Biochemical profiling of the rinds of commercial cultivars in Bangalore, Karnataka

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.

Keywords: Watermelon, Rind, Biochemial, Cultivar

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 (Paris, 2015).

The edible rind makes up approximately 40% of the total watermelon mass, yet is often discarded as a waste (Kassim et al., 2021). Direct disposal of the rind waste is causing environmental issues, though several approaches of reusing watermelon rind have been investigated at alaboratory scale. The specialized function of the rind's polysaccharide composition (pectinand fiber) has been considered a potential reason for its reuse (Romdhane et al., 2017). It would be favourable to take advantage of the nutritional potential of rind and create commercial value, ratherthan limiting it to agricultural waste. Approaches have been introduced to reduce theaccumulation of solid watermelon waste by converting the rind's polysaccharides intoother products such as biosorbent (Rambabu et al., 2020), bioremediation (Liu et al., 2012), biochar (Yang et al., 2021) and bioethanol (Kassim et al., 2021).Additionally, watermelon rind has been studied as a source of nutritional food ingredientssuch as antioxidants (Ho et al., 2018), amino acids such as citrulline (Egbounu et al., 2015) and pectin (Mendez et al., 2021). Inprocessed foods, rind has been tested in pickled form and in jam (Simonne et al., 2003). Watermelon rind in powder form has been examined to apply in carbohydrate-based goods including cakes (Al-Sayed and Ahmad, 2013), cookies (Naknaen et al., 2016), noodles (Chakrabarty et al., 2020), beef patties (Badr et al., 2018), and pork patties (Kumar et al., 2018). Furthermore,a few studies have investigated watermelon rind as a possible growth mediumfor microbials (Hasanin et al., 2020).

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), phenolic compounds, antioxidants, carbohydrates, proteins, dietary fibre, and sugars which provides a significant amount of energy to the consumers and offers its beneficial health effects as well (Nadeem *et al*., 2022).

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 literature 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.

MATERIALS AND METHODS

Plant materials

Six commercial watermelon varieties were selected which were available in Bengaluru city local markets(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.

Table 1. Watermelon cultivarsavailable 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	

Detailed analysis of watermelon rind

TSS in watermelon pulp and rind was evaluated by using a digital refractometer.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 AOAC (1990) guidelines. Total carbohydrate contents were determined using sulfuric acid method. Total protein content was assessed using Lowry's method as described by Lowry *et al.*~~in~~(1951).The ash content was determined according to AOAC (1990). Crude fat content was determined according to AOAC (2006). Energy was calculated as protein+CHO+fat method. The crude fiber content of the sample was determined using the double digestion technique as outlined by Sadasivam and Manickam (2005).Total sugars in watermelon samples were quantified using the Anthrone method.Total phenolic contents were determined by FCR method. The total antioxidant activity of the watermelon flesh and rind samples was estimated by the FRAP method (Benzie and Strain, 1996). Minerals present in watermelon were estimated as per the AOAC procedure (Anon., 1990). Instrumentalcolour was analyzed by using a lovibond lab colorimeter.

A "Statistical analysis" section should be included.

"Data are expressed as means ± standard deviation of XXX replicates. Differences between means of parameters from different cultivars were analyzed by eg. ANOVA (one way??) followed by Tukey test, p< significant level….0.05?? Specify the software used.

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 on par with Singh *et al.* (2016), who studied watermelon landraces from India and exotic germplasm. Sabeetha *et al*. (2017) 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.Olayinka and Etejer (2017) reported similar findings in their investigation of biochemical and mineral assessment of watermelon rind. Massri and Labban (2015) 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, Sabeetha *et al*. (2017) conducted a study on the physicochemical features of watermelon in Malaysia. Similarly, Olayinka and Etejer (2017) investigated the biochemical and mineral assessment of watermelon rind.

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.Rouphael*et al*. (2008) reported similar results in their study on the yield of mini-watermelon plants. Additionally, Sabeetha *et al*. (2017) observed comparable trends in their study on the physicochemical assessment of watermelon in Malaysia. Bazié*et al*. (2022) further supported these observations, exploring the nutraceutical potential of the pulp from five watermelon cultivars grown in Burkina Faso.

Table 2: Cultivar effect on TSS, pH, Moisture and Titratable acidity of watermelon rind

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 of carbohydrates, proteins, ash and fat contents were also significantly different between the rinds of all varietiesare shown in Table 3. Rind of Kiran variety had the highest carbohydrate contentssof (5.56 g/100g) followed by Anmol (4.48 g/100g) and crimson crush (4.45 g/100g). The rind of NS 295 varietyshown 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. These findings align with the research conducted by Sabeetha *et al*. (2017) on the physicochemical characteristics of watermelon in Malaysia, as well as, the investigation by Olayinka and Etejer (2017) into the biochemical and mineral profiling of watermelon rind. Nadeem *et al*. (2022) provided comprehensive insights in a review on the phytochemical assessment of watermelon and its bioactive and therapeutic effects.

Rind of all six watermelon varieties also had significant differencesinprotein contents. Rind of Kiran variety had the highest protein contentssof (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.The rind of NS 295 hybrid shown the lowest protein contents of (0.48 g/100g). These findings align with the research conducted by Sabeetha *et al*. (2017) on the physicochemical characteristics of watermelon in Malaysia, as well as the investigation by Olayinka and Etejer (2017) into the biochemical and mineral profiling of watermelon rind. Nadeem *et al*. (2022) 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 of (0.32 %) followed by crimson crush (0.31 %) while the rind of NS 295 variety had the lowest ash contents of (0.1%).Although the total ash content in the rind is not exceptionally high, it contributes to the overall mineral intake, making the rind potentially valuable for those seeking a nutrient boost. The findings presented here align with those reported by Olayinka and Etejer (2017) in their investigation of the biochemical and mineral assessment of watermelon rind. Similarly, Sabeetha *et al*.

(2017) observed parallel trends in their study on the physicochemical characteristics of watermelon in Malaysia.Additionally, Yimer and Tehlie (2020) 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 ~~of~~ (0.11 %) fat was recorded in the rind of Kiran hybrid while the lowest value ~~of~~ (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. Nadeem *et al.* (2022) reviewed phytochemical profile of watermelon and its bioactive properties. Similarly, Olayinka and Etejer (2017) investigated the biochemical and mineral characteristics of watermelon rind, Ibrahim *et al.* (2021) studied the proximate chemical composition of watermelon, Yimer and Tehlie (2020) explored the nutritional composition of various watermelon varieties in Gewane.

Table 3: Cultivar effect on Carbohydrates, Proteins, Ash and fat contents of watermelon rind

Varieties	Carbohydrates g/100g	Proteins g/100g	Ash %	Fat %
Anmol	4.78^{ab}±0.14	0.69^{b}±0.01	0.16^{c}±0.022	0.09^{b}±0.003
Vishala	4.16^{b}±0.03	0.77^{b}±0.00	0.20^{b}±0.007	0.10^{b}±0.000
Kiran	5.56^{a}±0.19	0.92^{a}±0.02	0.32^{a}±0.008	0.11^{a}±0.006
Crimson Crush	4.45^{ab}±0.86	0.61^{c}±0.02	0.31^{a}±0.012	0.10^{b}±0.000
NS 295	3.58^{b}±0.15	0.48^{d}±0.04	0.10^{d}±0.005	0.08^{c}±0.000
Snehal	4.06^{b}±0.06	0.73^{b}±0.02	0.20^{b}±0.002	0.09^{b}±0.003
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

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 ~~of~~ (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 Yimer and Tehlie (2020) on the nutritional composition of various watermelon fruits in Gewane, Northeastern Ethiopia. Similarly, Olayinka and Etejer (2017) observed similar trends in their investigation of the biochemical and mineral characterisation of watermelon byproduct.

The highest fibre~~of~~ (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 Olayinka and Etejer (2017) in their analysis of the biochemical and mineral characteristics of watermelon rind, Maoto*et al*. (2019) in their study investigated watermelon as a potential fruit snack, and Sabeetha *et al*. (2017) conducted a research on the physicochemical features of watermelon in Malaysia.

Rind of Kiran had the highest 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 total phenolic contents. Studies have indicated that watermelon rind contains a significant amount 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, phenolic acids, and carotenoids. 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 Tili *et al*. (2011), who studied bioactive compounds and antioxidant activities during the fruit ripening stages of watermelon cultivars. Similar trends were observed in the comprehensive review by Nadeem *et al*. (2022) on the watermelon phytochemical profile and its bioactive and therapeutic properties. Additionally, Bazié*et al*. (2022) 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 ~~of~~ (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 Yoo *et al*. (2012), who conducted a study on the variation of carotenoids, sugars, and ascorbic acid concentrations in 20 watermelon genotypes.Elmstrom and Davis (1981) explored sugars in developing and mature fruits of various watermelon cultivars, while Radulovic *et al*. (2007) investigated changes in quality parameters in watermelon during storage, further supporting the congruence of results across different studies.

Table 4: Cultivar effect on Energy, Fiber, Total sugars and total phenolic contents of watermelon rind.

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

The values of total antioxidants and L*****, a*****, b***** colorwere also significantly different between the rinds of all varieties (Table 5). Rind of Vishala had the highest value ~~of~~ (161.44 mg/100g) followed by Kiran (155.86 mg/100g) while the rind of NS 295 variety had the lowest value ~~of~~ (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.Nadeem *et al*. (2022) reviewed watermelon phytochemical profile and its bioactive and therapeutic effects. Additionally, Guo *et al*. (2003) 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 ~~of~~ (58.97) followed by NS 295 (56.94) while Kiran had the lowest **L*value ~~of~~ (39.27). Rind of Vishala had the highest **a*value ~~of~~ (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 ~~of~~ (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 valuesdue to the differences in carotenoid contents, chlorophyll contents, anthocyanin presence, genetic variations and environmental conditions. These findings are consistent with the research of Sabeetha *et al*. (2017), who investigated the physicochemical characteristics of watermelon in Malaysia. Additionally, alignment is observed with the study by Fredes *et al*. (2017) on fruit quality assessment of watermelon. Furthermore, Massri and Labban (2015) found comparable results in their study regarding quality properties of watermelon.

Table 5: Cultivar effect on Total antioxidants and L*,a*,b* values of watermelon rind.

Varieties	Total antioxidant activity (mgAAE/100g)	**L***	**a***	**b***
Anmol	$145.30^{b}\pm1.12$	$52.96^{c}\pm0.05$	$-3.69^{b}\pm0.24$	$27.33^{a}\pm0.34$
Vishala	$161.44^{a}\pm1.70$	$58.97^{a}\pm0.68$	$6.63^{a}\pm0.44$	$26.55^{ab}\pm0.40$
Kiran	$155.86^{a}\pm2.07$	$39.27^{f}\pm0.40$	$-4.69^{c}\pm0.32$	$20.64^{d}\pm0.46$
Crimson Crush	$146.75^{b}\pm1.10$	$47.07^{d}\pm0.37$	$-5.58^{d}\pm0.14$	$26.30^{b}\pm0.36$
NS 295	$121.50^{c}\pm4.05$	$56.94^{b}\pm0.20$	$-3.75^{b}\pm0.14$	$23.77^{c}\pm0.09$
Snehal	$147.75^{b}\pm2.28$	$45.71^{e}\pm0.14$	$-6.62^{e}\pm0.12$	$25.72^{b}\pm0.09$

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

Conclusion

Biochemical profiles of six watermelon rinds were investigated for the first time in this study. Watermelon rind biochemical profiles werecharacterized by the presence of carbohydrates, proteins, fat, fibre, sugars,and total phenolic compounds.total antioxidant activity and *L**, *a**, *b** color values. Variety differences for rind was observed. These results imply that rind has a high bioactive potential which can make positive contribution to the food products. These findingsprovide knowledge for that 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 ~~its~~ final products.

References

Adebowale K O, Olu-Owolabi B I, Olayinka O O, Olayide S L. 2005. Effect of heat moisturetreatment and annealing on physicochemical properties of red sorghum starch. African *Journal of Biotechnology*, 4(9):923-933.

Agoreyo, B. O., Akpiroroh, O., Orukpe, O. A., Osaweren, O. R. &Owabor, C. N. 2011. The effects of various drying methods on the nutritional composition of *Musa paradisiaca, Dioscorearotundata*and *Colocasia esculenta. Asian Journal of Biochemistry* 6**:** 458-464.

Akpan, E.J. and Umoh, B.I., 2004, Effect of Heat and Tetracycline Treatments on the Food Quality and Acridity Factors in Cocoyam [Xanthosoma sagittifolium (L) Schott]. *Pakistan. J. Nutri.*, 3(4)240-243.

Al-Sayed, H. M. A. & Ahmed, A. R. 2013. Utilization of watermelon rinds and Sharlyn melon peels as a natural source of dietary fiber and antioxidants in cake. *J. of Agricultural Sciences* 58: 83-95.

Anderson, R.A., Conway, H.F. and Peplinski, A.J. 1969. Gelatinization of Corn Grits by Roll Cooking, Extrusion Cooking and Steaming. *Jabrg*. 22. 131-134.

Anonymous, 1990. Official Methods of Analysis of the Association of Analytical Chemists. (14th Ed.). Arlington, Virginia, U.S.A.

AOAC., 1990, Official methods of analysis, *15th Edition*, Association of official analytical chemists, Washington, DC.

AOAC., 1990, Official methods of analysis, *15th Edition*, Association of official analytical chemists, Washington, DC.

AOAC., 2006, Official methods of analysis, *21th Edition*, Association of official analytical chemists, Washington, DC

Asif-Ul-Alam S M, Islam M Z, Hoque M M, Monalisa K. 2014. Effects of drying on the physicochemical and functional properties of green banana (Musa sapientum) flour anddevelopment of baked product. *American Journal of Food Science and Technology*, 2(4):128-133.

Bashir, N., Sood, M. and Bandral, D., 2020. Impact of different drying methods on proximate and mineral composition of oyster mushroom (*Pleurotus florida*). *Ind. J. Trad. Know*. 19(3) 656-661.

Bazié, D., Konaté, K., Kaboré, K., Dakuyo, R., Sanou, A., Sama, H. and Dicko, M. H., 2022, Nutraceutical potential of the pulp of five cultivars of watermelon [*Citrulluslanatus* (Thunb.) Matsum. & Nakai] grown in Burkina Faso. *Int. J. Food Prop*., 25(1): 1848-1861.

Benzie IF, Strain JJ. The ferric reducing ability of plasma (FRAP) as a measure of "antioxidant power": the FRAP assay. *Anal Biochem*. 1996 Jul 15;239(1):70-6.

Beuchat L R. 1977. Functional and electrophoretic characteristics of succinylated peanut flour protein. *Journal of Agricultural and Food Chemistry*, 25(2):258-261.

Bonazzi C, Dumoulin, E. Quality changes in food materials as influenced by dryingprocesses. In E. Tsotsas, & A. S. Mujumdar (Eds.), Modern drying technologyvolume3:Product quality and formulation. Weinheim: Wiley-VCH Verlag GmbH and Co. KGaA,2011, pp. 1-20.

Diosady, L.L., Patton, D., Rosen, N. & Rubin, L.J. (1985). Degradation of wheat starch in a single screw extruder: mechanokinetic breakdown of cooked starch. *Journal of Food Science*, 50, 1697–1706.

Duran, R., Villegas, M.E. and Neives, I., 2017, Characterization and extraction of citrulline of the watermelon rind (Citrullus lanatus “thunb”) consumed in Valledpur. *J.Themas.Agrar*. 22:61-67.

Elmstrom, G. W. and Davis, P. L., 1981, Sugars in developing and mature fruits of several watermelon cultivars. *J. Am. Soc. Hortic. Sci*., 106(3): 330-333.

FAO, FAO STAT, http://www.fao.org/faostat/en/#data/QC 2019

Fierascu,R.C., Sieniawska,E., Ortan,A., Fierascu,I., and Xiao,J., 2020, Fruits byproducts-A source of valuable active principles. *J.Frontiers in bioengineering and Biotechnology*, 8:319-25.

Fredes, A., Roselló, S., Beltrán, J., Cebolla- Cornejo, J., Pérez- de- Castro, A., Gisbert, C. and Picó, M. B., 2017, Fruit quality assessment of watermelons grafted onto citron melon rootstock. *J. Sci. Food Agric*., 97(5): 1646-1655.

Guiné, R.P.F. &Barroca, M.J. 2012. Effect of drying treatments on texture and color of vegetables (pumpkin and green pepper). *Food and Bioproducts Processing* 90: 58-63.

Guo, C., Yang, J., Wei, J., Li, Y., Xu, J. and Jiang, Y., 2003, Antioxidant activities of peel, pulp and seed fractions of common fruits as determined by FRAP assay. *Nutr Res*., 23(12): 1719-1726.

Haile, F., Admassu, S. & Fisseha, A. 2015. Effect of pre-treatments and drying methods on chemical compositon, microbial and sensory quality of orange-fleshed sweet potato flour and porridge. *American Journal of Food Science and Technology* 3: 82-88.

Hamrouni-Sellami, I., Wannes, W.A., Bettaieb, I., Berrima, S., Chahed, T., Marzouk, B. &Limam, F. 2011. Qualitative and quantitative changes in the essential oil of *Laurus nobilis* L. leaves as affected by different drying methods. *Food Chemistry* 126: 691-769.

Hoque, M. M. and Iqbal, A., 2015, Drying of watermelon rind and development of cakes from rind powder. *IJNRLS*., 2(1): 14-21.

Hsu, C.L., Chen, W.L., Weng, Y.M. & Tseng, C.Y. (2003). Chemical composition, physical properties, and antioxidant activities of yam flours as affected by different drying methods. *Food Chemistry*, 83, 85–92.

Ibrahim, S. E., Sulieman, A. M. E., Hassan, E. N., Ali, N. A., abd el hakeem, B. S., & Muhsin, A. M. A. A. 2021. Proximate Chemical Composition of Watermelon (Citrullus Vulgaris). *Plant Cell Biotechnol Mol Biol*, 114-121.

Lee, C. W., Oh, H. J., Han, S. H. and Lim, S. B., 2012, Effects of hot air- and freeze-drying methods on physicochemical properties of citrus 'hallabong' powders. *Food Sci. Biotechnol*., 21: 1633-1639.

Lee-Hoon, H., Mazaitul, A.S., Ishamri, I., Kamarul, A.M. 2016. Effect of Different Drying Conditions on Proximate Compositions of Red and Yellow Fleshed watermelon rind powders. *J. Agrobiotech*. 7:1-12.

Lee-Hoon, H., W.P. Pang., T.C. Tan., K.A. Mustafa. 2017. Effects of Drying Conditions on the Physicochemical and functional properties of Red and Yellow fleshed watermelon rind flour. *J. Fundamental Applied. Sci*. 9:898-923.

Li, S., Mao, X., Guo, L. and Zhou, Z. 2023. Comparitive analysis of the impact of three drying methods on the properties of *citrus reticulata* Blanco cv. Dahongpao Powder and Solid drinks. *J.Foods*. 12 (5) 232-250.

Louka, N. & Allaf, K. 2002. New process for texturizing partially dehydrated biological products using controlled sudden decompression to the vacuum: Application on potatoes. *Journal of Food Science* 67(8): 3033-3038.

Lowry, O. H., Rosebrough, N. J., Farr, A. L., and Randall, R. J., 1951, Protein measurement with the folin phenol reagent. *J. Biol. Chem.*, 19(3): 265–275.

Magda, R. A., Awad, A. M. & Selim, K. A. S. 2008. Evaluation of mandarin and navel peels as natural sources of antioxidant in biscuit. *Alex Journal of Food Science and Technology* Special Volume:75-82.

Maoto, M. M., Beswa, D. and Jideani, A. I., 2019, Watermelon as a potential fruit snack. *Int. J. Food Prop*., 22(1): 355-370.

Massri, M. and Labban, L., 2015, Comparison of different types of fertilizers on growth, yield and quality properties of watermelon (*Citrlluslanatus*). *Agric. Sci*., 13(2): 1113-1119.

Massri, M. and Labban, L., 2015, Comparison of different types of fertilizers on growth, yield and quality properties of watermelon (*Citrlluslanatus*). *Agric. Sci*., 13(2): 1113-1119.

Milton, D.L., Johnson, T.W., Johnson, K., Murphy, B., Carter, H., Hurt, R.T., Mundi, M.S, Epp, L., Spurlock, Y. and Hussey, J., 2020, Accepted Safe Food-Handling Procedures Minimizes Microbial Contamination of Home-Prepared Blenderized Tube-Feeding. *J.Nutri.Clin.Prac.*0(0) 1-8.

Mishra, P., Srivastava, V., Verma, D., Chauhan, O.P. and Rai, G.K., 2009, Physico-Chemical Properties of Chakiya Hybrid of Amla (Emblica Officinalis) and effect of different dehydration methods on quality of powder. *Afr.J.Food Sci.* 3(10). 303-306.

Mohan, A. and Shanmugam, S., 2016, Comparison of the nutritional, physico-chemical and anti-nutrient properties of freeze and hot air-dried watermelon (*Citrullus Lanatus*) rind. *Biosci. Biotechnol. Res. Asia*., 13(2): 1113-1119.

Movahhed M.K, Mohebbi M, Spray drying and process optimization of carrot-celery juice. 2016.*J. Food Process. Preserv*. 40:212–225.

Nadeem, M., Navida, M., Ameer, K., Iqbal, A., Malik, F., Nadeem, M.A., Fatima, H., Ahmad, A. and Din, A., 2022, A comprehensive review on the watermelon phytochemical profile and their bioactive and therapeutic effects. *Korean Journal of Food Preservation*. 29(4) 546-576.

Nomura K, Ogasawara Y, Uemukai H, Yoshida M. 1994. Change of sugar content in chestnut during low temperature storage. Postharvest Physiology of Fruits, 1994, 398:265-276.

Obasi N. E., Unamma N C, Nwofia G E. 2014. Effect of dry heat pre-treatment (toasting) on the cooking time of cowpeas (Vigna unguiculata L. Walp). *Nigerian Food Journal*, 32(2):16-24.

Olayinka, B. U. and Etejere, E. O., 2017, Proximate and chemical compositions of watermelon (*Citrullus lanatus* (*Thunb*.) Matsum and Nakai*cv*. red and cucumber (*Cucumis sativus* L. *cv*. Pipino). *Int. Food Res. J*., 25(3).

Omotoso, O. T. &Adedire, C. O. 2007. Nutrient composition, mineral content and the solubility of the proteins of palm weevil, *Rhynchophorusphoenicis*. (*Coleoptera: Curculionidae*). *Journal of Zhejiang University-SCIENCE B (Biomedicine & Biotechnology)* 8*:* 318-322.

Onifade, T.B., Aregbesola, O.A., Ige, M.T. and Ajayi, A.O. 2013. Some Physical Properties and Thin Layer Drying Characteristics of Local Varieties of Tomatoes (Lycopersiconlycopersicum). *Agr. Bio. J. N. Am.*, 4(3) 275-279.

Qi, X., Cheng, L., Li, X., Zhang, D., Wu, G., Zhang, H., Wang, L. and Qian, H., 2019, Effect of cooking methods on solubility and nutrition quality of brown rice powder. *Food chem*., 274: 444-451.

Quek, S. Y., Chok, N. K. and Swedlund, P., 2007, The physicochemical properties of spray-dried watermelon powders. *Chem. Eng. Process.: Process Intensif*., 46(5): 386-392.

Radulović, M., Ban, D., Sladonja, B. and Lusetić-Bursić, V., 2007, Changes of quality parameters in watermelon during storage. In: *III International Symposium on Cucurbits*., *731*: 451-456.

Rouphael, Y., Cardarelli, M., Colla, G. and Rea, E., 2008, Yield, mineral composition, water relations, and water use efficiency of grafted mini-watermelon plants under deficit irrigation. *Hort. Sci*., 43(3): 730-736.

Sabeetha, S., Amin, I. and Nisak, M. B., 2017, Physico-chemical characteristics of watermelon in Malaysia. *J. Trop. Agric*., 45(2): 209-223.

Sadasivam, S. and Manickam, A., 2005, Biochemical methods*2^{nd}Edition*., *New Age International (P) Ltd.*, New Delhi.

Singh, D., Singh, R., Saini, J. S. and Singh, P. K., 2016, Morpho-biochemical characterization and D^2 analysis of watermelon (*Citrullus lanatus*) landraces from India and exotic germplasm. *Indian J. Agric. Sci*., 88(10): 1633-1639.

Tlili, I., Hdider, C., Lenucci, M. S., Ilahy, R., Jebari, H. and Dalessandro, G., 2011, Bioactive compounds and antioxidant activities during fruit ripening of watermelon cultivars. *J. Food Compost. Anal*., 24(7): 923-928.

Yimer, Z. S. and Tehulie, N. S., 2020, Nutritional composition of different varieties of watermelon (*Citrullus lanatus*) fruit at gewane, northeastern Ethiopia. *J. Curr. Res. Food Sci.*, 1(1): 16-22.

Yoo, K. S., Bang, H., Lee, E. J., Crosby, K. and Patil, B. S., 2012, Variation of carotenoid, sugar, and ascorbic acid concentrations in watermelon genotypes and genetic analysis. *Hortic. Environ. Biotechnol*., 53: 552-560.

Zubairu, A., Gimba, A. S., Mamza, W. J. and Highina, B. K., 2018, Proximate analysis of dry watermelon (*Citrulluslanatus*) rind and seed powder. *J. Sci. Eng. Res*., 5(3): 473-478.