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Research Article

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Influence of Pressure-Cooking Parameters on the Color, Texture, Nutrient Composition, Antioxidant Capacity, Flavor and Sensory Profile of Drumstick (*Moringa oleifera*)

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Abstract

Our country's rich culinary culture has allowed us to enjoy a variety of vegetables and fruits, resulting in several health benefits. Drumstick, also known as *Moringa oleifera*, is a remarkable vegetable that is highly regarded and piques our curiosity. Therefore, the aim of the present study focused mainly on the effects of pressure cooking on the physicochemical, nutritional, antioxidant, flavor, and sensory profiles of drumsticks. The drumstick-water ratio and the amount of salt used during pressure cooking varied. The total phenol content and DPPH activity of pressure-cooked drumsticks ranged from 0.29–0.48 mg GAE/g and 31.76–56.70%, respectively. The flavor profiles consisted of 9 aldehydes, 2 alcohols, 5 organic compounds, 2 sulfur compounds, and ketones. Additionally, the phytonutrients identified by /MS were n-hexadecanoic acid, d-glucitol, 1-S-heptyl-1-thio-, benzeneacetonitrile, 4-hydroxy-, benzeneacetonitrile, 3-hydroxy-, and d-glucitol and 1-S-heptyl-1-thio-. Treatment T3 resulted in a high sensory score, whereas T9 resulted in a poor sensory score. Hierarchical cluster analysis supported the sensory results with nutrient components and grouped the treatments into four groups: Raw, A (T1-T4), B (T5 & T8), C (T9), and D (T6 & T7). The principal component analysis categorized all 19 data sets of treatments into four principal components. The results of this study reveal that the drumstick-water ratio and salt content during pressure cooking have no significant effect on any of the other parameters except vitamin C.

***Keywords*:** Pressure cooking; Drumstick; Bioactives; Sensory attributes; Principal component analysis.

1. Introduction

Drumstick is a more delicious vegetable in Indian cuisine and has a unique flavor. It is used for preparing dhal and fish curries. The drumstick contains 3.70 g of carbohydrates, 0.10 g of fat, 4.80 g of total fiber, and 2.50 g of protein. It is rich in minerals, namely, magnesium (24.00 mg), phosphorus (110.00 mg), calcium (30.00 mg), iron (5.30 mg), and potassium (259.00 mg).[1] Drumstick is a nutrient-rich vegetable that contains bioactive compounds, including flavonoids, phenolic compounds, phytochemicals, and volatile constituents, which contribute to its characteristic flavor and nutritional properties. These components appear, disappear, reappear, and transform during cooking because of the heat, water content, and ingredients used. Decreases in primary volatile compounds and the emergence of bioactive isothiocyanates in Brassica vegetable cultivars were observed during cooking.[2] The changes in bioactive compounds, phytochemicals, and volatile compounds are due to oxidation, heat degradation, leaching, emergence, and transformation of phytochemicals available in the products.[3,4] Cooking affects the biological, physical, and chemical composition of foods.[3,5]

Cooking methods such as boiling, pressure cooking, microwave cooking, and oil frying, as well as cooking conditions such as temperature, time, and with/without water, with/without oil, and the addition of salt and spices, have greater effects on the quality of vegetables. Cooking methods influence the total phenol content, flavonoid content, condensed tannin content, and DPPH activity of bottle gourd.[6,7]

Conventional, pressure, and microwave methods of cooking green leafy vegetables did not significantly affect nutrient content, whereas they did significantly affect ascorbic acid and β-carotene.[8] Similarly, appreciable differences were not detected in the protein, fat, total ash, calcium, phosphorus, iron, or dietary fiber of either raw or cooked beans (*Phaseolus vulgaris* var. *vulgaris*), brinjal (*Solanum melongena* var. *esculentum*), knol-khol (*Brassica oleracea* var. *caulorapa*), or radish (*Raphanus raphanistrum* subsp. *sativus*).[9] Ingredients and methods of preparation lead to significant changes in the nutritional and sensory properties of pureed products and the loss of enzyme cofactors in Brassica vegetables.[5,10] Among the cooking methods, pressure cooking takes less time, followed by microwave cooking and conventional cooking.[8]

Although the drumstick is among the important vegetables in Indian cuisine, culinary studies on drumstick have been almost nil. Studies on the shelf life of retort-processed drumsticks; the color, total flavonoids, antioxidants, frictional, mechanical, and cutting forces of drumstick pods; and the textural properties of pressure-cooked moringa have been reported.[11,12] In this study, the effects of pressure-cooking conditions on the color, nutrient composition, antioxidant capacity, flavor, and sensory scores of drumsticks were evaluated, and variations were analyzed using hierarchical cluster analysis (HCA) and principal component analysis (PCA).

2. Materials and methodology

2.1 Materials and sample preparation

The PKM-1 variety of drumstick was procured from a local market in Thanjavur, Tamil Nadu, India. Potable water and table salt (NaCl, an ionic compound used to enhance taste) were used for cooking. Laboratory-grade chemicals used for analysis were Folin–Ciocalteu's phenol reagent (RM10822), gallic acid monohydrate (GRM233), 2,2-diphenyl-1-picrylhydrazyl (DPPH; RM2798), L-ascorbic acid (CMS1014), 2,6-dichlorophenolindophenol sodium salt dihydrate (RM350), sodium carbonate anhydrous (GRM851), sodium hydrogen carbonate (GRM3955), oxalic acid dihydrate (GRM694), methanol (AS059; HPLC grade, AS061), sulfuric acid (AS016), potassium sulphate (GRM1403), copper(II) sulphate (GRM6391), sodium hydroxide (GRM467), boric acid (GRM1224), hydrochloric acid (AS004), methyl red (GRM121), bromocresol green (GRM118), petroleum ether 40–60 °C (AS063) and nitric acid (AS009) were purchased from HiMedia Laboratories Pvt. Ltd. (Mumbai, India).

2.2 Drumstick pressure cooking

The drumstick was cleaned, washed, cut into chewable pieces (4.5 cm), and cooked using a pressure cooker. The drumstick-to-water ratio was varied from 1:0.5 to 1:2 (g/mL), while the amount of salt ranged from 1.5 to 2.5 g. The treatments were Raw, T1 (1:0.5 & 1.5), T2 (1:0.5 & 2.0), T3 (1:0.5 & 2.5), T4 (1:1 & 1.5), T5 (1:1 & 2.0), T6 (1:1 & 2.5), T7 (1:2 & 1.5), T8 (1:2 & 2.0), and T9 (1:2 & 2.5). The cooking pressure and time were maintained at 2 psi and 10 min, respectively, for all the treatments. The cooked drumstick samples were cooled and used for color, texture, volatile compound, and sensory analyses. A portion of each sample was shadow-dried, powdered, and used for nutritional analysis.

2.3 Estimation of color of pressure-cooked drumstick

The color parameters were measured using a Hunter Lab ColorFlex EZ spectrophotometer.[11] The measurements were performed using the CIELAB color system under a D65 illuminant and a 10° standard observer. The total color difference (ΔE*) was calculated using the following equation (Eqn. 1):

$$\Delta E^* = \sqrt{(\Delta L^{*2} + \Delta a^{*2} + \Delta b^{*2})} \quad (1)$$

where ΔL* is (L*sample - L*standard), Δa* is (a*sample - a*standard) and Δb* is (b*sample - b*standard).

2.4 Estimation of the texture profile analysis of the pressure-cooked drumstick

The texture profile analysis (TPA) was carried out using a texture analyzer (Stable Micro Systems TA.HDplus). A two-bite compression test was performed using a flat cylindrical plunger probe (P/75, 75 mm diameter). The operating conditions included a pre-test speed of 1.00 mm/s, a post-test speed of 2.00 mm/s, a strain of 5%, and two compression cycles.[13] The texture parameters, including hardness, cohesiveness, springiness, gumminess, and chewiness, were determined from the

force–time curves. Hardness is expressed in N, whereas cohesiveness is reported as a dimensionless ratio.

2.5. Estimation of nutrient composition of pressure-cooked drumsticks

The moisture, crude protein, carbohydrate, fat, crude fiber, and ash contents of the drumstick were estimated by modified AOAC methods.[14,15] The vitamin C content was estimated by the volumetric method using the dye solution technique.[16] The iron content was estimated by the AOAC method using ICP-OES, and the emission intensity and concentration were recorded.[17] The amount of vitamin C and iron content were calculated using the formulas (Eqn. 2) and (Eqn. 3), respectively.

$$\text{Vitamin C, \%} = \frac{0.5\ \text{mg}}{V_1\ \text{mL}} \times \frac{V_2}{5\ \text{mL}} \times \frac{D \times 10}{W} \times 100 \quad (2)$$

$$\text{Iron content, mg/L} = \frac{C_e \times V_e \times D}{W} \quad (3)$$

where V1 is the volume of the dye consumed for standard vitamin C, mL; V2 is the average volume of dye consumed for the sample, mL; Ce is the analyte concentration in the final extract, µg/L; Ve is the final sample extract volume, mL; D is the dilution factor (Diluted volume/aliquot volume); and W is the sample weight, g.

2.6. Estimation of the total phenolic content of pressure-cooked drumsticks

The total phenolic content (TPC) was determined using the Folin–Ciocalteu method described by Golla *et al*., with slight modifications.[11] Briefly, 200 mg of the sample was mixed with 4 mL of methanol and vortexed for 5 min. The mixture was then incubated in an incubator and shaken for 2 h. Following the incubation, the mixture was centrifuged at 10,000 rpm for 5 min, and the resulting supernatant was collected in a centrifuge tube, covered with aluminum foil, and stored at 4°C until further analysis.

A gallic acid working standard solution (1 mg/mL) was prepared from the gallic acid stock solution. Working standards ranging from 0.1 to 0.5 mg/mL were prepared at 0.1 mg/mL intervals. For the analysis, 1 mL of the sample supernatant was transferred into a test tube, followed by the addition of 4 mL of 7.5% sodium carbonate solution, 1.5 mL of Folin–Ciocalteu reagent, and 1 mL of distilled water. The reaction mixture was thoroughly mixed and allowed to stand for 30 min at room temperature for color development. The absorbance was measured at 765 nm using a spectrophotometer. A calibration curve was prepared using the gallic acid working standards, and the coefficient of determination (R^2) was 0.991. The TPC of the samples was determined by extrapolation from the calibration curve and expressed as mg gallic acid equivalents (GAE) per g of sample.

2.7. Estimation of 2,2-diphenyl-1-picrylhydrazyl (DPPH) activity of pressure-cooked drumsticks

The DPPH radical-scavenging activity was estimated using the spectrophotometric method described by Golla *et al*, with slight modifications.[11] A 0.1 mM solution of DPPH was prepared in ethanol. One milliliter of the DPPH solution was added to 3 mg of sample prepared in ethanol at different concentrations (10, 30, and 50 µg/mL). The mixtures were allowed to stand at room temperature for 30 min, after which the absorbance was measured at 517 nm using a spectrophotometer. Vitamin C was used as the reference standard compound. The DPPH radical-scavenging activity was calculated using the following equation (Eqn. 4):

$$\text{DPPH radical-scavenging activity (\%)} = [(A_0 - A_i)/A_0] \times 100 \quad (4)$$

where A_0 is the absorbance of the control (in the absence of the sample/scavenger) and A_i is the absorbance of the sample. The absorbance measurements were recorded at 517 nm.

2.8. Screening of phytonutrients in pressure-cooked drumsticks

The phytonutrients were screened using a TSQ 9000 Triple Quadrupole GC-MS/MS system. The sample was extracted with methanol, and 1 µL of the extract was injected in split mode at a split ratio of 10:1. The sample was separated using a Trace GOLD™ TG-5MS capillary column (30 m × 0.25 mm ID × 1.4 µm film thickness). Helium was used as the carrier gas at a flow rate of 1 mL/min. The oven temperature was initially set at 110°C and held for 3.5 min, followed by an increase to 200°C at a rate of 10°C/min. The temperature was then increased to 280°C at a rate of 5°C/min and held at that temperature for 12 min. The injector temperature was maintained at 280°C. The total GC run time was approximately 45–50 min. The NIST 2011 library was used for the identification of the detected compounds. The inlet temperature, ion source temperature, and electron ionization energy were 290°C, 250°C, and 70 eV, respectively. Mass spectra were acquired over a scan range of m/z 50–500. The total MS acquisition time was approximately 40–50 min, with a solvent delay of 0–3.5 min.

2.9 Determination of volatile compounds in pressure-cooked drumsticks

The volatile profiles were determined using a HERACLES GC Flash electronic nose (AlphaMos, France).[18] Two grams of sample were placed in a 20-mL glass vial and sealed with a septum and cap. The sample vials were incubated in a shaker oven at 50°C and 500 rpm for 30 minutes. Afterward, an automatic headspace sampler draws the flavor from the head space and injects it. The column, injection, and detector temperatures were 40, 180, and 220°C, respectively. FID detected the signals at 0.01 s. Kovats indices were used to identify volatile compounds from AroChemBase software.

2.10 Sensory profile analysis of pressure-cooked drumsticks

Sensory profile analysis was carried out using a 9-point hedonic scale test.[19] Thirty panelists aged 21–48 years were selected, and their color, texture, aroma, taste,

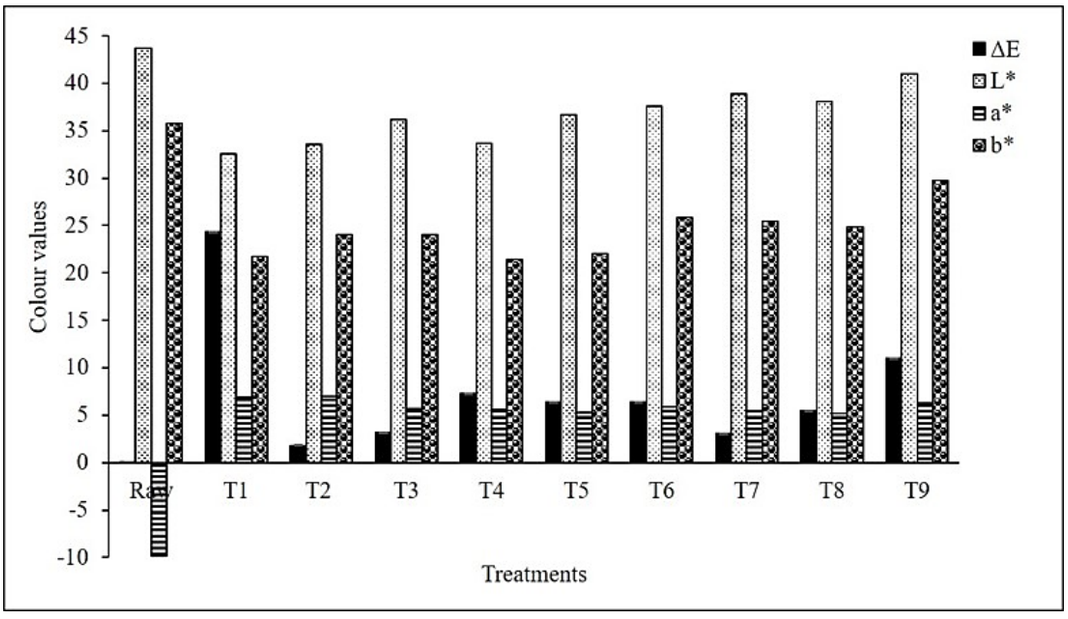


Fig. 1: Color values of the raw and pressure-cooked drumstick: The drumstick-to-water ratio (g/mL) and salt level (g) were varied. The treatments were Raw (uncooked control) and T1–T9: T1–T3 (1:0.5; 1.5, 2.0, and 2.5 g salt), T4–T6 (1:1; 1.5, 2.0, and 2.5 g salt), and T7–T9 (1:2; 1.5, 2.0, and 2.5 g salt), respectively.

overall acceptability, and mouthfeel were evaluated.

2.11 Statistical analysis

All measurements were performed in triplicate, and the results are expressed as the mean ± SD. Tukey's test was used to determine significant differences among treatments at $P < 0.05$. Hierarchical cluster analysis (HCA) was performed using the cophenetic coefficient, and a dendrogram was generated using Ward's method. Principal component analysis (PCA) was performed to classify the pressure-cooked drumstick samples on the basis of their sensory scores using MATLAB R2020.[20]

3. Results and discussion

3.1 Color of the pressure-cooked drumstick

The variation in the color values of the drumsticks was not significant ($p > 0.05$) (Fig. 1). The total color difference ΔE* was between 0.07 and 24.54. The lightness and a* and b* values decreased with increasing water and salt contents, whereas the ΔE* value increased. The T1 sample had the highest ΔE value (24.54), and sample T2 had the lowest ΔE value (2.5). Compared with the raw drumstick samples, all the pressure-cooked samples had higher ΔE* values. ΔE* decreased with increasing water and salt content. Sample T1 retained its green color after pressure cooking, whereas sample T2 turned brown because of charring because of insufficient water level and high salt concentration. Changes in color might be due to the leaching of pigments. No significant differences in color were observed between boiled and steamed parsnip and Jerusalem artichoke, whereas the color of boiled and steamed beetroot samples significantly differed.[21]

3.2 Analysis of the texture profile of the pressure-cooked drumstick

The texture profile of the drumstick samples did not significantly differ ($p > 0.05$) among the treatments. The texture profile results have been previously reported by the authors; however, the data were further used for hierarchical cluster analysis (HCA) and principal component analysis (PCA) in the present study.[12] The hardness of the drumstick samples ranged from 1.56 to 19.11 N. The cohesiveness ranged from 1.46 to 8.93 and was expressed as a dimensionless parameter. Springiness values ranged from 0.998 to 1.00 mm. The highest chewiness value was observed in the raw sample (28.12 N), whereas the lowest value was observed in T9 (4.00 N). Chewiness was expressed in N according to the instrument/software output.

3.3 Nutritional composition of pressure-cooked drumstick

The pressure-cooking factors had no significant ($p > 0.05$) effect on nutritional composition (Table 1). The carbohydrate content ranged from 78.27 to 84.24%. The raw drumstick contained 76.50% carbohydrate. The T9 and T2 samples had the highest (84.24%) and lowest (78.27%) carbohydrate contents, respectively. The carbohydrate content of pressure-cooked drumsticks was higher than that of raw drumsticks. This might be due to the leaching out of polysaccharides and bound carbohydrates from the ruptured drumstick cells and to increasing digestible starch in the drumstick during cooking. The carbohydrate content of mushrooms, such as Jerusalem parsnip and artichokes, increased with different cooking methods.[21,22] The total carbohydrate content in vegetables increases during boiling and steaming because of the leaching of soluble metabolites and the availability of insoluble cell wall polysaccharides upon thermal treatment.[21]

The crude protein content of the drumstick samples ranged from 14.00 to 18.81%, whereas that of the raw sample ranged from 19.03%. Among the pressure-cooked treatments, T3 and T4 resulted in the highest crude protein content (18.81%), whereas T9 resulted in the

lowest value (14.00%). Overall, compared with the raw sample, pressure cooking resulted in a slight reduction in crude protein. This reduction may be associated with the migration of soluble nitrogenous compounds into the cooking medium under the combined influence of heat, pressure, and moisture. Similar losses of nitrogenous components during boiling have been reported in mushrooms.[22]

The crude fat content ranged from 0.75 to 1.75% in the pressure-cooked drumstick samples, whereas it ranged from 2.00% in the raw sample. T4 and T7 presented the highest fat content (1.75%), whereas T9 presented the lowest (0.75%). The observed reduction in fat content following pressure cooking may be related to the redistribution or loss of soluble components during cooking. Similarly, changes in fat content have been reported in mushrooms subjected to microwave and boiling treatments.[22]

The crude fiber content of the pressure-cooked drumstick samples ranged from 69.25 to 76.50%, whereas that of the raw sample was 78.00%. T9 resulted in the highest crude fiber content (76.50%), whereas T7 resulted in the lowest (69.25%). Similar increases in the measured crude fiber content following pressure cooking and boiling have been reported for cowpea pods.[23]

The ash content of the pressure-cooked drumstick samples ranged from 0.25 to 1.65%, whereas that of the raw sample ranged from 2.21%. T8 and T2 presented the highest (1.65%) and lowest (0.25%) ash contents, respectively. Overall, a reduction in ash content was observed after pressure cooking, which may be attributed to the leaching of mineral components into the cooking medium. A comparable reduction in ash content was reported in pressure-cooked cowpea pods compared with raw samples, whereas no significant changes were observed in the ash content of sweet potatoes subjected to different cooking methods.[23,24]

3.4 Vitamin C content of pressure-cooked drumstick

The pressure cooking and cooking parameters significantly ($p < 0.05$) affected the vitamin C content (Table 1). The vitamin content of pressure-cooked drumsticks varied from 74.89% to 143.72%, and that of raw drumsticks was 181.22%. Treatment T2 resulted in the highest vitamin content (143.72%), whereas the lowest vitamin content (74.89%) was observed in T9 (1:2-2.5). The decrease in vitamin C occurred because of the water solubility of vitamin C. Compared with fresh-cut materials, microwave heating and steaming did not cause any significant loss of vitamin C in red cabbage, but stir-frying and boiling caused a significant reduction.[25] The greatest decrease in vitamin C in Brassica spp. was observed after boiling.[15]

3.5 Iron content of the pressure-cooked drumstick

The pressure-cooking factors did not significantly affect the Fe content of the drumsticks ($p > 0.05$) (Table 1). The iron content of pressure-cooked drumsticks ranged from 21.31 to 62.58 mg/L, whereas the iron content of the raw drumstick was 39.06 mg/L (Table 1). An iron concentration of approximately 62.58 mg/L was observed in T1 (1:0.5–1.5), and the lowest iron concentration of 21.3 mg/L was observed in T9 (1:2–2.5).

Table 1: Nutritional composition of raw and pressure-cooked drumsticks

Treat	Carbohydrates	Crude Fat	Crude Protein	Crude Fiber	Ash	Vitamin C	Iron	TPC	DPPH activity
Raw	76.76± 0.36a	2.00± 0.71a	19.03 ± 0.31a	78.00 ± 2.12a	2.21± 0.04a	181.22 ± 10.04a	39.06± 0.97e	0.33+0.02a	50.05±1.30a
T1	80.27± 3.49a	1.50± 1.41a	17.72±1.55a bc	69.25 ± 1.77c	0.51±0.53 bc	137.54±11.6 6abc	62.57± 0.33a	0.49+0.03a b	48.81±2.34a b
T2	78.28± 1.74a	1.25± 1.06a	18.81± 0.62ab	71.25±1.0 6abc	1.66±0.06a b	143.72± 10.18ab	51.04± 0.07c	0.3+0.02ac	36.74±1.40a b
T3	83.94± 1.20a	1.50± 1.41a	14.00 ± 0.62c	70.75± 1.77bc	0.56±0.41 bc	137.54±29.1 2abc	36.72± 0.34f	0.33+0.01 bc	56.71±1.25b c
T4	82.53± 3.09a	1.75± 1.06a	14.88±1.24a bc	73.75±0.3 5abc	0.84±0.79 bc	124.97±10.2 6bcd	33.72± 0.47 g	0.47+0.04 bc	56.4±0.910b c
T5	80.28± 0.64a	1.25± 0.35a	17.72±0.31a bc	74.00±2.1 2abc	0.75±0.02 bc	99.93 ± 9.68bcde	36.52± 0.55f	0.35+0.02 bc	47.38±1.38a bc
T6	80.07± 0.44a	1.50± 0.71a	17.72±0.31a bc	73.25±2.4 7abc	0.71±0.04 bc	93.75 ±18.89cde	53.20± 0.23b	0.29+0.02a c	45.13±2.30a bc
T7	79.66± 1.32a	1.75± 1.06a	17.72±0.31a bc	69.25 ± 1.77c	0.87±0.05 bc	75.00 ± 18.88e	47.46± 0.47d	0.35+0.01a c	31.77±1.22a bc
T8	82.96± 3.08a	1.25± 0.35a	15.53±2.78a bc	70.75± 1.77bc	0.26± 0.06c	87.46 ± 10.43de	30.92± 0.27 h	0.42+0.01a c	43.22±1.33a bc
T9	84.24± 0.09a	0.75± 0.35a	14.44 ±0.62bc	76.5 ± 1.41ab	0.57±0.17 bc	74.88 ± 18.00e	21.31± 0.43i	0.28+0.01a c	49.25±2.33a bc

* Mean ± standard deviation of three treatment replications. Values in the same column with different letters are significantly different ($P<0.05$). The drumstick-to-water ratio (g/mL) and salt level (g) were varied. The treatments were Raw (uncooked control) and T1–T9: T1–T3 (1:0.5; 1.5, 2.0, and 2.5 g salt), T4–T6 (1:1; 1.5, 2.0, and 2.5 g salt), and T7–T9 (1:2; 1.5, 2.0, and 2.5 g salt), respectively.

Table 2: Phytochemical components in raw and pressure-cooked drumsticks

Name of the compound	Retention time					Peak area				
	RAW	T2	T3	T7	T9	RAW	T2	T3	T7	T9
Thymine	3.38	3.883	3.893	3.83	3.38	3.15	4.81	5.81	3.76	4.12
4-Amino-1,5-pentandioic acid	*	*	*	*	4.25	*	*	*	*	1.39
4H-Pyran-4-one, 2,3-dihydro-3,5-dihydroxy-6-methyl-	4.45	4.9	4.887	4.864	4.45	5.45	5.07	4.41	3.33	4.27
5-Methoxypyrrolidin-2-one	4.91	*	*	*	4.91	5.2	*	*	*	0.97
5-Hydroxymethylfurfural	*	6.101	6.13	*	*	*	3.66	7.99	*	*
Methyl 3-hydroxytetradecanoate	6	6.318	6.335	6.301	6	3.06	1.31	1.89	2.06	4.56
Methyl 6-oxoheptanoate	6.67	6.83	*	*	6.67	10.45	0.25			7.77
2-Propyl-tetrahydropyran-3-ol	*	*	*	6.857	*	*	*	*	1.78	
2-(2-Hydroxy-2-methyl-4-phenyl-but-3-ynylamino) hexanoic acid	*	7.485	*	*	*	*	1.08	*	*	*
á-D-Glucopyranose,4-O-á-Dgalactopyranosyl	7.59	*	*	*	7.59	1.77	*	*	*	1.31
Octadecanedioic acid	8.3	*	*	*	8.3	1.63	*	*	*	0.55
9-Hexadecenoic acid	8.46	*	*	*	*	0.84	*	*	*	*
Lactose	9.5	*	*	*	*	11.24	*	*	*	*
Benzeneacetonitrile, 3-hydroxy-	*	9.858	9.835	9.784	9.72	*	13.13	10.08	5.27	6.13
2,4-Di-tert-butylphenol	*	10.238	10.236	10.233	*	*	2.12	2.27	4.17	*
9-Octadecenoic acid (Z)-	11.23	*	*	*	11.23	1.48	*	*	*	0.57
Dodecanoic acid, 3-hydroxy	*	*	*	*	12.07	*	*	*	*	0.55
Quinic acid	*	*	*	11.68		*	*	*	2.31	*
Dodecanoic acid, 3-hydroxy-	*	*	*	*	13.21	*	*	*	*	1.39
(E)-4-(3-Hydroxyprop-1-en-1-yl)-2-methoxyphenol	*	13.053	*	13.044	13.06	*	0.65	*	1.23	0.8
Melezitose	14.37	*	*	*	*	1.56	*	*	*	*
n-Hexadecanoic acid	15.63	15.696	15.678	15.678	15.63	15.1	2.74	1.94	2.57	3.25
cis-Sinapyl alcohol	*	*	*	*	16.14		*	*	*	0.66
Linoleic acid ethyl ester	17.42	*	*	*	*	0.36	*	*	*	*
9,12-Octadecadienoic acid (Z,Z)-	17.94	*	18.073	18.07	17.94	9.14	*	1.29	1.69	1.78
9,12,15-Octadecatrienoic acid, (Z,Z,Z)-	18.03	18.191	18.176	18.176	18.03	17.89	3.43	2.92	4.79	4.21
Dienestrol, 2TMS derivative	*	21.478	21.482	*	*	*	1.25	2.86	*	*
3-(1,5-Dimethyl-hexyl)-3a,10,10,12b-tetramethyl-1,2,3,3a,4,	*	*	*	21.479	*	*	*	*	7.5	*
d-Glucitol, 1-S-heptyl-1-thio-	*	*	*	*	22.95	*	*	*	*	48.36
Dotriacontane	23.11	*	*	*	23.11	4.08	*	*	*	3.04
Hexadecanoic acid, 2-hydroxy-1-(hydroxymethyl)ethyl ester	*	23.544	23.536	23.53	*	*	1.01	1.62	1.71	*
Acetic acid, [(2,4,6-triethylbenzoyl)thio]-	*	*	24.41	*	*	*	*	1.73	*	*
β-l-Rhamnofuranoside, 5-O-acetyl-thio-octyl-	*	*	24.557	*	*	*	*	1.11	*	*
Heptacosane	25.91	*	*	*	25.91	7.6	*	*	*	4.33
9,12-Octadecadienoic acid (Z,Z)-, 2,3-dihydroxypropyl ester	*	26.087	26.083	26.078	*	*	1.78	2.22	1.92	*
Vitamin E	*	33.053	33.053	33.055	*	*	1.38	1.39	1.65	*

Campesterol	*	35.147	35.151	35.145	*	*	6.05	5.65	6.3	*
Stigmasterol	*	35.964	35.966	35.957	*	*	4.25	4.13	4.28	*
γ-Sitosterol	*	37.583	37.566	37.546	*	*	13.74	12.9	14.27	*
Betulin	*	39.866	*	*	*	*	1.67	*	*	*

* Not detected

The drumstick-to-water ratio (g/mL) and salt level (g) were varied. The treatments were Raw (uncooked control) and T1–T9: T1–T3 (1:0.5; 1.5, 2.0, and 2.5 g salt), T4–T6 (1:1; 1.5, 2.0, and 2.5 g salt), and T7–T9 (1:2; 1.5, 2.0, and 2.5 g salt), respectively.

Compared with the raw pods, the iron content of sample T1 was greater, but the iron content was lower in the other treatments. The increase in iron content might be due to iron being leached from the cooking vessel because the charred drumstick skins were stuck to the vessel. Compared with raw pods with longer cooking times, a significant reduction ($p < 0.05$) in the Fe content was detected in both the boiling and pressure cooking of cowpea pods.[23]

3.6 Total polyphenol content of the drumstick

The total polyphenol content ranged from 0.28 to 0.48 mg GAE/g in pressure-cooked drumsticks (Table 1). The drumstick-water ratio and table salt concentration did not significantly affect the total polyphenol content of pressure-cooked drumsticks ($p > 0.05$). The raw drumstick contains 0.32 mg GAE/g. The highest phenolic content (0.49 mg GAE/g) was observed in T1, and the lowest (0.28 mg GAE/g) was observed in T9. The increase in total phenols in vegetables is dependent on food matrices, time-temperature combinations, and heating conditions.[26] There were no significant differences in the total phenolic content of red cabbage between the steaming, microwave heating, and fresh-cut treatments; nonetheless, compared with the fresh-cut samples, the boiling and stir-frying treatments resulted in a significant decrease in the total phenolic content.[25]

3.7 DPPH activity of the pressure-cooked drumstick

The DPPH radical-scavenging activity of pressure-cooked drumsticks ranged from 31.77% to 56.70%, while the raw drumstick activity was 50.04% (Table 1). The highest (56.71%) and lowest (31.77%) DPPH activities were observed in T3 and T7, respectively, at the concentration used for the DPPH assay. All cooking methods increase the antioxidant activity of *Hericium erinaceus* (Lion's mane).[27] In contrast, a decrease in antioxidant activity was reported in Brussels sprouts following cooking.[10] The bioavailability of antioxidants varies depending on the nature of cooking.[25,29] The antioxidant cascade system plays a major role in preventing non-communicable diseases.

3.8 Phytochemical components of pressure-cooked drumstick

The major phytochemical components present in raw and pressure-cooked drumsticks are shown in Table 2. Cooking caused the appearance and disappearance of various phytonutrients. Antimicrobial compounds, fatty acids, methyl esters, aromatic compounds, organic compounds, and sugars were found on the drumstick. The peak areas of n-hexadecanoic acid, benzeneacetonitrile, 3-hydroxyl-; D-glucitol, 1-S-heptyl-1-thio-; methyl 6-oxoheptanoate; benzeneacetonitrile, 4-hydroxyl-; and 2,4-di-tert-butyl phenol were greater than those of the other compounds. These phytonutrients have anticancer, antimutagenic, antiaging, antibacterial, and antidiabetic properties. Drumstick peel extract has shown antibacterial, hemolytic, and photocatalytic activity.

The major fatty acids present in raw and pressure-cooked drumsticks were dodecanoic acid, 3-hydroxy; 9-hexadecenoic acid; linoleic acid ethyl ester; and 10-undecenoic acid, octyl ester. The fatty acids methyl 3-hydroxytetradecanoate, octadecanedioic acid, n-hexadecanoic acid, 9,12-octadecadienoic acid (Z, Z)- and 9,12,15-octadecatrienoicacid (Z, Z, Z)- were commonly present in both the raw and cooked pods. The methyl esters present were methyl 6-oxoheptanoate and 9-octadecenoic acid (Z)-. The major alcoholic compounds observed were (E)-4-(3-hydroxyprop-1-en-1-yl)-2-methoxyphenol and cis-sinapyl alcohol. The aromatic compounds were thymine and benzeneacetonitrile, 3-hydroxy-. Thymine was present in both raw and cooked drumsticks, whereas benzylacetonitrile, 3-hydroxy-, was seen only in cooked drumsticks. In addition to 5-hydroxymethylfurfural, 5-methoxypyrrolidin-2-one, and dotriacontane are common organic compounds. The major sugars found were α-D-glucopyranose, 4-O-á-D-galactopyranosyl, lactose, melezitose, DL-arabinose, d-mannose, and D-ribose. 4H-Pyran-4-one,2,3-dihydro-3,5-dihydroxy-6-methyl; d-Glucitol, 1-S-heptyl-1-thio-; 4-Amino-1,5-pentandioic acid; and Heptacosane were the other phytonutrients present in the raw and pressure-cooked drumstick pods. Phytochemicals play a major role in the alleviation of major kinds of lifestyle disorders, such as cancer, diabetes, cardiovascular diseases and obesity.[30]

3.9 Volatile components of the pressure-cooked drumstick

The 130 volatile compounds and corresponding flavor and taste characteristics (AlphaMos, France) are listed in Table 3. The esters, aldehydes, alcohols, ketones, organic compounds, aromatic compounds, sulfur compounds, and other volatile compounds found in the drumstick are associated with unique sensory properties and acceptance. Esters such as ethyl formate, isopropyl acetate, ethyl propanoate, bornyl acetate, ethyl acrylate, ethyl salicylate, benzyl phenyl acetate, and isopentyl

salicylate were found in drumsticks. These esters contribute to the sensory properties of cognac, sweet, rose, pine, winter green, and minty. Isopropyl acetate, ()-bornyl acetate, and ethyl salicylate were found in both raw and pressure-cooked drumsticks. Esterification of isopropanol and acetic acid releases isopropyl acetate and ()-bornyl acetate and a fruity odor. These esters are liquid in nature and are present in sweet-smelling foods.

Nine major aldehydes, viz. Acetaldehyde, propanal, 2-methylpropanal, ethyl formate, butanal, 3-methylbutanal, heptanal, hexanal and pentanal were found in both the raw and pressure-cooked drumsticks. These aldehydes contribute to the "green," "fresh," "floral," and "fruity" sensory properties of the raw and pressure-cooked drumstick pods.[2] The oxidation of aldehydes produces carboxylic acid during pressure cooking. The levels of hexanal, octanal, nonanal, and decanal increase in green beans during cooking because of enzymatic and nonenzymatic oxidation.[31] 3-Methylbutanal is derived from the amino acid leucine during the cooking process, and a wide range of aldehydes are generated by Strecker degradation.

Two major alcohols, namely, 2-propanol and n-butanol, were found in both raw and cooked drumsticks. 2-Propanol was commonly found in both raw and pressure-cooked drumsticks with a high peak area, whereas n-butanol was found only in raw drumsticks with a lower peak area. These alcohols contribute to the solvent, pungent, ethereal, nutty, earthy, musty, and woody sensory properties of the drumstick. n-Butanol is lost during pressure cooking, which might be due to heat degradation of alcoholic compounds. High loss of alcohols in pot-cooked green beans was observed.[31]

The ketones butan-2-one, 2,3-pentanedione, and pentan-2-one were found. 2,3-Pentanedione, also known as acetylpropionyl, is a flavoring agent released during pressure cooking. These ketones contribute to burnt, buttery, caramelized, grainy, malty, nutty, oily, and sickly sensory properties. Increased ketones during heat treatments, except for pressure cooking, were observed by Rodríguez-Bernaldo De Quirós *et al*., whereas the present study revealed an increase in ketones during pressure cooking.[31] This might be due to the minimal cooking time, temperature, and presence of salt.

Five major organic compounds, butane-2,3-dione, 1-propanol, 2-methyl-, 1S- ()-a-pinene, nonanoic acid, and phenylacetic acid, were observed. Among these compounds, butane-2,3-dione and nonanoic acid were commonly found in raw and treated drumsticks. These organic compounds contribute to alliaceous, fishy, meaty, and rotten food; onion, fusel, leek, licorice, unpleasant, chlorine, acidic, and bitter sensory properties.

Isobornyl acetate, hydroxycitronellal, citronellyl formate, and 2,4-decadienal were the four major aromatic compounds observed. They contribute to the herbal, lily of the valley, melon, tropical, waxy, leafy, citrus, fatty, orange, and tallowy sensory properties. Dimethyl sulfide and dimethyl trisulfide were the two major sulfur compounds present in both the raw and pressure-cooked drumsticks. Dimethyl trisulfide has alliaceous, cauliflower, cabbage, meaty, rotten food, onion, and fishy-like sensory properties.[31]

A trivial loss of volatiles was observed in some of the pressure-cooked drumstick samples from T1-T3, T5, T8, and T9, whereas slightly increased volatile compounds were observed in T4, T6, and T7. This might be due to alterations in the chemical compounds present in the drumstick during pressure cooking. Ravi *et al*. reported that the number of volatile compounds in sweet potato increased after cooking.[18]

3.10 Sensory scores of pressure-cooked drumsticks

In terms of the sensory scores (Fig. 2), T3 had the highest scores for all the sensory factors, whereas T9 had low scores. The sensory scores of the sensory parameters did not significantly differ ($p > 0.05$) among the treatments. However, the highest overall acceptability was observed for T3, followed by T1, T2, T5, T6, T4, T7, T8, and T9. Compared with the other treatments, the T3 and raw treatments resulted in higher color values. Compared with all the other treatments, the T7, T8, and T9 treatments resulted in the lowest color values and taste values. In terms of texture, aroma, and aftertaste, compared with T9, all the treatments resulted in almost equivalent scores. Compared with the other samples, treatment T3 resulted in higher overall acceptability (9 = like extremely), whereas T8 and T9 resulted in the lowest score (5 = neither like nor dislike). The lowest score of the treatments was due to the light-colored drumstick causing more water to be used for pressure cooking to leach the color pigments and high and salty taste. Poor taste acceptability might be due to high salt content. The appearance and color, raw and T3 (9 = extremely), had the highest score, indicating bright green pods. With respect to appearance, T6 scored the lowest, followed by T7, T8, and T9.

3.11 Classification of pressure-cooked drumsticks on the basis of color, texture, nutrient composition, antioxidant capacity, and sensory score

(A) Hierarchal cluster analysis

Hierarchical cluster analysis was performed to categorize the treatments on the basis of similarity. The height of the clades is greater; the treatments are more dissimilar. From the dendrogram (Fig. 3a), it was observed that when the raw drumstick was grouped alone (RAW), the treatments T1–T4 were grouped A, T5 and T8 were grouped B, T9 was in a group (C), and T6 and T7 were grouped C. Treatment T3 resulted in the highest sensory score, which decreased in group A. Therefore, it appears that the group A samples were more sensorily acceptable than the other groups were.

(B) Principal component analysis

From the principal component analysis, the first four principal components that can describe the variation in 19 parameters were found using eigenvalues (Fig. 3b). Biplots between PC1 and PC2 and between PC3 and PC4 show the variation and group variables (Fig. 3c&d). The first 2 components, namely, PC1 and PC2, had variabilities of 36.40% and 22.65%, respectively, whereas the other 2 components, PC3 and PC4, had data variabilities of 15.48% and 8.49%, respectively. The

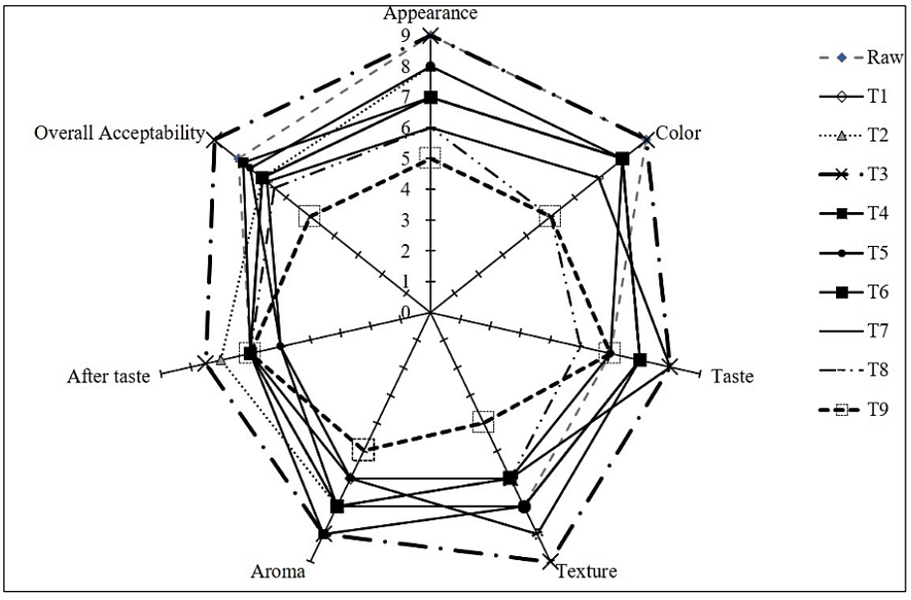


Fig. 2: Spider graph of the sensory analysis of raw and pressure-cooked drumsticks: The drumstick-to-water ratio (g/mL) and salt level (g) were varied. The treatments were Raw (uncooked control) and T1–T9: T1–T3 (1:0.5; 1.5, 2.0, and 2.5 g salt), T4–T6 (1:1; 1.5, 2.0, and 2.5 g salt), and T7–T9 (1:2; 1.5, 2.0, and 2.5 g salt), respectively.

Table 3: Volatile components in raw and pressure-cooked drumsticks

Name	Formula	Sensory descriptors	Relevance index				
			RAW	T2	T3	T7	T9
Acetaldehyde	C_2H_4O	Aldehydic; Etheral; Fresh; Fruity; Pleasant; Pungent	49.04	55.35	51.37	41.58	40.38
dimethyl sulfide	C_2H_6S	Cabbage; Corn; Fruity; Gaseous; Gasoline; Green; Moldy; Onion; Sulfurous; Sweet; Tomato; Vegetable; Vegetable soup	76.79	17.96	19.9	18.22	6.17
Propanal	C_3H_6O	acetaldehyde; Cocoa; Earthy; Etheral; Nutty; Plastic; Pungent; Solvent	59.24	28.27	24.26	28.58	31.43
2-propanol	C_3H_8O	Acetone; Alcoholic; Ethanol; Etheral; Musty; Pleasant; rubbing alcohol; Woody	34.89	13.02	12.34	16.16	19.35
2-methyl propanal	C_4H_8O	Aldehydic; Bakedpotato; Burnt; Floral; Fresh; Fruity; Green; Malty; Pungent; Sharp; Spicy; Toasted	68.87	16.23	13.69	23.32	27.6
ethyl formate	$C_3H_6O_2$	Cognac; Etheral; Fruity; Green; Pungent; Rose	*	*	NA	NA	*
butane-2,3- dione	$C_4H_6O_2$	Butter; Caramelized; Chlorine; Creamy; Fruity; Pineapple; Pungent; Spirit; Strong; Sweet	11.61	17.65	7.07	29.8	3.36
Butanal	C_4H_8O	Chocolate; Cocoa; Green; Malty; Musty; Pungent	*	10.73	9.28	29.1	*
butan-2-one	C_4H_8O	Acetone; Butter; Cheese; Chemical; Chocolate; Etheral; Fragrant; Fruity; Gaseous; Pleasant; Pungent; Sharp; Sweet	12.81	13.39	7.12	16.42	4.21
1-Propanol, 2-methyl-	$C_4H_{10}O$	Alcoholic; Bitter; Chemical; Fusel; Glue; Leek; Licorice; Musty; Oil; Solvent; Sweet; unpleasant; Winey	54.41	32.18	39.19	34.46	57.62
acetic acid	$C_2H_4O_2$	acetic; Acidic; Odorless; Pungent; Sharp; Sour; Vinegar	55.3	31.66	38.57	33.99	57.62
3-methyl butanal	$C_5H_{10}O$	Aldehydic; Almond; Apple; Cheese; Chocolate; Fatty; Fruity; Green; Herbaceous; Malty; Peach; Toasted	*	31.74	90.91	33.12	91
Isopropyl acetate	$C_5H_{10}O_2$	Banana; Chemical; Etheral; Fruity; Sweet	89.37	31.31	39.59	81.37	31.3
2,3-Pentanedione	$C_5H_8O_2$	Almond; Apple; Burnt; Butter; Butterscotch; Caramelized; Cheese; Creamy; diacetyl; Fresh; Fruity; grain; Malty; Nutty; Oily; Pungent; sickly; Sweet	*	*	*	*	80.72
Heptanal	$C_7H_{14}O$	Aldehydic; Citrus; Fatty; fish(dry); Fresh; Fruity; Green; Heavy; Oily; Ozone; Pesticide; Pungent; putty; Rancid; Smoky; Solvent	*	*	*	*	19.03
Dimethyl trisulfide	$C_2H_6S_3$	Alliaceous; Cabbage; Cauliflower; Fishy; Meaty; Onion; onion(cooked); Rotten food; Sulfurous	*	*	*	*	75.67
Methyl eugenol	$C_{11}H_{14}O_2$	Carnation; Cinnamon; Clove; Fresh; Mild; Spicy; Sweet; Warm	*	*	*	*	43.66
Ethyl propanoate	$C_5H_{10}O_2$	Banana; Chemical; Etheral; Fruity; Sweet	*	*	*	61.91	*

ethyl butyrate	$C_6H_{12}O_2$	Acetone; Banana; Bubblegum; Caramelized; Fruity; Pineapple; Strawberry; Sweet	*	*	*	4.6	*
Propyl propanoate	$C_6H_{12}O_2$	Apple; Chemical; Fruity; fruity(sweet); Pineapple; Pungent; Sharp; Sweet; Winey	*	*	*	5.71	*
Butyl acetate	$C_6H_{12}O_2$	Banana; Bitter; Etheral; Fruity; Green; Pear; Pine; apple; Pleasant; Solvent; Strong; Sweaty; Sweet	*	*	*	8.28	*
Hexanal	$C_6H_{12}O$	Acorn; Aldehydic; Fatty; Fishy; Fresh; Fruity; Grassy; Green; Herbaceous; Leafy; Sharp; Strong; Sweaty; Tallowy; vinous	*	*	*	13.13	*
3-methylbutanal	$C_5H_{10}O$	Aldehydic; Almond; Apple; Cheese; Chocolate; Fatty; Fruity; Green; Herbaceous; Malty; Peach; Toasted	*	31.74	90.91	33.12	*
n-butanol	$C_4H_{10}O$	Alcoholic; amylalcohol; Banana; Cheese; Fermented; Fruity; Fusel; Harsh; Medicinal; Oil; Rancid; Strong; Sweet	*	18.48	23.79	*	*
1S-()-a-pinene	$C_{10}H_{16}$	Fresh; Herbaceous; Pine; Resinous; Sharp; Terpenic; Turpentine; Warm	12.58	*	*	*	*
Isobornyl acetate	$C_{12}H_{20}O_2$	Camphor; herbal (weak); Pine	*	NA	NA	NA	*
Hydroxy citronellal	$C_{10}H_{20}O_2$	Floral; Green; Herbaceous; Lily; Melon; Lily of valley; Sweet; Tropical; Waxy	*	NA	NA	NA	*
()-bornyl acetate	$C_{12}H_{20}O_2$	Balsamic; Floral; Fresh; herb; Pine; Sweet; Woody	*	NA	NA	NA	*
Ethyl salicylate	$C_9H_{10}O_3$	Floral; Heavy; Minty; Spicy; Sweet; Wintergreen	*	NA	NA	NA	*
2,4-decadienal	$C_{10}H_{16}O$	Citrus; Fatty; Fresh; Fruity; Green; Orange; Sweet; Tallowy; Waxy	*	NA	NA	NA	*
Phenylacetic acid	$C_8H_8O_2$	Candy; Floral; Honey; Pollen; Rose; Sour; Sweet; Urine; Vanilla; Waxy	*	*	NA	*	*
Myristicin	$C_{11}H_{12}O_3$	Balsamic; Mild; Spicy; Warm; Woody	*	*	*	*	56.14
Benzyl phenyl acetate	$C_{15}H_{14}O_2$	Cocoa; Floral; Sweet	*	*	*	*	NA

* Not detected; NA- Not applicable

The drumstick-to-water ratio (g/mL) and salt level (g) were varied. The treatments were Raw (uncooked control) and T1–T9: T1–T3 (1:0.5; 1.5, 2.0, and 2.5 g salt), T4–T6 (1:1; 1.5, 2.0, and 2.5 g salt), and T7–T9 (1:2; 1.5, 2.0, and 2.5 g salt), respectively.

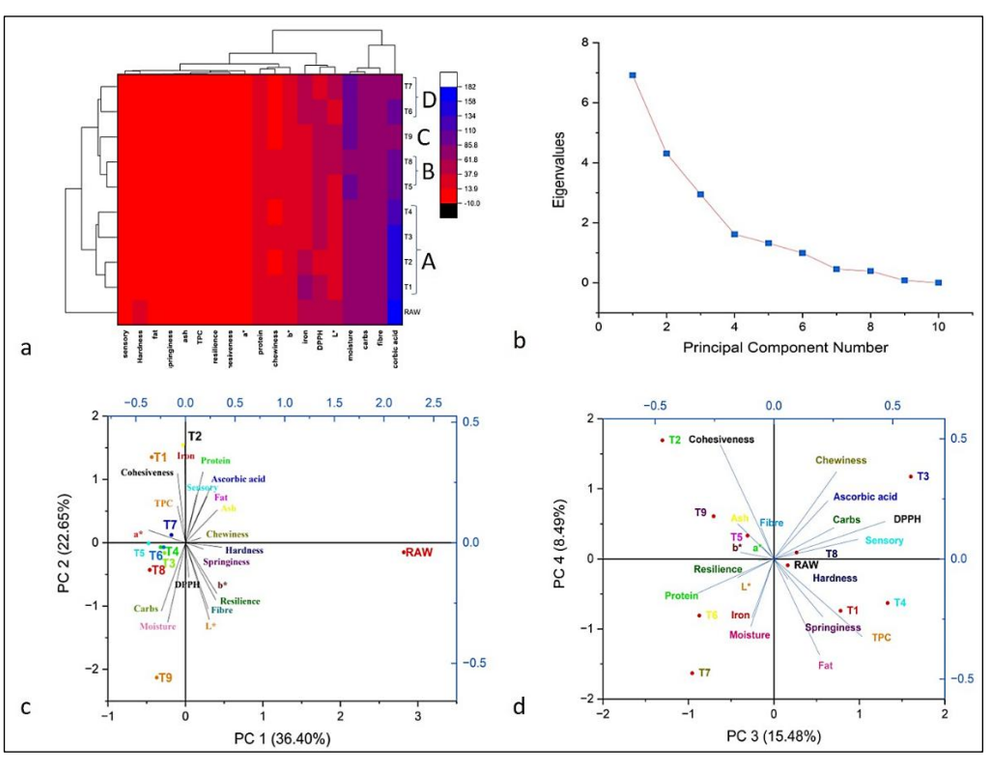


Fig. 3: (a) Heat map with hierarchical cluster diagram, (b) Scree plot of Eigen value diagram to indicate the PC, (c) PCA classification of raw and pressure-cooked drumsticks between PC1 and PC2, (d) PCA classification of raw and pressure-cooked drumsticks between PC3 and PC4.

separation of PC1 was due mainly to iron, cohesiveness and a*, whereas the separation of PC2 constituted the protein content, overall acceptability, ascorbic acid, fat, ash, and chewiness. The main attributable components in PC2 are chewiness and overall acceptability, where both can be correlated. However, carbohydrates and moisture are on the negative side of PC. In the case of PC3, the separation was mainly chewiness, which was again sensory, followed by carbohydrate, DPPH, and ascorbic acid. The correlations between the overall acceptability of carbohydrate, DPPH, ascorbic acid, and chewiness were good for PC3, whereas the ash, fiber, and color characteristics were good for PC4. The biplots revealed that cooking strongly affected the proximate components.

4. Conclusion

The pressure-cooked drumstick of treatment T2 (1:0.5-2) resulted in higher color, textural, nutritional, phytonutrient, and volatile contents, and T9 (1:2-2.5) presented the lowest values. Treatment T3 resulted in better consumer acceptability. The HCA concludes that the treatments T2, T1, T3, and T4 are grouped together. Since T3 and T2 are grouped together, T3 (1:0.5–2.5) is greater among the other treatments. The pressure-cooking factors, the drumstick-water ratio, and salt did not significantly affect the color, texture, or nutrient profiles. However, color and vitamin C content were significantly affected. The phytonutrient and volatile profiles were affected by the drumstick–water ratio and salt content during pressure cooking. More research is needed exclusively on the emergence and disappearance of phytonutrients and volatile profiles for optimizing water and salt.

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CRediT Author Contribution Statement

R Rashmitha: Investigation, Formal analysis, Data curation, Writing – Original draft. **G Sai Preetham:** Investigation, Formal analysis, Writing – Original draft. **V. Chandrasekar:** Conceptualization, Methodology, Writing – Review & editing, Supervision, Project administration. **V Eyarkai Nambi:** Methodology, Writing – Review & editing, Supervision. **N. Baskaran:** Methodology, Data curation, Writing – Review & editing, Supervision.

Funding Declaration

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Ethics Statement

The sensory analysis study was reviewed by the National Institute of Food Technology, Entrepreneurship and Management (NIFTEM) Institutional Board, and ethical approval was waived. The School of Sensory Sciences (NIFTEM-Thanjavur) follows standard procedures for sensory evaluation. Panelists were screened in accordance with the recommendations of the E-18 Committee, and written informed consent was obtained from all participants/panelists using the prescribed consent forms/score sheets. The sensory analysis was conducted in accordance with ISO 8586. The results of the sensory analysis are presented in a radar chart. The study was conducted in accordance with local legislation, institutional requirements, and the guidelines of the Declaration of Helsinki. The plant material used in this study (*Moringa oleifera* Lam., PKM-1 variety) was procured as a commercially cultivated agricultural produce from Thanjavur, Tamil Nadu, India in February 2022. As the material is a cultivated crop obtained through commercial purchase and was used solely for research purposes, no prior approval from the NBA or the State Biodiversity Board was required. No wild plant material was collected for this study.

Data Availability Statement

The data supporting the findings of this study are available from the corresponding author upon reasonable request.

Conflict of Interest

Dr. N. Baskaran, an author of this article, is a member of the Editorial Board of the *Journal of Food Processing Technology and Nutrition*. He had no involvement in the editorial handling, peer review or decision-making for this manuscript, which was handled independently of him. The authors declare no other conflicts of interest.

Artificial Intelligence (AI) Use Disclosure

The authors declare that no generative artificial intelligence tools were used in the conceptualization, analysis, interpretation, or generation of the scientific content of this manuscript.

Supporting Information

Not applicable

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