calcium, phosphorus, and iron), and in vitro available iron of the raw and cooked samples were estimated. The cooked samples were further subjected to sensory analysis. The results showed that the nutrient content of each green leafy vegetable was distinct and spinach was comparatively a poor source of all nutrients. Cooking caused a significant difference only in the ascorbic acid and β-carotene content of the greens. No significant difference was observed in the nutrient content due to the three different methods of cooking adopted. Results of the sensory test revealed that color was the only attribute that varied to a large extent due to cooking. Color of pressure cooked greens was considered inferior to conventionally cooked and microwave cooked samples. The sensory attributes of microwave cooked greens were similar to the conventionally cooked samples.

*Correspondence: Jamuna Prakash, Department of Studies in Food Science and Nutrition, University of Mysore, Manasagangotri, Mysore-570 006, India; E-mail: jampr55@hotmail.com.

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Key Words: Carotenoids; Conventional cooking; Microwave cooking; Dietary fiber; In vitro available iron; Nutritional composition; Sensory attributes.

INTRODUCTION

Vegetables form a considerable part of an Indian diet, which is basically vegetarian. The composition and nutrient content of the vegetables vary widely depending on the part of the plant used as food.[1] Generally, vegetables are considered to contribute appreciable amounts of vitamins and minerals but when compared with other groups of vegetables, green leafy vegetables are known to be exceptionally rich in minerals, β-carotene,[2] and are also a good source of dietary fiber and antioxidants.[3,4] It is well established that common cooking methods generally do not lead to any macronutrient (carbohydrate, protein, and fat) or mineral losses but vitamins especially, water soluble and heat labile vitamins are the most vulnerable. The amount of ascorbic acid in plant tissues however, is known to vary tremendously and in green leafy vegetables the age of the leaf is also known to affect the ascorbic acid content.[5] β-carotene content of greens is also known to depend on various factors such as species, genetic variation, and post harvest losses.[6] Green leafy vegetables are also reported to contribute significant amount of protein[7,8] but their availability is limited due to the presence of nondigestible fiber to which protein is bound.[9] The consumption of green leafy vegetables is generally low probably due to its unattractive organoleptic properties such as grassy flavors and odors as stated by Friedman.[7]

Microwave cooking is relatively new for household use and there is limited information on the effects of microwave cooking on nutrient as well as sensory attributes of green leafy vegetables. Hence, the present study aimed at comparative evaluation of nutrient composition and sensory profile of green leafy vegetables cooked by three different methods namely, conventional boiling, pressure cooking, and microwave cooking. Raw samples from the same batch were also analyzed which served as controls.

MATERIALS AND METHODS

Four commonly consumed fresh greens namely, Amaranth (*Amaranthus gangeticus*), Kilkeerai (*Amaranthus tricolor*), Shepu (*Peucedanum graveolens*), and Spinach (*Spinacia oleracea*) were purchased from a local market on the day of processing. They were cleaned and washed thoroughly under running water followed by distilled water and spread out on dry filter papers to remove the surface moisture. The greens were then cut evenly and divided into four equal parts, of which one part (raw) served as the control and the other three parts were subjected to the three different cooking methods namely, (i) conventional cooking (boiling, covered), (ii) pressure cooking (15 lbs), and (iii) microwave cooking (covered, using high power only). The nutrients analyzed were moisture, protein,[10] total ash, ether

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extract, iron, phosphorus,[11] total dietary fiber,[12] calcium,[13] in vitro available iron measured as ionizable iron,[14] ascorbic acid, and β-carotene.[15] All the analysis was carried out in duplicate for two separate batches of green leafy vegetables. The sensory attributes were analyzed using ranking test[16] and Qualitative Descriptive Analysis (QDA).[17] The panel members for ranking test comprised of 20 postgraduate students of the Institution. Based on the performance in the ranking test, 10 best panelists were selected for QDA. Nutrient analysis results were analyzed statistically using ANOVA. Sensory analysis data was analyzed using the standard table for ranking test[16] and using mean and SD (standard deviation) for QDA.

RESULTS AND DISCUSSION

The conditions followed for cooking greens presented in Table 1 show that the water required for cooking in pressure cooker and in microwave oven method was lesser than that required for conventional cooking. Microwave cooking of spinach did not require the addition of water as observed earlier by Eheart and Gott[18] and Kylen et al.[19] Pressure cooking required the least amount of time followed by microwave method and then by conventional method. The cooked weight of spinach decreased to a considerable extent in all the three variations. The amount of weight gained due to cooking however, varied with the type of green leafy vegetable irrespective of the water added or the time taken.

The proximate composition of the raw and cooked greens is presented in Table 2. The moisture content of the raw greens ranged from 90.4 to 94.7%. Shepu,

Table 1. Cooking conditions of green leafy vegetables (per 300 g of edible portion).

Vegetable	Variations	Water added (ml)	Time taken (min)	Cooked weight (g)
Amaranth	Con	100	22	305
	Pre	85	9	325
	Mic	85	14	290
Kilkeerai	Con	120	18	310
	Pre	85	8	330
	Mic	90	10	300
Shepu	Con	175	21	306
	Pre	110	8	310
	Mic	145	10	295
Spinach	Con	40	12	250
	Pre	40	6	255
	Mic	—	8	265

Values are mean of two batches.
Con—conventionally cooked; Pre—pressure cooked; Mic—microwave cooked.

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Table 2. Proximate composition of green leafy vegetables (g/per 100 g edible portion, wet basis).

Vegetables	Variations	Moisture	Protein	Ether extract	Total ash	Total dietary fiber
Amaranth	Raw	$90.7^{a} \pm 0.42$	2.12 ± 0.09	0.35 ± 0.03	1.81 ± 0.1	3.72 ± 0.13
	Con	$90.2^{a} \pm 0.35$	2.18 ± 0.08	0.37 ± 0.04	1.90 ± 0.04	3.99 ± 0.02
	Pre	$90.0^{a} \pm 0.49$	2.23 ± 0.14	0.42 ± 0.04	1.86 ± 0.08	3.97 ± 0.22
	Mic	$89.1^{b} \pm 0.48$	2.42 ± 0.15	0.38 ± 0.04	1.96 ± 0.08	3.64 ± 0.11
"*F*" ratio		8.880*	2.594ns	1.982ns	2.371ns	—
Kilkeerai	Raw	91.0 ± 0.78	2.39 ± 0.37	0.29 ± 0.09	1.75 ± 0.04	3.65 ± 0.56
	Con	90.4 ± 0.31	2.63 ± 0.38	0.37 ± 0.09	1.77 ± 0.03	3.85 ± 0.09
	Pre	90.5 ± 0.77	2.42 ± 0.52	0.42 ± 0.06	1.65 ± 0.02	3.68 ± 0.66
	Mic	90.3 ± 0.53	2.48 ± 0.64	0.37 ± 0.09	1.77 ± 0.00	3.71 ± 0.42
"*F*" ratio		1.025ns	0.178ns	1.335ns	1.957ns	—
Shepu	Raw	90.4 ± 1.26	2.60 ± 0.36	0.47 ± 0.01	1.62 ± 0.14	3.42 ± 0.19
	Con	89.5 ± 0.94	2.71 ± 0.24	0.42 ± 0.02	1.74 ± 0.07	3.51 ± 0.28
	Pre	90.8 ± 2.41	2.51 ± 0.56	0.49 ± 0.01	1.53 ± 0.25	3.45 ± 0.06
	Mic	88.3 ± 2.29	2.92 ± 0.10	0.55 ± 0.03	1.63 ± 0.47	4.06 ± 1.13
"*F*" ratio		1.465ns	0.225ns	2.174ns	0.432ns	—
Spinach	Raw	$94.7^{a} \pm 0.10$	1.51 ± 0.03	$0.17^{a} \pm 1.25$	1.25 ± 0.08	1.87 ± 0.19
	Con	$92.6^{b} \pm 1.88$	2.17 ± 0.69	$0.40^{b} \pm 4.60$	1.59 ± 0.38	2.23 ± 0.39
	Pre	$93.3^{b} \pm 0.23$	2.05 ± 0.02	$0.40^{b} \pm 0.11$	1.29 ± 0.05	2.24 ± 0.16
	Mic	$93.0^{b} \pm 0.14$	1.92 ± 0.24	$0.39^{b} \pm 3.55$	1.45 ± 0.04	2.30 ± 0.16
"*F*" ratio	—	3.749*	2.410ns	13.316*	2.409ns	—

Values represent mean ± SD of duplicate determination of two separate batches.
Values with different superscripts in a column (for a specific vegetable) are significantly different.
ns—not significant; *—$p \leq 0.05$.
Con—conventionally cooked; Pre—pressure cooked; Mic—microwave cooked.

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amaranth, and kilkeerai were similar with slightly lower moisture content compared to spinach. Noble and Hanig[20] showed that moisture content of spinach varied with lots i.e., from around 87.7–90.1%. Cooking of green leafy vegetables in general resulted in moisture loss. It was however, significant ($p \leq 0.05$) only between the raw and the microwave cooked spinach and amaranth. The overall comparison of greens showed that microwave cooked samples lost 10–12% more moisture. Klein et al.[21] and Kylen et al.[19] have also reported weight loss in microwave cooked and conventionally cooked spinach. The protein content of the raw greens was almost similar in amaranth, kilkeerai, and shepu (2.12–2.60 g per 100 g) with spinach containing least amount (1.51 g per 100 g). Cooking caused an insignificant ($P \geq 0.05$) increase in the protein content of all the greens which was due to greater moisture loss. The ether extract of raw greens (Table 2) ranged from 0.17 g in spinach to 0.47 g in shepu. Amaranth and kilkeerai had intermediate amount of 0.35 and 0.29 g respectively. Gopalan et al.[22] also reported a large variation in the ether extracts of amaranth tender, which ranged from 0.5 to 2.69% in dry matter. Comparison between the ether extracts of raw and cooked sample showed that the cooked samples had greater amounts of ether extract. This increase may be due to greater extractability on cooking of not only fat but also certain other fat-soluble substances such as pigments.[23] The total dietary fiber (TDF), content of raw greens ranged from 1.87 to 3.72 g. TDF content of spinach by Uppsala method A (2.2 g/100 g fresh) and AOAC, enzymatic method (2.6 g/100 g fresh) however, has been reported to be greater.[24] Cooking caused an insignificant increase in the TDF content of all greens except pressure cooked kilkeerai and shepu. The slight increase in the fiber content may probably be due to hydration or polymerization of its fractions.[25] The total ash content of greens varied to a less extent ranging from 1.25 to 1.81 g (Table 2). Neither cooking nor the different cooking methods caused any significant difference in mineral content probably due to their greater stability. However, an insignificant loss in pressure cooked samples may be due to the soluble mineral salts of phosphorus, potassium, sodium, or iron.[2]

The minerals and vitamins analyzed were calcium, phosphorus, iron, ionizable iron, and ascorbic acid and β-carotene respectively. The results for 100 g of edible portion are presented in Table 3, which show that among minerals, calcium content varied to a large extent i.e., from 38–55 mg in spinach to 182–195 mg in amaranth. Significant increase in the calcium content of cooked samples of spinach was due to greater moisture loss on cooking. The phosphorus content of the raw and cooked greens was as follows: kilkeerai—60–68 mg followed by amaranth and shepu—40–53 mg, and spinach—26–32 mg/100 g. The values reported by Gopalan et al.[22] for raw spinach and shepu were comparable. The total iron content of raw greens ranged from 3.0 mg in shepu to 8.7 mg in amaranth. The values obtained in the present study are lower than those reported by Gopalan et al.[22] and higher than those reported by Chawla et al.[26] The iron content of greens is however, known to be influenced due to soil fortification,[27] growth conditions, difference in variety or species.[28] Cooking caused a significant difference ($p \leq 0.05$) only in the total iron content of shepu. Calculation on dry basis showed that this difference was only due to low moisture content in cooked shepu. Raw greens contained significantly ($p \leq 0.05$) greater amounts of ionizable iron than the respective cooked ones.

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Table 3. Minerals, ascorbic acid, and β-carotene content of green leafy vegetables (mg/100 g edible portion, wet basis).

Vegetable	Variation	Calcium	Phosphorus	Iron	Ionizable iron	In vitro available iron[1]	Ascorbic acid	β-carotene[2]
Amaranth	Raw	183 ± 15.54	45 ± 9.19	8.68 ± 1.71	2.45^{a} ± 0.09	1.20	37.3^{a} ± 4.81	10.96
	Con	195 ± 12.52	50 ± 12.15	8.87 ± 1.79	1.62^{b} ± 0.03	0.81	12.6^{b} ± 3.32	13.86
	Pre	190 ± 11.16	47 ± 13.30	7.84 ± 1.15	1.46^{bc} ± 0.14	0.73	7.9^{c} ± 0.39	19.17
	Mic	182 ± 29.26	53 ± 13.36	8.79 ± 2.41	1.89^{bd} ± 0.22	0.93	12.1^{b} ± 2.22	11.75
"*F*" ratio		0.619ns	0.357ns	0.271ns	37.810**	—	36.55*	—
Kilkeerai	Raw	192 ± 26.14	65 ± 12.70	5.92 ± 1.11	2.06^{a} ± 0.15	1.0	24.3 ± 11.1	14.30
	Con	201 ± 21.54	67 ± 16.74	5.67 ± 1.01	1.52^{a} ± 0.54	0.74	13.2 ± 6.4	14.23
	Pre	190 ± 21.91	60 ± 13.85	5.84 ± 1.05	1.08^{b} ± 0.26	0.54	8.0 ± 6.2	23.96
	Mic	209 ± 19.82	68 ± 14.73	5.96 ± 1.23	1.29^{a} ± 0.33	0.64	12.2 ± 9.6	23.51
"*F*" ratio		0.614 ns	0.237ns	0.052ns	5.866*	—	0.627ns	—
Shepu	Raw	113 ± 30.16	40^{a} ± 0.95	3.38^{a} ± 0.14	2.51^{a} ± 0.28	1.20	35.0 ± 15.2	21.01
	Con	106 ± 4.64	51^{b} ± 12.15	5.03^{b} ± 0.89	1.81^{ac} ± 0.06	0.87	18.9 ± 14.5	31.47
	Pre	109 ± 14.66	42^{a} ± 5.35	4.19^{b} ± 0.41	1.51^{bc} ± 0.14	0.72	20.6 ± 13.9	21.81
	Mic	137 ± 47.59	53^{b} ± 6.18	4.45^{b} ± 0.38	2.02^{a} ± 0.59	0.97	18.4 ± 11.3	31.67
"*F*" ratio		1.968 ns	3.151*	3.938*	3.313*	—	0.285ns	—
Spinach	Raw	38^{a} ± 4.96	26 ± 5.25	3.00 ± 0.53	2.00^{a} ± 0.49	0.96	9.4^{a} ± 0.50	3.57
	Con	55^{b} ± 4.23	32 ± 2.51	2.97 ± 0.75	1.11^{b} ± 0.35	0.55	0.46^{b} ± 0.08	6.54
	Pre	52^{b} ± 8.5	30 ± 8.68	2.69 ± 0.87	1.18^{b} ± 0.33	0.58	0.72^{b} ± 0.45	6.20
	Mic	53^{b} ± 7.14	30 ± 7.32	3.56 ± 4.43	1.36^{b} ± 0.44	0.66	0.52^{b} ± 0.16	5.18
"*F*" ratio		4.698*	0.677ns	1.77ns	3.938*	—	316.92***	—

Values represent mean ± SD of duplicate determination of two separate batches.
Values with different superscripts in a column (for a specific vegetable) are significantly different.
ns—not significant; *—$p \leq 0.05$; **—$p \leq 0.01$; ***—$p \leq 0.001$.
Con—conventionally cooked; Pre—pressure cooked; Mic—microwave cooked.
[1]Values calculated from ionizable iron as suggested by Rao and Prabhavathi.[14]
[2]Values are of duplicate samples of one batch.

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Cooking methods on the whole caused a loss of around 20–48% of ionizable iron. The in vitro available iron was derived as suggested by Rao and Prabhavathi.[14] The percent in vitro availability of iron from cooked greens was in the range of 9–14%. The availability from shepu and amaranth was greater than those reported by Chawla et al.[26] and Rao and Prabhavathi[14] respectively. Hence, from the above studies it may be concluded that the iron availability from greens depend on many other factors such as presence of oxalates, phytate, fiber or polyphenols[26] and the total iron content alone cannot form the basis to consider a particular green leafy vegetable to be a rich source of iron. The ascorbic acid content of the raw green ranged from 9.4–37.0 mg. Cooking irrespective of the method caused considerable loss of ascorbic acid in all greens. The extent of loss however varied with the greens. The percent loss was least in shepu with 41–47% and highest in spinach with 92–95%. The extent of loss however was similar in conventionally and microwave cooked greens. The β-carotene content of the raw greens ranged from as low as 3.57 mg in spinach to 21.0 mg in shepu (Table 3). Amaranth and kilkeerai were similar with 11 and 14 mg respectively. Comparable values for amaranth and spinach has been reported by Bhaskarachary et al.[29] and Granado et al.[30] Comparison between the cooked and the raw greens revealed that cooking caused considerable increase in all samples. The percent increase ranged from 7 to 38% on wet basis. Calculations on dry basis to eliminate the differences due to moisture showed that the extent of increase ranged from 8–68%. Increase in the carotene content of cooked samples has been reported by Granado et al.[30] and Park et al.[31] and they attributed this to increased extractability on cooking and/or due to destruction of enzymes which otherwise caused carotene degradation. Ang et al.[32] and Eheart and Gott[18] however, reported an insignificant loss of carotene due to microwave and conventional cooking.

The sensory attributes of cooked greens were analyzed using ranking test and QDA. The attributes analyzed were color, appearance, aroma, taste, and texture. The results of ranking test and QDA are presented in Table 4 and Fig. 1 respectively. The results of these tests indicate that color was the only attribute that was affected to a significant extent ($p \leq 0.05$). Comparison between conventional and microwave methods showed that in case of amaranth and shepu, color of microwave cooked greens was preferred more than conventional and the reverse was true for kilkeerai and spinach, however they were not statistically significant. The color of the pressure cooked amaranth, kilkeerai, and shepu had the highest ranking and low mean scores which showed that the color of the greens that resulted due to this cooking method was liked the least. The reason for this obviously is the change in the color from green to olive green due to the formation of pheophytin. The high temperature attained in pressure cooking (121°C), the time taken for cooking and inability of volatile acids to escape are probably the factors that has lead to increased formation of pheophytin. Aroma of all the cooked samples were similar in amaranth whereas in shepu and spinach the pressure cooked samples were considered relatively inferior and that of conventionally cooked and microwave cooked were similar. The difference in the aroma of the greens however was not statistically significant. Texture of pressure cooked kilkeerai and shepu had a lower ranking but was not statistically significant and was followed by similar rankings of conventionally cooked and microwave cooked samples. In case of amaranth and shepu the texture

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Table 4. Result of rank sum analysis.

Attributes	No. of panelists[a]	Total of ranks marked		
		Con	Pre	Mic
Amaranth				
Color	19	35.0	48.0[b]	29.0
Aroma	17	33.0	36.0	33.0
Texture	18	32.5	34.0	41.5
Overall quality	20	37.0	46.5	36.5
Kilkeerai				
Color	18	30.5	45.0[b]	32.5
Aroma	18	25.5	36.0	40.5[b]
Texture	18	34.5	29.0	35.0
Overall quality	18	33.0	35.0	40.0
Shepu				
Color	20	38.5	50.5[b]	31.0
Aroma	16	29.5	39.0	27.5
Texture	19	38.5	30.5	35.0
Overall quality	19	33.5	45.5	35.0
Spinach				
Color	20	29.0[b]	38.0	41.0
Aroma	18	30.0	42.0	36.0
Texture	19	27.0	40.0	37.0
Overall quality	20	29.0[b]	33.5	35.5

Con—conventionally cooked; Pre—pressure cooked; Mic—microwave cooked.
[a]Variation in no. of panelists is due to editing.
[b]Significantly different at 5% level.

of conventionally cooked sample was considered to be better and was followed by pressure cooked amaranth and microwave cooked spinach. Taste of microwave cooked amaranth was considered best. In kilkeerai, taste and overall quality of all the three different cooked samples were similar. The taste of shepu was acceptable to a lesser extent when compared with the other greens. However, the taste of microwave cooked shepu (Fig. 1c) was considered better among the three. In spinach, the taste and overall quality was considered to be better in conventionally cooked sample. Eheart and Gott[18] and Kylen et al.[19] showed that the conventional cooking and microwave cooking had similar effect on the sensory attributes of spinach. Klein et al.[21] however reported that total palatability of microwave cooked spinach was significantly ($p \leq 0.05$) better than conventionally cooked.

CONCLUSION

It can be concluded that while cooking methods do not influence the nutritional composition of green leafy vegetables to a significant extent, they do affect the

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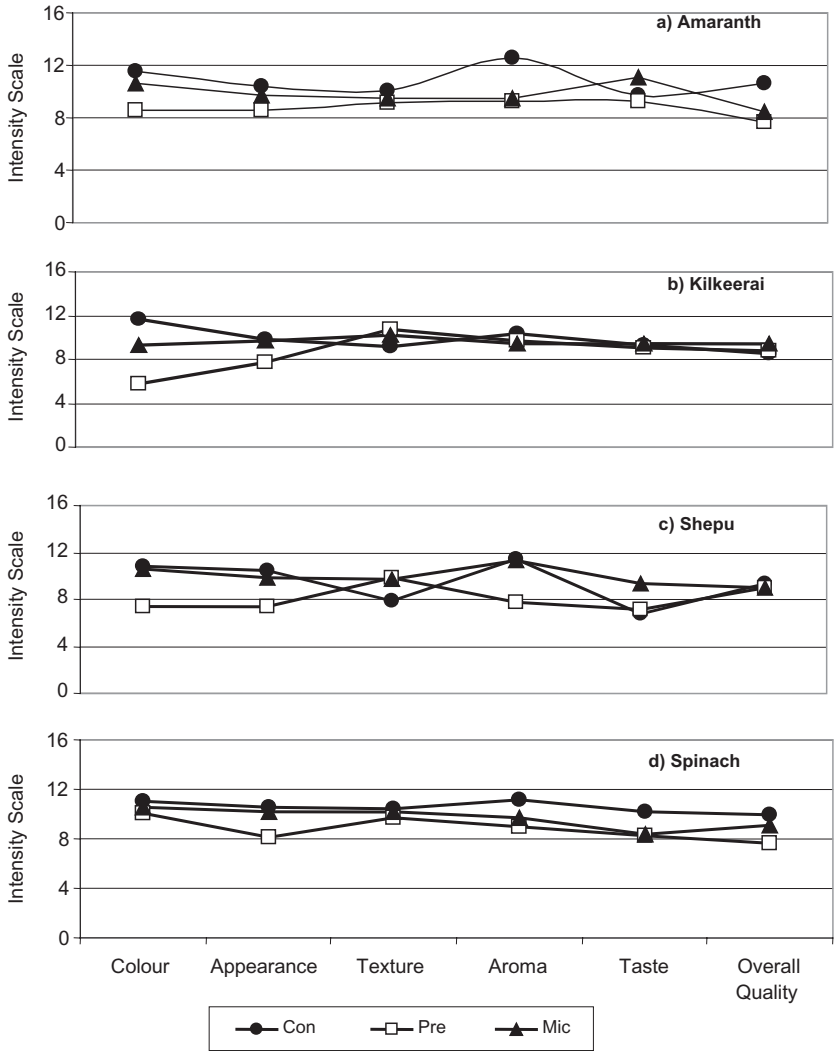

Figure 1. Mean scores of profile test of cooked greens (Con—conventionally cooked, Pre—pressure cooked, Mic—microwave cooked).

sensory quality. Microwave cooking was found to be similar to conventional method whereas pressure cooking affected certain sensory parameters of green leafy vegetables.

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