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Exploring the Nutritional and Functional Value of Karonda (*Carissa carandas*): an Underutilized Fruit

Govindamma Bai M.[1], Nimala Devi G.[1*], Lakshmi K.[1] and Bhagyalakshmi K.[2]

[1]Dept. of Food Science and Nutrition, College of Community Science, ANGRAU, Lam, Guntur, Andhra Pradesh (522 034), India
[2]Dept. of Extension Education and Communication Management, ANGRAU-KVK, Amadalavalasa, Srikakulam, Andhra Pradesh (532 184), India

Corresponding Author

Nimala Devi G.
e-mail: g.nirmaladevi@angrau.ac.in

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Abstract

The experiment was conducted during July, 2024–September, 2024 at Department of Food Science and Nutrition, ANGRAU-College of Community Science, Lam, Guntur, Andhra Pradesh, India to assess the physicochemical, nutritional, and functional properties of karonda fruits at four developmental stages: immature, mature (half red–half white), red ripe, and purple ripe. Karonda (*Carissa carandas*), an underutilized fruit known for its nutritional and therapeutic potential. Fruit dimensions increased significantly during ripening, from 2.12×1.55 cm^2 (length×width) in immature fruits to 2.77×2.47 cm^2 in purple ripe fruits, along with an increase in fruit weight from 3.03 g to 6.24 g. Total soluble solids rose from 5.35°Brix to 9.26°Brix, while titratable acidity declined from 4.21% to 2.93%. Total sugars increased from 1.11% to 5.34%, and reducing sugars from 0.54% to 3.27%. Ascorbic acid showed a marked rise from 5.12 mg 100 g^{-1} to 34.28 mg 100 g^{-1} with ripening. Proximate composition revealed a decrease in crude fiber (1.66% to 0.75%) and fat (2.61% to 2.00%), while protein content increased from 0.40% to 0.91%. Functional properties improved substantially, as reflected by increases in total phenolics (68.22 to 179.10 mg GAE (100 g^{-1}), total flavonoids (134.74 to 242.44 mg RE (100 g^{-1}), FRAP (7.01 to 31.69 mg TE (100 g^{-1}), and DPPH activity (86.23 to 283.42 mg TE (100 g^{-1}). Strong positive correlations were found among phenolics, flavonoids, vitamin C, and antioxidant activity (r=0.86–0.98). These findings indicated that purple ripe karonda fruits possessed the highest nutritional and antioxidant value, supporting their potential use in functional foods, value-added products, and nutraceutical applications.

Keywords: Karonda, underutilized, antioxidants, value addition, brix, correlation, nutraceutical

1. Introduction

Underutilized fruit crops constitute an important yet insufficiently explored component of global horticultural biodiversity. Despite their substantial nutritional, medicinal, and economic significance, these fruits receive limited attention in terms of organized cultivation, commercialization, and scientific investigation. In India, several native species-including Karonda (*Carissa carandas*), Tamarind (*Tamarindus indica*), Jamun (*Syzygium cumini*), Wood apple (*Feronia limonia*), Ber (*Ziziphus mauritiana*), Chironji (*Buchanania lanzan*), Aonla (*Emblica officinalis*), and Bael (*Aegle marmelos*)-are widely available but remain underutilized.(Srivastava et al., 2017 and Pal et al., 2019). These fruits have long contributed to traditional food systems and offer considerable potential to address micronutrient deficiencies, enhance dietary diversity, and strengthen national nutritional security. Enhancing their utilization and developing value-added products could provide sustainable avenues for improving rural livelihoods and building resilience within local food systems, particularly in nutrient-insecure regions through scientifically informed interventions. Among these species, Karonda (*Carissa carandas* L.) is a promising yet underutilized fruit crop with significant horticultural and nutritional value. Native to the sub-Himalayan region and now widespread across tropical and subtropical India, it has traditionally been grown as a protective hedge due to its dense foliage, thorny branches, and strong tolerance to drought and heat. Its ornamental appearance further supports its use in rural landscapes. The fruit exhibits a notable color transition-from white to pink to deep purple-as it ripens, reflecting corresponding biochemical and nutritional changes that highlight its dynamic physiological nature and adaptive capacity. Karonda is known by various vernacular names across India, such as Karonda

(Hindi), Karvand (Marathi), Vakkay (Telugu), Kilaakkaai (Tamil), Karamardaka (Sanskrit), and Koromcha (Bengali). In English, it is commonly referred to as Bengal currant or Christ's thorn. The genus Carissa includes about 32 species, of which five-C. carandas, C. spinarum, C. congesta, C. edulis, and C. grandiflora-are recognized for their economic and nutritional relevance within India (Meena et al., 2020). The crop is predominantly distributed in Maharashtra, Bihar, West Bengal, Gujarat, Madhya Pradesh, Odisha, Rajasthan and Uttar Pradesh. Nutritionally, Karonda is recognised as a rich source of iron, vitamin C, vitamin A, and B-complex vitamins. It also contains significant amounts of minerals such as calcium, phosphorus, potassium, sodium, and sulfur. Recent phytochemical studies have identified bioactive compounds with antioxidant, hepatoprotective, and anti-hyperglycemic properties (Singh et al., 2012; Ahuja et al., 2024). These insights strengthen its traditional medicinal applications and highlight potential as a functional food capable of supporting micronutrient supplementation and promoting preventive healthcare practices effectively for communities. Despite its nutritional value and adaptability, Karonda remains underutilized due to significant post-harvest challenges. Its high moisture content and delicate pericarp make the fruit highly susceptible to microbial spoilage and physical damage. Consequently, it becomes extremely perishable, limiting storage life and reducing marketability, especially for long-distance trade. Limited awareness of scientific processing methods among rural and tribal communities further increases post-harvest losses (Meena et al., 2022). Moreover, the lack of standardized value-addition technologies restricts its processing potential and prevents the fruit from entering organized commercial markets effectively. Promoting the development of value-added products-dried raisins, jams, pickles, jellies, and fermented beverages-can significantly enhance the fruit's market potential and economic value. Additionally, understanding its physicochemical characteristics, including size, shape, surface area, density, and moisture-dependent behavior, is crucial for designing efficient grading, cutting, pulping, and deseeding equipment to support large-scale processing. In view of these limitations and opportunities, a comprehensive scientific assessment of Karonda is necessary. Therefore, the present study aimed to evaluate the nutritional composition, functional properties, and potential applications of *Carissa carandas*, with the broader goal of promoting its value addition and advancing public health and agro-industrial sustainability.

2. Materials and Methods

The experiment was conducted during July, 2024–September, 2024 at Department of Food Science and Nutrition, ANGRAU-College of Community Science, Lam, Guntur, Andhra Pradesh. For present study, Karonda berries of various maturity stages were collected based on colour. Immature fruits (white coloured), mature fruits (Half Red, Half White), Red ripe and Purple ripe fruits were collected from orchards maintained by local farmers and all other ingredients from local market.

2.1. Physicochemical analysis

Twenty mature fruits were selected randomly from each accession to record observation on morphological and biochemical parameters. Fruit size (length and girth) was measured with the help of digital vernier calliper, while fruit weight was taken by digital balance. Seed number, fruit volume, and density was taken as per standard procedures

The total soluble solids (TSS) were determined with Ranganna (1986) method using Erma Hand Refractometer (0–32°Brix). The titratable acidity (%) Baur and Ensminger 1977 and ascorbic acid content (mg 100 g^{-1}) were determined.

2.2. Determination of nutritional composition of Karonda

The proximate analysis was a quantitative method to determine different macronutrients present in Karonda. Basically it was the partition of root compounds into various categories such as moisture (g %), crude protein (g %), fats (g %), ash (g %), crude fiber (g %),carbohydrate (g %), and energy (K.cal). The proximate analysis was estimated as per Baur and Ensminger (1977) for karonda and its maturity stages

2.3. Functional properities

Antioxidant activity and Total phenolic content (TPC) of fruit pulps extracts Hydrophilic and lipophilic extracts of fruit pulps were analysed for antioxidant activity by ABTS radical scavenging assay, DPPH radical scavenging assay and FRAP as described by George et al., 2022). The extracts total carotenoids as described by (Baur and Ensminger, 1977)

2.4. Statistical analysis

The data related to physico-chemical characteristics and antioxidant activity of the samples was analysed using statistical design CRD with equal number of observations as per the method of Snedecor and Cochran (1994). The bivariate correlation between total phenolic content, Vitamin C and antioxidant activity measured using different methods were analysed. The differences in the means of each agronomic trait between accession were compared using ANOVA (analysis of variance), while mean values were used for analysis of variance

3. Results and Discussion

Utilization of fruits for consumption or processing is largely influenced by their physicochemical properties. Therefore, characterization of karonda fruits at different developmental stages is essential for improving their utilization and for developing value-added products. The physicochemical attributes of ripe and unripe karonda fruits evaluated in the present study are summarized below.

3.1. Physical characteristics

Karonda fruits at four developmental stages-immature, mature (half-red, half-white), red ripe, and purple ripe (Plate 1) were assessed, and the results are presented in Table 1.

Table 1: Physical parameters of karonda fruit at various stages of development

Developmental stages	Physical characteristics of karonda fruits									
	Fruit length (cm)	Fruit width (cm)	Fruit shape index	Mean fruit weight (g)	Pulp weight fruit^{-1} (g)	Seed number Fruit^{-1}	Seed weight Fruit^{-1} (g)	Pulp to seed ratio	Fruit volume (ml)	Density (g ml^{-1})
Immature	2.12	1.55	1.36	3.03	2.25	3.18	0.14	21.64	2.10	1.44
Mature (half red half white)	2.57	2.28	1.13	5.47	5.34	7.63	0.35	15.26	5.26	1.03
Red ripe	2.70	2.35	1.14	5.58	5.45	7.69	0.39	13.97	5.69	0.98
Purple ripen	2.77	2.47	1.12	6.24	5.88	7.69	0.43	13.67	6.38	0.97
SEm±	0.01	0.13	0.07	0.04	0.02	0.13	0.01	0.99	0.06	0.01
CD (*p*=0.05)	0.04	0.33	0.17	0.11	0.06	0.32	0.04	2.43	0.16	0.04
CV	1.27	11.18	10.13	2.28	1.50	11.69	14.84	11.40	3,34	2.75

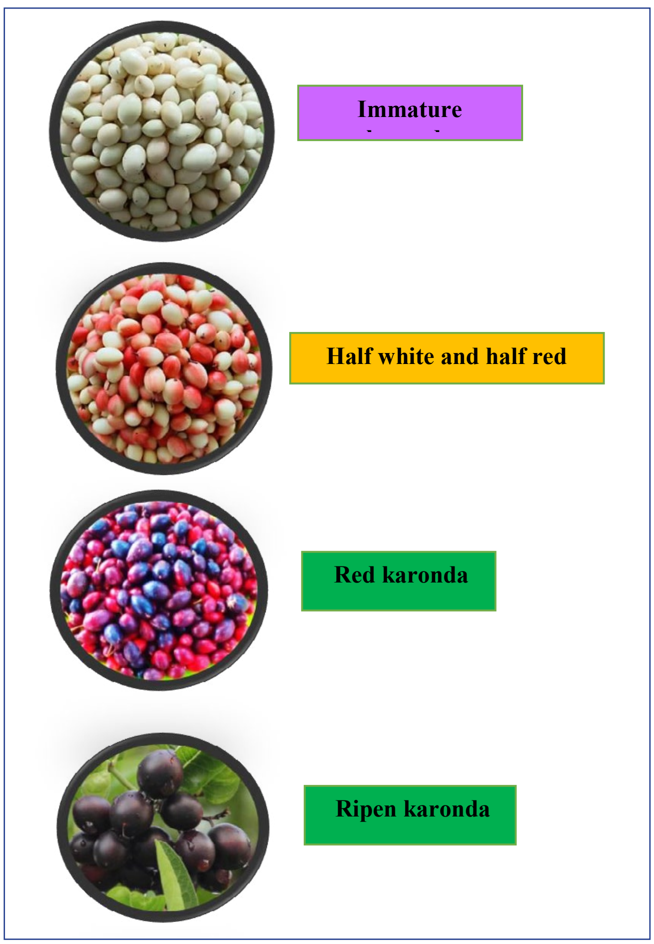

Plate 1: Karonda fruit at various stages of development

Fruit length increased significantly from 2.12 cm (immature) to 2.77 cm (purple ripe), while fruit width increased from 1.55 cm to 2.47 cm over the same stages. The fruit shape index was highest in immature fruits (1.36) and decreased slightly from the mature (1.13) to ripe (1.12) stages. The observed increase in fruit length and width during development might be attributed to the accumulation of biochemical constituents. Similar trends have been reported by Singh et al. (2025) and Senger et al. (2023)

Mean fruit weight increased significantly with ripening, ranging from 3.03 g (immature) to 6.44 g (purple ripe). Pulp weight also increased steadily from 2.25 g to 5.88 g across the same stages. This natural increase in fruit and pulp weight could be attributed to rapid physiological processes such as cell multiplication and enlargement, which enhanced biomass accumulation as fruits act as physiological sinks**.** These findings were consistent with earlier reports by Singh et al. (2025)

Seed number was lowest in immature fruits (3.18) and increased with maturity. This may be due to immature seeds adhering to each other. Although seed number did not differ significantly between mature and ripe fruits, seed weight increased significantly from 0.14 g in immature fruits to 0.43 g in purple ripe fruits. Correspondingly, the pulp-to-seed ratio decreased from 21.64 to 13.67, which might be attributed to the increase in seed weight. These results aligned with the findings of Senger et al. (2023).

Fruit volume also increased significantly during development, with values of 2.10, 5.26, 5.69, and 6.38 ml recorded for immature, mature, red ripe, and purple ripe fruits, respectively. Fruit density decreased from 1.44 g ml^{-1} (immature) to 0.97 g ml^{-1} (purple ripe). Similar trends were reported by Megha et al. (2024), Sabale et al. (2024), Senger et al. (2023), Nicoli et al. (1999).

Overall, the study revealed considerable morphological variation across the developmental stages of karonda fruits. Comparable variations in physical parameters have been documented by Sabale et al. (2024) who reported progressive increases in fruit weight across five defined maturity stages of Kair fruits. Ndou et al. (2019**)** also reported similar developmental changes in Natal plum (*Carissa macrocarpa*) across distinct maturity stages (M_1–M_5).

3.2. *Chemical characteristics of karonda fruits at various stages of development*

Karonda fruits at four developmental stages-immature, mature (half red–half white), red ripe, and purple ripe-were evaluated for their chemical characteristics (Table 2).

The results indicated a steady increase in pH with ripening, from 2.63 in immature fruits to 3.16 in purple ripe fruits. Total soluble solids (TSS) also increased significantly across all stages, rising from 5.35°Brix (immature) to 9.26°Brix (purple ripe). This increase might be attributed to the release of water-soluble compounds and the conversion of starch to sugars during ripening. A similar rise in TSS across maturity stages has been reported by Singh et al. (2025) and, Ranasinghe and Marapana (2019)

Table 2: Chemical characteristics of karonda fruits at various stages of development

Developmental stages	Chemical characteristics of karonda fruits						
	pH	TSS (˚Brix)	Titrable acidity (%)	Total sugars (%)	Reducing sugars (%)	Iron (mg 100 g^{-1})	Ascorbic acid
Immature	2.63	5.35	4.21	1.11	0.54	1.88	5.12
Mature (Half red half white	2.73	6.29	3.77	2.24	1.22	3.76	11.21
Red ripe	2.82	7.43	3.27	3.0	2.24	3.88	20.13
Purple ripe	3.16	9.26	2.93	5.34	3.27	3.97	34.28
SEm±	0.02	0.14	0.14	0.02	0.01	0.04	0.10
CD (*p*=0.05)	0.06	0.35	0.34	0.06	0.04	0.12	0.25
CV	1.40	7.99	16.33	0.90	1.52	3.01	0.90

Titratable acidity decreased progressively from 4.21% in immature fruits to 2.93% in purple ripe fruits. This decline might be due to the rapid utilization of organic acids in respiration as fruits mature. Changes in TSS and acidity were typically associated with cell wall degradation and starch hydrolysis, contributing to reduced sourness and increased sweetness during ripening. Similar decreasing trends in acidity have been documented by Ranasinghe and Marapana (2019) and Balamaze et al. (2019) also reported decreasing acidity in jackfruit, although differences among later maturity stages were minimal.

Total sugars increased significantly from 1.11% in immature fruits to 5.34% in purple ripe fruits. This pattern aligned with reports by Devi and Singh (2023), Reducing sugars showed a similar trend, rising from 0.54% to 3.27% across the developmental stages. Comparable increases in reducing sugars during ripening have been observed by Ranasinghe and Marapana (2019) and Balamaze et al. (2019)

Iron content varied significantly among the stages, increasing from 1.88 mg 100 g^{-1} (immature) to 3.97 mg 100 g^{-1} (purple ripe). The highest iron concentration was recorded in purple ripe fruits, which was statistically similar to red ripe fruits but significantly higher than the immature and mature stages. These results were consistent with findings by Devi and Singh (2023) who also reported increasing iron levels with ripening.

Ascorbic acid content increased markedly during development, ranging from 5.22 mg 100 g^{-1} in immature fruits to 34.28 mg 100 g^{-1} in purple ripe fruits. This increasing trend agrees with the observations of Ndou et al. (2019).

3.3. *Proximate composition of karonda fruits at various stages of development*

The proximate composition of karonda fruits at four developmental stages-immature, mature (half red–half white), red ripe, and purple ripe-was evaluated, and the results were presented in Table 3. Moisture content ranged from 86.81% to 88.80% across the stages, with a slight increase at the onset of ripening. Moisture was highest in immature fruits (88.80%), decreased at the mature and red ripe stages (86.81% and 86.89%), and increased again in the purple ripe stage (87.78%). Similar moisture patterns have been reported by Devi and Singh (2023), Senger et al. (2023) in karonda and Ranasinghe and Marapana (2019) in jackfruit. These fluctuations were expected due to hydrolysis of carbohydrates into sugars during ripening, which enhances osmotic movement of moisture toward the pulp. Moisture acts as a solvent for salts and sugars, influencing flavor development; thus, the slight increase during ripening might contribute to improved taste and aroma.

Protein content increased significantly from the immature (0.40%) to the red ripe stage (0.91%), followed by a slight decline at the purple ripe stage (0.88%). The rise in protein content during ripening might be attributed to the transcriptional activation of mRNA involved in enzyme synthesis required for ripening processes (Devi and Singh 2023), Red ripe and purple ripe fruits did not differ significantly in protein content. Similar patterns have been observed by Patel and Rao (2013) in karonda and by Kumar and Thimmaiah (2018**)** in banana cultivars at different maturity stages.

Fat content declined progressively from 2.61% in immature fruits to 2.00% in purple ripe fruits. This reduction during maturation and ripening was consistent with findings in banana varieties reported by Kumar and Thimmaiah (2018). Despite the decline, the relatively high fat content of karonda

Table 3: Proximate composition of karonda at various stages of development							
Developmental stages	Proximate composition of karonda fruits (g %)						
	Moisture	Protein	Fat	Ash	CF	CHO	Energy (Kcal)
Immature	88.80	0.40	2.61	0.21	1.66	6.32	50
Mature (Half red half white	86.81	0.77	2.50	0.53	1.52	7.87	57
Red ripe	86.89	0.91	2.47	0.66	1.00	8.07	58
Purple ripe	87.78	0.88	2.00	0.58	0.75	8.01	53
SEm±	0.18	0.10	0.04	0.02	0.04	0.07	0.16
CD (p=0.05)	0.62	0.36	0.16	0.09	0.15	0.22	0.24
CV	0.36	8.21	2.58	3.45	5.43	1.12	1.13

suggested the presence of fat-soluble vitamins and a potential contribution to dietary caloric intake Saeed et al., 2024

Ash content varied significantly among the stages, recording values of 0.21%, 0.53%, 0.66%, and 0.58% in the immature, mature, red ripe, and purple ripe fruits, respectively. The overall increase in ash content from immature to red ripe stages reflects the accumulation of mineral constituents in the fruit during development. Similar increases have been reported in apricot (Alexa et al., 2018) and in banana genotypes (Kumar and Thimmaiah, 2018).

Crude fiber content decreased steadily with ripening, from 1.66% in immature fruits to 0.75% in purple ripe fruits. This decline might be associated with the enzymatic breakdown of structural polysaccharides during maturation. Fiber played an important role in human health by aiding digestion, glucose regulation, and toxin elimination. The observed reduction in fiber content during ripening agreed with the findings of Mahmood et al. (2013) in cherry, and Kumar and Thimmaiah (2018) in banana.

Carbohydrate content increased from 6.32% in immature fruits to higher levels at subsequent stages, with the mature stage showing a significant rise comparable to red ripe and purple ripe fruits. This increase reflected the accumulation of sugars and other carbohydrates during ripening. Similar trends in carbohydrate buildup have been documented in snake tomato (Bamidele and Fasogbon, 2017) and apricot (Alexa et al., 2018)

3.4. Functional properties of karonda fruits at various stages of development

The functional properties of karonda fruits were assessed at four developmental stages-immature, mature (half red–half white), red ripe, and purple ripe-and the results were summarized in Table 4. The evaluated parameters included ascorbic acid, total phenolics, total flavonoids, ferric reducing antioxidant power (FRAP), and DPPH radical scavenging activity. All parameters exhibited significant differences among the stages (p≤0.05).

Ascorbic acid content increased progressively with ripening, from 6.67 mg 100 g^{-1} in immature fruits to 41.58 mg (100 g^{-1}) in purple ripe fruits. The significant increase in vitamin C might be attributed to enhanced biosynthesis or reduced enzymatic degradation during later stages of ripening. Similar trends were reported by Ndou et al. (2019) in Natal plum and Bhandari and Lee (2016) in tomato.

Total phenolic content also varied significantly across stages, with values of 68.22, 25.50, 132.84, and 179.10 GAE mg (100 g^{-1}) for the immature, mature, red ripe, and purple ripe stages, respectively. The marked increase in phenolic content during ripening might result from the enhanced biosynthesis of

Table 4: Functional properties of karonda fruits at various stages of development					
Stage of development	Ascorbic acid (mg 100 g^{-1})	Total phenols (GAE mg 100 g^{-1})	Total flavonoids (RE mg (100 g^{-1})	FRAP (TE mg 100 g^{-1})	DPPH (TE mg 100 g^{-1})
Immature	6.67	68.22	134.74	7.01	86.23
Mature (Half red half white)	12.87	125.50	158.67	9.42	170.98
Red ripe	37.09	132.84	206.93	10.64	228.96
Purple ripe	41.58	179.10	242.44	31.69	283.42
SEm±	0.18	0.04	0.02	0.04	0.07
CD (p=0.05)	0.62	0.16	0.09	0.15	0.22
CV	0.36	2.58	3.45	5.43	1.12

phenolic precursors and the accumulation of anthocyanins and other pigment compounds. These findings aligned with earlier reports by Berwal (2018), Azeez et al. (2016) and Schulz et al. 2015. Similar increasing trends across ripening stages have been documented in jamun, black currant, apricot (Fernández-Poyatos et al., 2021, Alexa et al., 2018), and banana varieties (Kumar and Thimmaiah, 2018).

Total flavonoid content increased significantly ($p \leq 0.05$) with fruit maturity, ranging from 134.74 RE mg (100 g)$^{-1}$ at the immature stage to 242.44 RE mg 100 g^{-1} at the purple ripe stage. The rise in flavonoids corresponds to the progressive synthesis of pigment compounds and antioxidants throughout ripening. Flavonoids contributed to fruit coloration and antioxidant potential, and their accumulation might be related to the conversion of flavanones to anthocyanins. Comparable trends were observed by Mahmood et al. (2013) in cherry fruits and Francini et al. (2021) in apple varieties.

Antioxidant activity, evaluated using FRAP and DPPH assays, increased markedly during fruit development. FRAP values rose from 7.01 TE mg 100 g^{-1} at the immature stage to 31.69 TE mg 100 g^{-1} at the purple ripe stage, indicating a significant enhancement ($p \leq 0.05$) in reducing power with ripening. This increase closely paralleled the rise in phenolic and flavonoid contents, supporting the role of these compounds as major contributors to antioxidant capacity. These observations were consistent with the findings of Azeez et al. (2016), who reported the highest antioxidant activity in purple-stage karonda fruits.

DPPH radical scavenging activity exhibited a similar trend, increasing from 86.23 TE mg 100 g^{-1} (immature) to 283.42 TE mg 100 g^{-1} (purple ripe). The enhanced scavenging capacity at advanced stages reflected the simultaneous increases in ascorbic acid, phenolics, and flavonoids. Comparable ripening-related increased in antioxidant activity have been reported in other antioxidant-rich fruits such as Morus alba and Phyllanthus emblica.

3.5. Correlation analysis of functional properties of karonda fruits

Correlation analysis was performed to determine the interrelationships among the functional properties of Carissa carandas fruits at different developmental stages. Pearson's correlation coefficients (r-values) were calculated between antioxidant parameters (DPPH) and other functional components, including ascorbic acid, total phenols, total flavonoids, and FRAP values. The results were summarized in (Figure 1).

A clustered correlation heatmap combined with hierarchical clustering (Ward's method) was used to assess the interrelationships among ascorbic acid, total phenols, total flavonoids, FRAP, and DPPH across developmental stages of karonda fruits. The reordered correlation matrix and associated dendrogram revealed a distinct clustering of total phenols, total flavonoids, and DPPH activity, all showing very strong positive correlations (r>0.95). This close grouping indicated that these antioxidant traits accumulate in a coordinated manner during fruit maturation.

Ascorbic acid also exhibited strong associations with total phenols (r=0.86), total flavonoids (r=0.98), and DPPH activity (r=0.95), positioning it adjacent to the main phenolic cluster and suggesting partially overlapping metabolic pathways. In contrast, FRAP formed a separate branch and showed comparatively lower correlations (r=0.73–0.85), implying that FRAP reflected broader redox mechanisms beyond those captured by phenolic and ascorbic acid levels.

Overall, the clustering pattern demonstrated that biochemical maturation in karonda fruits was marked by a synchronized increase in phenolic-based antioxidant attributes, while FRAP represented a more complex antioxidative response. These results highlighted the enhanced antioxidant potential of fully ripe karonda fruits and emphasized their value as a promising source of natural bioactive compounds

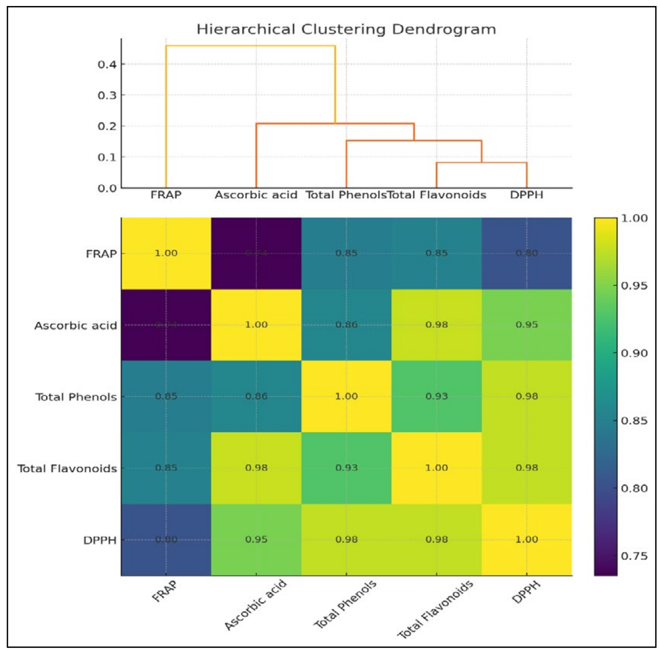

Figure 1: Correlation analysis of functional properties of karonda fruits

4. Conclusion

Fully ripe purple karonda showed major improvements in physicochemical, nutritional, and functional qualities, including higher soluble solids, sugars, ascorbic acid, phenolics, flavonoids, and antioxidant activities. Strong correlations among these bioactive compounds indicated coordinated accumulation that boosted antioxidant potential, making ripe karonda a valuable natural source of health-promoting nutrients.

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