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Biochemical Profiling of the Rinds of Commercial Watermelon Cultivars in Bangalore, Karnataka, India

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Authors' contributions

This work was carried out in collaboration between all authors. Author SS designed the study, performed the statistical analysis, wrote the protocol, and wrote the first draft of the manuscript. Authors VKR and JSL managed the analyses of the study. Author SM, JU and AK managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Watermelon rind, often considered agricultural waste and frequently disposed of, contributes to environmental problems and biomass loss. This study seeks to analyze the distinct Biochemical profiles of watermelon rind, highlighting variations among different cultivars of Bangalore, Karnataka. Total soluble solids, pH, Moisture, titratable acidity, total carbohydrates, total proteins, ash, fat, total energy, fibre, total sugars, total phenolic contents, total antioxidant activity and *L*, a*, b** color values were estimated for six local commercial varieties to observe the differences between them. The rinds of all six cultivars had significant variations for all the parameters. This study provides the first-hand knowledge regarding watermelon rind biochemical profiles and cultivar difference and shows the potential use of rind in food or beverages due to its naturally contained bioactive compounds.

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1. INTRODUCTION

Watermelon [*Citrullus lanatus* (Thunb.) Matsum. & Nakai] fruit has both therapeutic and nutritional interest. *Citrullus lanatus* is an annual herbaceous included in the Cucurbitaceae plants family and is native from Africa [1].

The edible rind makes up approximately 40% of the total watermelon mass, yet is often discarded as a waste [2]. Direct disposal of the rind waste is causing environmental issues, though several approaches of reusing watermelon rind have been investigated at a laboratory scale. The specialized function of the rind's polysaccharide composition (pectin and fiber) has been considered a potential reason for its reuse [3]. It would be favourable to take advantage of the nutritional potential of rind and create commercial value, rather than limiting it to agricultural waste. Approaches have been introduced to reduce the accumulation of solid watermelon waste by converting the rind's polysaccharides into other products such as biosorbent [4], bioremediation [5], biochar [6] and bioethanol [2]. Additionally, watermelon rind has been studied as a source of nutritional food ingredients such as antioxidants [7], amino acids such as citrulline [8] and pectin [9]. In processed foods, rind has been tested in pickled form and in jam [10]. Watermelon rind in powder form has been examined to apply in carbohydrate-based goods including cakes [11], cookies [12], noodles [13], beef patties [14], and pork patties [15]. Furthermore, a few studies have investigated watermelon rind as a possible growth medium for microbials [16].

Watermelon rind is a rich source of pigments (lycopene and β-carotene), amino acids (citrulline and arginine), vitamins (vitamin A and vitamin C), minerals (sodium, potassium, phosphorus, iron, calcium, zinc and magnesium), antioxidants such as phenolic compounds, carbohydrates, proteins, dietary fibre, and sugars which provides a significant amount of energy to the consumers and offers its beneficial health effects as well [17].

Unfortunately, there is no study on the biochemical profile of watermelon cultivars in Bangalore, Karnataka. This study aimed to document the nutraceutical potential of six watermelon cultivars grown in Bangalore. This paper can contribute to the food and pharmaceutical valorization of watermelon, to the conservation of the best genetic heritage, and especially to the achievement of food security.

2. MATERIALS AND METHODS

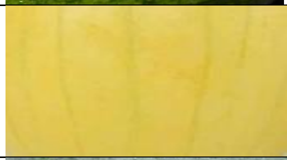
2.1 Plant Materials

Six commercial watermelon varieties were selected which were available in Bengaluru city local markets grown in college of horticulture Bengaluru (Table 1). All the commercially available watermelon varieties were selected based on their rind color. All the fruits were brought in bulk to department of postharvest technology, College of Horticulture, Bengaluru. Fruits were sorted to select clean, evenly mature, free from injuries, pests and diseases for further biochemical profiling. Rind of watermelon were separated, crushed and used for further analysis.

2.2 Detailed Analysis of Watermelon Rind

Total soluble solids in watermelon pulp and rind was evaluated by using ATAGO digital refractometer (Spectrum technologies, Inc.). CONTECH pH meter model (CpCH) was used to measure the pH value of samples. Sartorius moisture analyzer (Model: MA-35) was used to estimate the moisture content of the sample. Titratable acidity was determined through the titration method according to [18] guidelines. Total carbohydrate contents were determined using [19]. Total protein content was assessed using Lowry's method [20]. The ash content was determined according to [18]. Crude fat content was determined according to [21]. Energy was calculated according to the equation: Energy (kcal) = [Protein (gm) × 4] + [Carbohydrate (gm) × 4] + [Fat (gm) × 9]. The crude fiber content of the sample was determined using the double digestion technique as outlined by [22]. Total sugars in watermelon samples were quantified using the Anthrone method. Total phenolic contents were determined by folin ciocalteu reagent (FCR) method and expressed as mg GAE/100g. The total antioxidant activity of the watermelon flesh and rind samples was estimated by the ferric reducing antioxidant power (FRAP) method [23]. Minerals present in watermelon were estimated as per the AOAC procedure [24]. Instrumental colour (L*, a*, b*) values were analyzed by using a lovibond lab colorimeter.

Table 1. Watermelon cultivars available in Bengaluru local market

Sl. No.	Watermelon hybrids	Characteristics	
1	Anmol	Yellow flesh, striped rind and large size	
2	Vishala	Red flesh, yellow rind and medium size	
3	Kiran	Red flesh, dark green rind and medium size	
4	Crimson Crush	Red flesh, striped rind and small size	
5	NS 295	Red flesh, striped rind and large size	
6	Snehal	Red flesh, striped rind, medium size and seedless	

2.3 Statistical Analysis

Data are expressed as means ± standard deviation of four replicates. Differences between means of parameters from different cultivars were analyzed by ANOVA (one way) followed by duncan multiple range test, p< significant level at 0.01% using SPSS version 25 software.

3. RESULTS AND DISCUSSION

The results indicate that the rind of all six varieties had significant differences for TSS, pH, Moisture and titratable acidity contents (Table 2). The TSS values for the fresh rind of all six watermelon varieties differed significantly. Rind of Crimson crush hybrid had the highest TSS contents of (3.29 ^{o}B) followed by Vishala (3.14 ^{o}B) and Kiran (2.99 ^{o}B). The lowest TSS contents of (2.25 ^{o}B) was recorded in the rind of NS 295 watermelon hybrid. The primary components of TSS in watermelon include sugars, predominantly fructose, glucose, and sucrose. Differences in the composition and concentration of these sugars among various watermelon varieties play a crucial role in determining sweetness and TSS values. These results were similar with [25], who studied watermelon landraces from India and exotic germplasm. [26] also reported similar results in a study of physicochemical characteristics of watermelon in Malaysia.

The rinds of all six watermelon varieties had significantly different pH values. The highest pH value of (5.7) was recorded in the rind of Vishala while the lowest of (5.16) was recorded in the rind of Crimson crush. The lower acidity in the rind contributes to a milder taste compared to the pulp. While the rind is not typically consumed on its own, it is sometimes used in culinary applications, such as pickling, where the pH level becomes crucial for both flavor and preservation. [27] reported similar findings in their investigation of biochemical and mineral assessment of watermelon rind. [28] also studied the quality properties of watermelon and their pH values were consistent with the observations in our research.

Moisture contents were also different in the rind of all six watermelon hybrids. The highest value of (93.07%) was recorded in the rind of NS 295 followed by Vishala (92.07%) and Snehal (90.86). The rind of Kiran hybrid had the lowest moisture contents of (89.08 %). In line with our findings, [26] conducted a study on the physicochemical features of watermelon in Malaysia. Similarly, [27] investigated the biochemical and mineral assessment of watermelon rind and found moisture of (91.97%) in the rind of watermelon.

Titratable acidity was significantly different in the rind of all six watermelon varieties. The highest value was recorded in the rind of Anmol (0.098 %) followed by Crimson crush (0.095%) while the lowest value of (0.06%) was recorded in the rind of NS 295. The milder acidity in the rind contributes to its neutral taste, allowing it to be more adaptable for culinary applications where a less pronounced acidity is desired. [29] reported similar results in their study on the yield of mini-watermelon plants. Additionally, [26] observed comparable trends in their study on the physicochemical assessment of watermelon in Malaysia. [30] further supported these observations, exploring the nutraceutical potential of the pulp from five watermelon cultivars grown in Burkina Faso.

Data of carbohydrates, proteins, ash and fat contents were also significantly different between the rinds of all varieties are shown in Table 3. Rind of Kiran variety had the highest carbohydrate content (5.56 g/100g) followed by Anmol (4.48 g/100g) and crimson crush (4.45 g/100g). The rind of NS 295 variety showed the lowest carbohydrate contents of (3.58 g/100g). The variations in total carbohydrate contents between the rinds of different watermelon varieties can be ascribed to various factors, such as genetic differences, growing conditions, and ripeness [17].

Rind of all six watermelon varieties also had significant differences in protein contents. Rind of Kiran variety had the highest protein content (0.92 g/100g) followed by Snehal (0.73 g/100g) and Vishala (0.77 g/100g). The differences in total protein contents between the rinds of various watermelon hybrids can be influenced by several factors, including genetic variations, plant physiology, and the intended use of different parts of the fruit [17]. The rind of NS 295 hybrid shown the lowest protein contents (0.48 g/100g). These findings align with the research conducted by [26] on the physicochemical characteristics of watermelon in Malaysia, as well as the investigation by [27] into the biochemical and mineral profiling of watermelon rind. [17] provided comprehensive insights in a review on the phytochemical assessment of watermelon and its bioactive and therapeutic effects.

Rinds of all six watermelon varieties also had different ash contents. Rind of Kiran variety had the highest Ash contents (0.32 %) followed by crimson crush (0.31 %) while the rind of NS 295 variety had the lowest ash contents (0.1%). Although the total ash content in the rind is not exceptionally high, it contributes to the overall

Table 2. Total Soluble Solids, pH, moisture and titrable acidity of watermelon rinds from six cultivars

Varieties	TSS	pH	Moisture %	TA %
Anmol	2.93^{a} ±0.13	5.3^{a} ±0.12	89.14^{bc} ± 0.89	0.098^{a} ± 0.003
Vishala	3.14^{a} ±0.05	5.7^{a} ±0.002	87.01^{c} ± 0.99	0.088^{ab} ± 0.002
Kiran	2.99^{a} ±0.21	5.23^{a} ±0.06	88.98^{bc} ± 1.10	0.080^{b} ± 0.000
Crimson Crush	3.29^{a} ±0.12	5.1^{a} 6±0.03	92.28^{a} ± 0.63	0.095^{a} ± 0.003
NS 295	2.25^{b}±0.05	5.21^{a} ±0.07	93.58^{a} ±0.45	0.060^{c} ± 0.000
Snehal	2.88^{a} ±0.10	5.59^{a} ±0.03	89.72^{b} ± 0.79	0.0780^{b} ± 008
Mean	2.91	5.36	90.11	0.083
SE (m)±	0.12	0.068	0.84	0.004
C.D. @ 1%	0.38	0.204	2.51	0.011

Data are expressed as means ± standard deviation of four replicates. Distinct letters indicate significant differences between cultivars p< significant level @ 0.01%

mineral intake, making the rind potentially valuable for those seeking a nutrient boost. The findings presented here align with those reported by [27] in their investigation of the biochemical and mineral assessment of watermelon rind. Similarly, [26] observed parallel trends in their study on the physicochemical characteristics of watermelon in Malaysia. Additionally, [31] explored the nutritional composition of various watermelon varieties in Gewane, Northeastern Ethiopia, supporting our results.

Rinds of all six watermelon varieties were also different in fat contents. The highest value (0.11%) fat was recorded in the rind of Kiran hybrid while the lowest value (0.08 %) was recorded in the rind of NS 295 hybrid. Although the rind is consumed less frequently than the pulp, its minimal fat content is in line with its potential as a culinary ingredient. Variances in fat content can be attributed to variations in metabolic processes and cellular functions between the pulp and rind. These values align with the findings of several studies. [17] reviewed phytochemical profile of watermelon and its bioactive properties and reported the fat contents of (0.44%) in watermelon rind. Similarly, [27] represented fat contents of (0.21%) watermelon rind, [32] studied the proximate chemical composition of watermelon, [31] explored the nutritional composition of various watermelon varieties in Gewane.

The values of energy, fibre, total sugars and total phenolic contents were also significantly different between the rinds of all varieties (Table 4). The rind of Kiran had the highest value (26.63 kcal /100g) followed by Anmol (22.73 kcal/100g) and Crimson crush (21.16 kcal /100g) while the rind of NS 295 variety had the lowest value of (16.91 kcal /100g) for energy. The total energy content in watermelon pulp and rind provides valuable insights into the fruit's nutritional profile and culinary versatility. These differences of energy between the pulps and rinds is associated with the differences in carbohydrates, proteins and fat contents between varieties. These findings are consistent with the research conducted by [31] on the nutritional composition of various watermelon fruits in Gewane, Northeastern Ethiopia. Similarly, [27] observed similar trends in their investigation of the biochemical and mineral characterization of watermelon byproduct.

The highest fibre (0.39) percent were recorded in the rind of Kiran followed by Anmol 0.34 percent while the lowest of fibre (0.26%) was recorded in the rind of NS 295 variety. The rind offers a more diverse fiber profile, potentially providing additional health benefits related to heart health and blood sugar regulation. These findings align with those reported by [27] in their analysis of the biochemical and mineral characteristics of watermelon rind, [33] in their study investigated watermelon as a potential fruit snack, and [26] conducted a research on the physicochemical features of watermelon in Malaysia.

Rind of Kiran had the highest total phenolic contents value of (445 mg/100g) followed by Crimson crush (439.75 mg/100g) while the rind of NS 295 variety had the lowest value of (333.75 mg/100g) for. Studies have indicated that watermelon rind contains a significant amount (300-500 mg/100g) of phenolic compounds, contributing to its antioxidant capacity. The specific phenolic profiles may vary among watermelon varieties, but common phenolic compounds found in the pulp include flavonoids

Table 3. Carbohydrates, Proteins, Ash ant Fat contents of watermelon rinds from six cultivars

Varieties	Carbohydrates g/100g	Proteins g/100g	Ash %	Fat %
Anmol	$4.78^{ab}\pm0.14$	$0.69^{b}\pm0.01$	$0.16^{c}\pm0.022$	$0.09^{b}\pm0.003$
Vishala	$4.16^{b}\pm0.03$	$0.77^{b}\pm0.00$	$0.20^{b}\pm0.007$	$0.10^{b}\pm0.000$
Kiran	$5.56^{a}\pm0.19$	$0.92^{a}\pm0.02$	$0.32^{a}\pm0.008$	$0.11^{a}\pm0.006$
Crimson Crush	$4.45^{ab}\pm0.86$	$0.61^{c}\pm0.02$	$0.31^{a}\pm0.012$	$0.10^{b}\pm0.000$
NS 295	$3.58^{b}\pm0.15$	$0.48^{d}\pm0.04$	$0.10^{d}\pm0.005$	$0.08^{c}\pm0.000$
Snehal	$4.06^{b}\pm0.06$	$0.73^{b}\pm0.02$	$0.20^{b}\pm0.002$	$0.09^{b}\pm0.003$
Mean	4.43	0.70	0.21	0.095
SE (m)±	0.37	0.02	0.01	0.003
C.D. @ 1%	1.12	0.08	0.03	0.009

Data are expressed as means ± standard deviation of four replicates. Distinct letters indicate significant differences between cultivars p< significant level @ 0.01%

and phenolic acids. These compounds not only give watermelon its vibrant color but also offer potential health-promoting effects. These findings are consistent with the research conducted by [34] who studied bioactive compounds and antioxidant activities during the fruit ripening stages of watermelon cultivars. Similar trends were observed in the comprehensive review by [17] on the watermelon phytochemical profile and its bioactive and therapeutic properties. Additionally, [30] provided congruent results in their study on the nutraceutical potential of the pulp from five watermelon cultivars grown in Burkina Faso.

Rind of Crimson Crush had the highest value of (8.75 g/100g) for total sugars followed by Kiran (5.10 g/100g) while the rind of NS 295 variety had the lowest value (3.40 g/100g). The total sugars in watermelon rind contribute to the fruit's overall appeal and nutritional richness. These results align with those reported by [35], who conducted a study on the variation of carotenoids, sugars, and ascorbic acid concentrations in 20 watermelon genotypes. [36] explored sugars in developing and mature fruits of various watermelon cultivars, while [37] investigated changes in quality parameters in watermelon during storage, further supporting the congruence of results across different studies.

The values of total antioxidants and L*****, a*****, b***** color were also significantly different between the rinds of all varieties (Table 5). Rind of Vishala had the highest value (-161.44 mg/100g) followed by Kiran (155.86 mg/100g) while the rind of NS 295 variety had the lowest value (121.50 mg/100g) for total antioxidants. Different watermelon varieties may contain varying levels of antioxidant compounds, such as phenolic compounds, carotenoids, and vitamin C, which contribute to the overall antioxidant activity measured by the FRAP assay. The presence and activity of enzymes involved in antioxidant pathways, such as superoxide dismutase or catalase, can influence FRAP values. Inherent genetic differences among watermelon varieties can result in variations in the types and quantities of antioxidant compounds, affecting FRAP values. [17] reviewed watermelon phytochemical profile and its bioactive and therapeutic effects. Additionally, [38] explored the antioxidant activities of peel, pulp, and seed fractions of common fruits as determined by the FRAP assay, further reinforcing the consistency of results across different research activities.

In the rinds of all watermelon varieties, Vishala had the highest **L* value (58.97) followed by NS 295 (56.94) while Kiran had the lowest **L* value (39.27). Rind of Vishala had the highest **a* value (6.63) followed by Anmol (-3.69) and the lowest of **a* value (-6.62) was recorded in the rind of Snehal. Rind of Anmol had the highest **b* value (27.33) followed by Vishala (26.55) and crimson crush (26.30) while rind of Kiran recorded the lowest (20.64) of **b* value. Different watermelon varieties may contain varying levels of **L *a *b* colour values due to the differences in carotenoid contents, chlorophyll contents, anthocyanin presence, genetic variations and environmental conditions [17]. These findings are consistent with the research of [26], who investigated the physicochemical characteristics of watermelon in Malaysia. Additionally, alignment is observed with the study by [39] on fruit quality assessment of watermelon. Furthermore, [28] found comparable results in their study regarding quality properties of watermelon.

Table 4. Total energy, Fibre, Total sugars and total phenolic contents of watermelon rinds from six cultivars

Varieties	Energy kcal/100g	Fibre %	Total Sugars g/100g	Total phenolic contents (mg GAE/100g)
Anmol	22.73^{ab}±0.60	0.34^{b}±0.006	4.82^{ab}±0.18	402.75^{b}±2.49
Vishala	20.67^{bc}±0.13	0.32^{bc}±0.013	8.75^{ab}±0.06	416.25^{b}±5.54
Kiran	26.63^{a}±0.76	0.39^{a}±0.019	5.10^{a}±0.09	445^{a}±11.90
Crimson Crush	21.16^{bc}±3.47	0.30^{cd}±0.014	4.07^{a}±0.04	439.75^{a}±5.48
NS 295	16.91^{c}±0.68	0.26^{d}±0.018	3.40^{c}±0.16	333.75^{c}±2.39
Snehal	20.03^{bc}±0.15	0.31^{bc}±0.003	4.60^{b}±0.04	400^{b}±4.56
Mean	21.23	0.32	5.12	406.24
SE (m)±	1.50	0.01	0.11	6.26
C.D. @ 1%	4.50	0.04	0.33	18.74

Data are expressed as means ± standard deviation of four replicates. Distinct letters indicate significant differences between cultivars p< significant level @ 0.01%

Table 5. Total antioxidants and L*, a*, b* values of watermelon rinds from six cultivars

Varieties	Total antioxidant activity (mgAAE/100g)	L*	a*	b*
Anmol	145.30^{b}±1.12	52.96^{c}±0.05	-3.69^{b}±0.24	27.33^{a}±0.34
Vishala	161.44^{a}±1.70	58.97^{a}±0.68	6.63^{a}±0.44	26.55^{ab}±0.40
Kiran	155.86^{a}±2.07	39.27^{f}±0.40	-4.69^{c}±0.32	20.64^{d}±0.46
Crimson Crush	146.75^{b}±1.10	47.07^{d}±0.37	-5.58^{d}±0.14	26.30^{b}±0.36
NS 295	121.50^{c}±4.05	56.94^{b}±0.20	-3.75^{b}±0.14	23.77^{c}±0.09
Snehal	147.75^{b}±2.28	45.71^{e}±0.14	-6.62^{e}±0.12	25.72^{b}±0.09
Mean	146.43	50.15	-17.7	25.05
SE (m)±	2.28	0.37	0.26	0.33
C.D. @ 1%	6.84	1.11	0.79	0.98

Data are expressed as means ± standard deviation of four replicates. Distinct letters indicate significant differences between cultivars p< significant level @ 0.01%.

4. CONCLUSION

Biochemical profiles of six watermelon rinds were investigated for the first time in this study. Watermelon rind biochemical profiles were characterized by the presence of carbohydrates, proteins, fat, fibre, sugars, and total phenolic compounds. Total antioxidant activities of all cultivars were also studied. Finally *L*, a*, b** color values of the rinds of all cultivars were measured. Variety differences for rind was observed. These results suggest that rind has a high bioactive potential which can make positive contribution to the food products. These findings valorize watermelon rind as a promising supplemental ingredient for food and beverages potentially contributing to nutritional profile depending on how it is used and the types of final products.

COMPETING INTERESTS

Authors have declared that no competing interests exist

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