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Nutritional characterization of fruits from selected mulberry accessions for functional food potential

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Abstract
Mulberry fruits are gaining increasing attention as functional foods owing to their rich nutrient profile and associated health-promoting properties. The present study evaluated the nutritional composition of fruits from fifteen mulberry accessions with respect to carbohydrates, protein, fat and vitamin C content. Significant variability was observed among the accessions, highlighting their diverse nutritional potential. The carbohydrate content ranged from 10.43% (MI-0657) to 21.43% (MI-0300), indicating a broad spectrum of energy-yielding capacity among accessions. The protein levels varied between 1.10% (MI-0715) and 2.67% (MI-0632), demonstrating the potential of certain accessions as moderate protein sources. The fat content, although generally low, showed notable differences, ranging from 0.21% (MI-0555) to 0.92% (MI-0783). The vitamin C, an essential antioxidant, also displayed considerable variation, with MI-0715 recording the lowest (10.10 mg/100 g) and MI-0300 the highest (19.77 mg/100 g) content. The results emphasized the nutritional heterogeneity among mulberry accessions, which can be strategically utilized for dietary diversification and cultivar improvement programs. The accessions such MI-0300 and MI-0632, with superior carbohydrate, protein and vitamin C content, may serve as promising candidates for breeding and functional food development. The findings also suggest the potential of mulberry fruits as a natural source of antioxidants, micronutrients, and bioactive compounds that can support human health and nutrition.

Keywords: Mulberry, accessions, nutrition, carbohydrate, protein, vitamin C, fat

Introduction
Mulberry fruits (*Morus* species) represent one of the most nutritionally significant yet underutilized fruit crops globally, belonging to the family Moraceae and comprising approximately 68 species worldwide. The genus Morus includes economically important species such as *M. alba* L. (white mulberry), *M. nigra* L. (black mulberry) and *M. rubra* (red mulberry), which have been cultivated for centuries primarily for sericulture but are increasingly recognized for their exceptional nutritional and therapeutic properties. These aggregate fruits are characterized by their rich phytochemical composition, including anthocyanins, flavonoids, phenolic acids and essential nutrients that contribute to their functional food status (Sun *et al*., 2023) [10]. The nutritional composition of mulberry fruits exhibit remarkable variability among different genotypes, influenced by genetic factors, environmental conditions, harvest maturity and post-harvest handling practices (Tian *et al*., 2025) [14]. This compositional diversity presents both opportunities and challenges for commercial exploitation and breeding programs aimed at developing nutritionally superior cultivars. Carbohydrates constitute the primary macronutrient component in fresh as well as dry mulberry fruits, typically ranging from 10-26% depending on the variety and maturity stage, making them significant sources of readily available energy (Tantray *et al*., 2021) [11]. The protein content, though relatively modest compared to other macronutrients provides essential amino acids that complement the overall nutritional profile (Ramappa *et al*., 2020) [7]. The lipid content in mulberry fruits is characteristically low, generally below 1%, which contributes to their low-calorie appeal and suitability for various dietary applications (Yuan and Zhao, 2017) [17]. However, the lipid fraction contains valuable fatty acids that contribute to the fruit's nutritional density.

The vitamic C (ascorbic acid) stands out as a particularly significant component, with concentrations often exceeding those found in many conventional fruits, thereby positioning mulberry as an excellent source of this essential antioxidant (Yang *et al*., 2010) [16]. India maintains one of the world's largest collections of mulberry germplasms, with over 1,300 accessions preserved in Central Sericultural Germplasm Resources Centre (CSGRC) in Hosur, representing a valuable genetic resource for nutritional improvement and commercial development (Thriveni *et al*., 2021) [13]. The genetic diversity within these collections offers unprecedented opportunities to identify superior genotypes with enhanced nutritional profiles suitable for functional food applications and nutraceutical development. However, comprehensive biochemical characterization of these genetic resources remains incomplete, limiting their optimal utilization in breeding programs and commercial applications.

Materials and Methods

The fifteen mulberry accessions were selected for the study. The fruits were harvested from the fifteen mulberry accessions from the Mulberry Germplasm Garden, Department of Sericulture, Forest College and Research Institute, Mettupalayam in the period of October to November. The collected mulberry fruits were stored in the refrigerator for further use. The nutritional analysis was carried out in the PG laboratory.

Carbohydrates determination (%)

The total carbohydrate content was determined by Anthrone reagent method outlined by Tantray *et al*., 2021 [11].

Protein determination (%)

Protein content of the mulberry fruit was determined using Lowrys method (Imran *et al*., 2010) [5].

Fat determination (%)

Fat content was determined by the Soxhlet extraction method outlined by Jiang and Nie, 2015 [6].

Vitamin C determination (mg/100 g)

Ascorbic acid (Vitamin C) content was quantified by using the spectrophotometric method.

Results and Discussion

The present study results were mentioned in the Table 1. The carbohydrate content of mulberry fruits in the present study exhibited between 10.43 to 21.43% (Fig. 1) with MI-0300 showing the highest value, which was similar to the results obtained by Tantray *et al*. (2021) [11] who reported the carbohydrate content of mulberry fruits of Botutal (13.48%) and Ichinose (10.99%). The findings of Sangteerakiji *et al*. 2023 showed the higher content of carbohydrates in fully ripened (53.98%) and semi-ripened (55.40%) mulberry fruits from Thailand which was nearly twice the value, when compare to the present study results. This may be due to different climatic zones and environmental conditions. Similarly, Ali *et al*., 2023 [1] found that the carbohydrate content of mulberry fruits was 59.75% *per* 100 g of dry fruit. This result may insist that the carbohydrates content was comparatively higher in dry mulberry fruits than the fresh ones. The amount of protein content among the fruits of different accessions was fall in the range from 1.10 to 2.67% (Fig. 2) with the highest being recorded in MI-0632 which agree with the findings of Tantray *et al*. (2021) [11] who found the protein content of 2.51% in Goshoerami and 3.17% in Botatul variety. Similarly, Sangteerakiji *et al*. 2023 reported that the protein content in fully ripened mulberry fruits was recorded as 1.90% and in semi-ripened stage as 1.30% which supported the present findings. The lower protein content may found due to premature harvest of fruits. Gungor and Sengul (2008) [3] found lower protein contents of white mulberry genotype with the range of 0.82 to 0.89 g/100 g fresh weight which was slightly vary from the present findings. These slight variations may be due to different environmental conditions during fruit development. The fat content of the mulberry fruits ranged from 0.21 to o.92% (Fig. 3) in the present study with the accessions MI-0783 showing the highest amount which was in the line with the findings of Ercisli and Orhan (2007) [2] who reported the fat content of *M. nigra* (0.95%), *M. rubra* (0.85%) and *M. alba* (1.10%). Sangteerakiji *et al*. (2023) reported the fat content (1%) in mulberry fruits which supported the current study. Similarly, Imran *et al*. (2010) [5] and Jiang and Nie (2015) [6] reported the fat content of 0.48% and 0.40% respectively which agrees the current findings of the study. These results showed that there was a minute amount of fat present in the mulberry fruits. The present study revealed that the vitamin C content in the fruits of different mulberry accessions was in the range from 10.10 to 19.77 mg/100 g (Fig. 4) with the highest vitamin C content in MI-0300 which align with the findings of Ercisli and Orhan (2007) [2] who reported the vitamin C content of *M. alba* (22.4mg/100 g) and *M. rubra* (19.4 mg/100 g). The results also agrees with the findings of Imran *et al*. (2010) [5] who reported 15.20 to 17.03 mg/100 g of vitamin C in *M. alba*, *M. nigra* and *M. laevigata* from Pakistan. Similarly, Skrovanka *et al*. (2021) reported the vitamin C content among different black mulberry genotypes between 17.41 and 28.33 mg/100 g. The results showed that the mulberry fruits are the good source of vitamin C.

Table 1: Nutritional analysis of fruits of Mulberry accessions

S. No.	Mulberry accessions	Carbohydrates (%)	Protein (%)	Fat (%)	Vitamin C (mg/100g)
1	MI-0657	10.43 ± 0.25^{k}	1.37 ± 0.05^{gh}	0.29 ± 0.02^{i}	14.10 ± 0.20^{g}
2	MI-0789	16.87 ± 0.15^{d}	2.35 ± 0.11^{c}	0.84 ± 0.03^{b}	11.27 ± 0.21^{j}
3	MI-0478	13.20 ± 0.26^{gh}	1.53 ± 0.06^{f}	0.42 ± 0.04^{g}	16.37 ± 0.31^{d}
4	MI-0489	18.30 ± 0.26^{b}	1.36 ± 0.03^{h}	0.71 ± 0.03^{c}	14.30 ± 0.26^{g}
5	MI-0675	11.97 ± 0.15^{j}	1.63 ± 0.05^{e}	0.38 ± 0.02^{gh}	12.17 ± 0.25^{i}
6	MI-0715	13.87 ± 0.15^{f}	1.10 ± 0.02^{j}	0.31 ± 0.03^{i}	10.10 ± 0.20^{l}
7	MI-0555	12.97 ± 0.15^{hi}	1.59 ± 0.05^{ef}	0.21 ± 0.02^{j}	15.63 ± 0.21^{e}
8	MI-0300	21.43 ± 0.25^{a}	2.53 ± 0.03^{b}	0.64 ± 0.03^{d}	19.77 ± 0.31^{a}
9	MI-0252	12.93 ± 0.15^{hi}	1.41 ± 0.03^{gh}	0.47 ± 0.03^{f}	15.13 ± 0.57^{f}

10	MI-0632	17.30±0.20^{c}	2.67±0.04^{a}	0.72±0.02^{c}	18.13±0.21^{b}
11	MI-0783	15.30±0.26^{e}	2.38±0.03^{c}	0.92±0.03^{a}	17.20±0.30^{c}
12	MI-0818	12.00±0.20^{j}	1.44±0.03^{g}	0.52±0.03^{e}	14.07±0.25^{g}
13	ME-0006	13.53±0.15^{fg}	1.14±0.02^{ij}	0.23±0.04^{j}	12.73±0.15^{h}
14	ME-0024	10.87±0.15^{k}	1.22±0.03^{i}	0.36±0.03^{h}	10.80±0.20^{k}
15	ME-0018	12.67±0.15^{i}	1.71±0.02^{d}	0.41±0.03^{gh}	16.13±0.25^{d}
SEd		0.16	0.04	0.02	0.22
CD (0.05)		0.33	0.07	0.05	0.46

Values are expressed in mean ± SD with three replications (n=3)

Means followed by different small superscript in a column are statistically different at $p \leq 0.05$

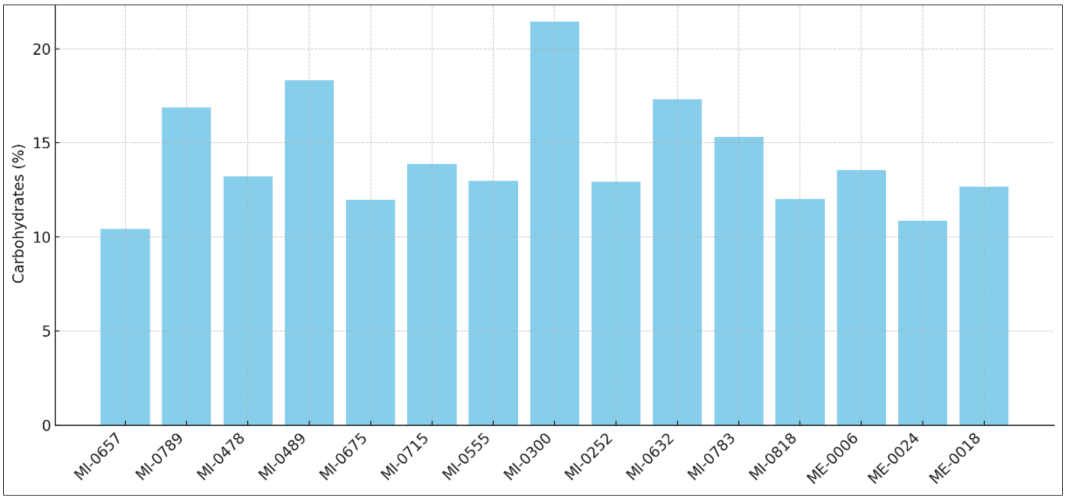

Fig 1: Carbohydrates content in the fruits of Mulberry accessions

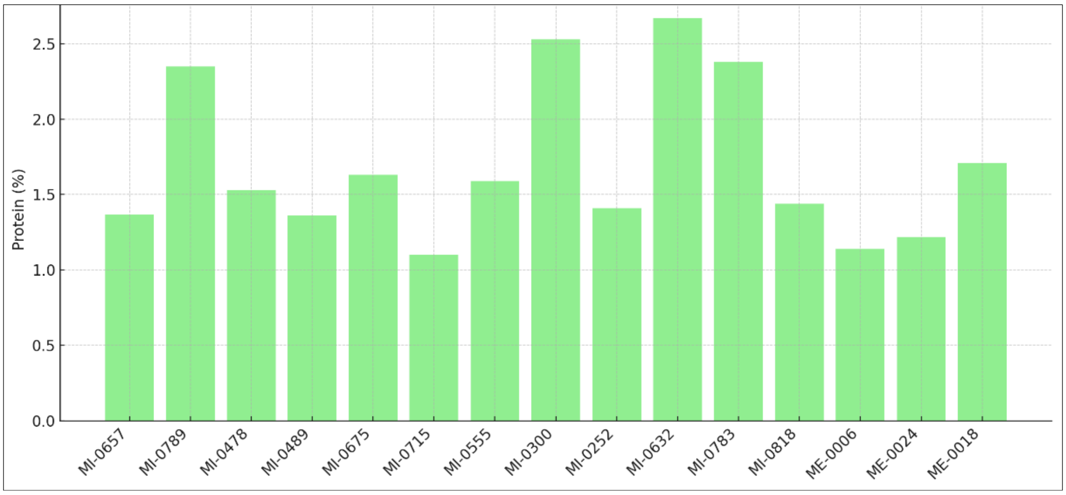

Fig 2: Protein content in the fruits of Mulberry accessions

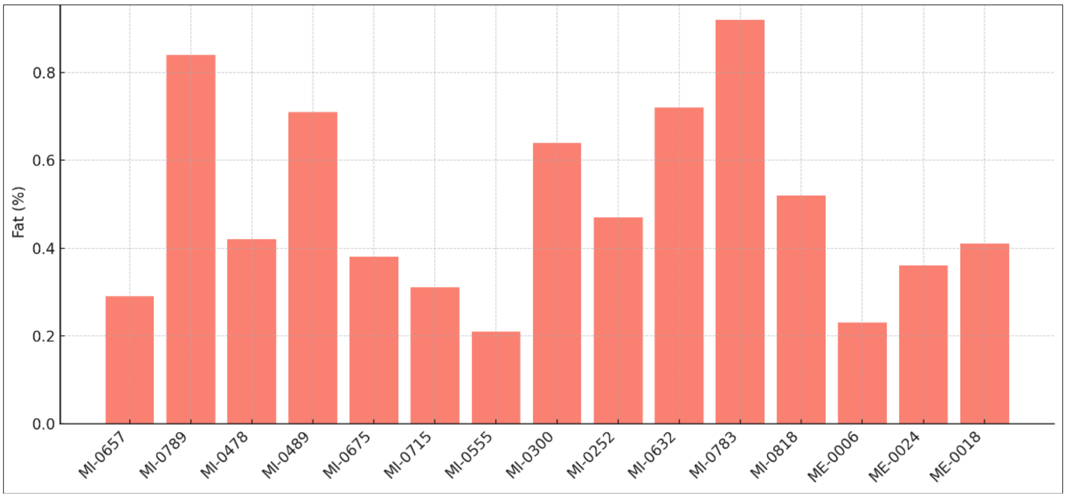

Fig 3: Fat content in the fruits of mulberry accessions

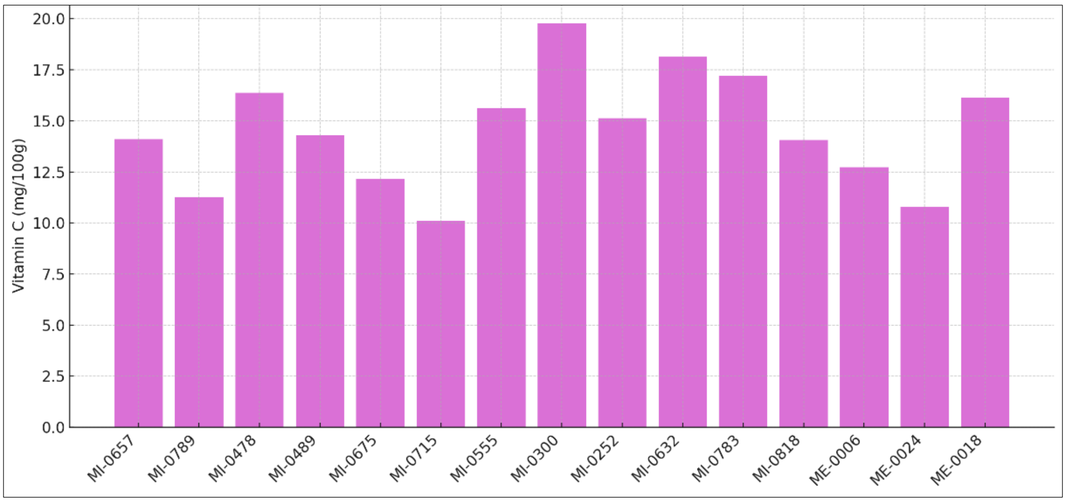

Fig 4: Vitamin C content in the fruits of mulberry accessions

Conclusion

These findings agreed broadly with previous reports while also demonstrated variation that may be attributed to genotype, harvest maturity and environmental conditions. Such variability emphasized the importance of evaluating diverse germplasm to identify nutritionally superior accessions for functional food and nutraceutical development. Carbohydrate levels ranged from 10.43 to 21.43%, confirming mulberry as a significant source of readily available energy, while protein content (1.10 to 2.67%) provided valuable amino acids contributing to the overall nutritional profile. The fat content remained consistently low, supporting the classification of mulberry as a low-calorie fruit with minimal lipid contribution, yet containing nutritionally relevant fatty acids. The accessions such as MI-0300 and MI-0632, which recorded higher carbohydrate, protein and vitamin C levels, emerge as promising candidates for further breeding and commercial utilization. Overall, the results confirmed that mulberry fruits, though underutilized, represent a valuable dietary resource with potential to contribute significantly to human nutrition and health.

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