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Evaluation of Physico-Chemical Characteristics of Different Ber Cultivars for Optimal Candy Production

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ABSTRACT

The present study was conducted to assess the physico-chemical properties of four Indian jujubes (Ziziphus mauritiana) cultivars—Gola, Kaithli, Umran, and Apple Ber to identify the most suitable cultivar for candy production. Fresh fruits were procured from the experimental orchard of the department of horticulture, CCSHAU, Hisar, during the 2023–24. The cultivars were evaluated based on key parameters, including total soluble solids (TSS), acidity, ascorbic acid content, chlorophyll, carotenoids, phenols, browning, and antioxidant activity. Significant varietal differences were observed, indicating the potential for selective utilization of specific fruit cultivars in processing industries for value addition. One of the main challenges encountered in the study was maintaining uniform post-harvest handling and minimizing variability due to environmental factors affecting fruit composition. Despite these challenges, significant varietal differences were observed, indicating the potential for selective utilization of specific fruit cultivars in processing industries. The findings contribute to the development of value-added products by identifying promising cultivars for candy production and supporting future research on underutilized fruits.

Keywords: *Ber Candy, Consumer acceptability, Fruits, Indian jujube, Nutritional Evaluation, Physico-chemical, Postharvest utilization, Processing, Product development, Value-addition, Varieties, Ziziphus mauritiana*

Introduction

Ber (*Ziziphus mauritiana*), an underutilized fruit commonly referred to as Indian jujube, is a tropical fruit known for its adaptability to harsh climatic conditions and high nutritional value. It is widely cultivated in arid and semi-arid regions of South Asia and has garnered interest for its rich content of vitamin C, polyphenols, and other bioactive compounds [23, 24]. It can be cultivated on a wide range of soil from shallow to deep, from gravely and sandy to clay soil. It can also grow on marginal soil that is unfit for cultivation. It can withstand saline and alkaline soil as well as in water-logged soil to some extent. Deep sandy loamy soils with good drainage capacity are ideal soil for ber cultivation.

The fruit has recently gained attention in processed forms such as candies, juices, and preserves due to increased consumer demand for natural and functional snacks. Among these, ber-based candies offer an innovative way to preserve the nutritional benefits of the fruit in a shelf-stable osmo-dehydrated form [19].

The physico-chemical attributes of raw ber fruits, such as total soluble solids (TSS), titratable acidity, ascorbic acid, phenolic content, and antioxidant activity, are crucial determinants of the final product's quality and sensory acceptability [23]. Variations among ber cultivars in these parameters significantly affect their suitability for specific processing purposes, including candy formulation. For instance, cultivars with higher TSS and moderate acidity are generally preferred for candy-making due to better flavor and stability [15]. Hence, this study aims to evaluate and compare the physico-chemical properties of selected ber cultivars to identify those most suitable for candy production. A detailed understanding of these characteristics will guide processing optimization and enhance the development of value-added ber products that align with the market demands for health, taste, and shelf life. It will also open new avenues for utilizing underutilized fruits in food processing applications.

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Material and Methods

Procurement of Materials

Fresh and matured fruits of four *Ziziphus mauritiana* cultivars Gola, Kaithli, Umran, and Apple Ber were harvested during the 2023–24 growing season from the Experimental Orchard of the Department of Horticulture, CCS Haryana Agricultural University (CCSHAU), Hisar. Different cultivars of ber fruits were handpicked at physiological maturity and analyzed for different physico-chemical parameters in the laboratory under ambient conditions.

Physico-Chemical Analysis

Physico-chemical analysis of fresh fruit samples was carried out in triplicate to assess key quality parameters. Total Soluble Solids (TSS) were determined at 20°C using a digital hand-held refractometer (0-32 °Brix) following the AOAC Official Method [2]. Titratable acidity was measured by titrating fruit juice against 0.1N NaOH using phenolphthalein as an indicator, with results expressed as percent citric acid equivalents, per AOAC Official Method [3].

Ascorbic acid content was estimated by the 2, 6-dichlorophenol indophenol dye titration method as per AOAC Official Method [4]. Total chlorophyll content was quantified following the method described by [7], where pigments were extracted using 80% acetone and absorbance was measured at 645 and 663 nm. Total carotenoids were extracted using acetone and petroleum ether and quantified spectrophotometrically at 450 nm based on the procedure outlined by [25].
Total phenolic content [25] was analyzed using the Folin-Ciocalteu colorimetric method with gallic acid as the standard, following AOAC Official Method [5]. Non-enzymatic browning was assessed by measuring the absorbance at 420 nm using a UV–Vis spectrophotometer. Finally, antioxidant activity was evaluated using the DPPH (2, 2-diphenyl-1-picrylhydrazyl) radical scavenging assay as described by [8], and the results were expressed as the percentage inhibition of DPPH radicals. All analyses were conducted in triplicate under controlled laboratory conditions, and results were statistically evaluated to ensure accuracy and reproducibility.

Results and Discussion

The results of the physico-chemical properties were evaluated for different ber fruit cultivars presented in Table 1 and Fig. 1. Considerable variations were noted among the cultivars in most of the tested parameters. The physicochemical attributes of ber (*Ziziphus mauritiana*) cultivars are critical in determining their suitability for candy production

Total Soluble Solids (TSS)

A considerable variation in total soluble solids (TSS) content was recorded among the four jujube cultivars, with Umran exhibiting the highest TSS value (18.40%), followed by Gola (17.60%), Kaithli (17.20%), and Apple Ber (15.90%). The TSS values of different ber cultivars ranged from 15.90±0.10 to 18.40±0.06 % (Table 1, Fig. 1). TSS is a vital quality parameter influencing the sweetness and overall palatability of fruits, thereby playing a key role in determining consumer preference and the suitability of cultivars for processing applications such as candy production. The elevated TSS content in Umran suggests a naturally sweeter profile, making it a promising option for confectionery products. In contrast, the lower TSS in Apple Ber may result in reduced sweetness, potentially diminishing its appeal in sweet-based processed products. These results are consistent with earlier findings by [30], who emphasized the desirability of high TSS in ber cultivars for value-added processing.
Genotypic differences and environmental influences on carbohydrate metabolism during fruit development are primary factors contributing to TSS variation among cultivars. A broad range of TSS content (12.5 to 24.2 °Brix) among jujube, underscoring the genetic diversity in sugar accumulation, was reported by [15]. Furthermore, environmental conditions such as temperature and light exposure significantly impact enzymatic activities related to sugar synthesis, consequently affecting TSS levels [1]. Beyond its role in sweetness, TSS is also linked with other critical fruit quality attributes, including texture and postharvest shelf life. Elevated TSS levels have been associated with improved fruit firmness and extended storage potential, traits that are advantageous for both fresh consumption and industrial processing [10].

Fig. 1 Morphological appearance of different ber cultivars analyzed for quality attributes.

Titratable Acidity (TA)

Titratable acidity among different varieties of ber varied from 0.36±0.32 to 0.51±0.32 %. (Table 1, Fig. 1). Likewise, in other fruits like jamun [26], Indian jujube [13], and grape berries [22], variation in titratable acidity was noted between different varieties. Similarly, titratable acidity among different cultivars of ber (*Z. mauritiana*), *viz.* Karela, Aakash, Pak white, and Dil-bahar was ranged from 2.96 % to 3.5 % [20]. Variation in titratable acidity of different ber varieties under the rainfed conditions of Jammu, which ranged from 0.28 to 0.72 %, was also observed by [16]. In the present study, titratable acidity among the four ber cultivars ranged from 0.36% in Umran to 0.51% in Kaithli, with no statistically significant differences observed.
Acidity is primarily attributed to organic acids such as malic and citric acids, which play a pivotal role in determining the fruit's flavor profile by influencing both tartness and overall palatability. A lower acidity levels, as observed in Umran (0.36%), are often associated with a milder taste, enhancing consumer acceptability—particularly in processed products like candies and preserves.
The balance between TSS and acidity is crucial for assessing fruit quality. A higher TSS to acidity ratio is indicative of better taste and is considered a desirable trait in ber cultivars intended for processing [1]. These findings align with those of [30], who highlighted the importance of lower acidity for improved sensory appeal and extended shelf life in processed ber products.
Previous research has shown that at commercial maturity, ber fruits exhibited a wide range of acidity values (0.13% to 1.42%), depending on genotype and environmental conditions [21]. Specifically, the Gola ber variety has been reported to have acidity levels ranging from 0.20% to 0.24%, which is consistent with the results observed in this study. Furthermore, twelve ber genotypes under sodic soil conditions were evaluated by [24], and acidity values ranging from 0.01% to 0.43 % were reported, suggesting that soil environment and cultivar selection

significantly influence organic acid composition.

Thus it can be inferred that low acidity observed in Umran enhances its suitability for processing, offering a more balanced and mellow flavor profile. These insights are valuable for targeted breeding and selection of cultivars intended for specific processing goals and consumer preferences.

Ascorbic Acid

A significant variation in ascorbic acid content was observed among the four ber cultivars. Indian jujube is a rich source of ascorbic acid, with concentrations ranging from 19.54 to 99.49 mg/100 g across 12 commercial cultivars as reported by [13]. Among different varieties, Apple Ber showed the highest ascorbic acid content (94.50 mg/100 g), followed closely by Kaithli (92.30 mg/100 g), Gola (84.50 mg/100 g), and Umran (77.60 mg/100 g) (Table 1, Fig. 1). These differences were statistically significant ($p \leq 0.05$), indicating inherent genetic variability among the cultivars. Ascorbic acid is a vital antioxidant contributing to the nutritional value of fruits. High ascorbic acid levels enhance the health benefits of fruit-based products and improve their market appeal. The elevated ascorbic acid content in Apple Ber and Kaithli suggests their potential for developing nutritionally enriched processed products.

Variations in ascorbic acid content among jujube cultivars have been documented in previous studies. Ascorbic acid levels ranging from 28.7 to 139.1 mg/100 g among different jujube genotypes, highlighting the influence of genetic factors on vitamin C accumulation, were observed by [15]. Furthermore, environmental conditions, cultivation practices, and maturity stages significantly affect ascorbic acid content. It was observed that ascorbic acid concentration in jujube fruits decreased from the young fruit stage to full maturity, emphasizing the importance of proper harvest timing in maximizing vitamin C content [33].

The high ascorbic acid content in Apple Ber and Kaithli aligns with findings from other studies. A study [11] reported vitamin C levels ranging from 225 to 820 mg/100 g fresh weight among 46 jujube cultivars, with certain cultivars exhibiting exceptionally high concentrations. These findings underscore the potential of selecting specific cultivars for developing functional foods rich in vitamin C.

Total Chlorophyll

A significant variation in total chlorophyll content was observed among the four ber cultivars. Apple Ber showed the highest total chlorophyll content of 14.19 µg/g, followed by Kaithli (11.21 µg/g), Gola (10.76 µg/g), and Umran (10.25 µg/g), with statistically significant differences ($p \leq 0.05$), suggesting inherent genetic variability (Table 1, Fig. 1).

Chlorophyll is the primary pigment responsible for green coloration and plays a vital role in photosynthesis. The higher chlorophyll content is associated with fresher appearance and may enhance consumer perception of quality in processed products. The high chlorophyll content in Apple Ber suggests the potential for producing green-hued, visually appealing processed items.

Previous studies have indicated that chlorophyll content in fruits varies significantly with cultivar, maturity stage, and environmental factors. A considerable variation in pigment concentration among different jujube cultivars was found by [10]. Similarly, [29] emphasized the influence of environmental stressors, such as mite infestation and leaf aging, on chlorophyll degradation. The value of chlorophyll monitoring in assessing fruit physiological status under stress was further demonstrated by [18].

Table 1 Physico-Chemical Analysis of Ber Cultivars (Mean ± SD)

Parameters	Gola	Kaithli	Umran	Apple Ber	CD ($p \leq 0.05$)
TSS (%)	$17.60^{b}\pm0.23$	$17.20^{b}\pm0.06$	$18.40^{a}\pm0.06$	$15.90^{c}\pm0.10$	0.28
Acidity (%)	$0.45^{b}\pm0.09$	$0.51^{b}\pm0.32$	$0.36^{b}\pm0.32$	$0.48^{b}\pm0.03$	NS
Ascorbic acid (mg/100 g)	$84.50^{c}\pm0.15$	$92.30^{b}\pm0.45$	$77.60^{d}\pm0.56$	$94.50^{a}\pm0.50$	0.61
Total chlorophyll (µg/g)	$10.76^{b}\pm0.21$	$11.21^{b}\pm0.43$	$10.25^{b}\pm0.57$	$14.19^{a}\pm0.17$	0.63
Total carotenoids (µg/100 g)	$20.13^{b}\pm0.27$	$21.11^{a}\pm0.20$	$18.21^{c}\pm0.11$	$14.13^{d}\pm0.23$	0.34
Total phenols (mg/100 g)	$82.30^{c}\pm0.03$	$86.44^{b}\pm0.02$	$90.17^{a}\pm0.05$	$81.15^{d}\pm0.03$	0.11
Browning (OD)	$0.20^{b}\pm0.01$	$0.22^{a}\pm0.02$	$0.18^{c}\pm0.01$	$0.21^{ab}\pm0.01$	0.02
Antioxidant activity (%)	$29.20^{c}\pm0.07$	$31.10^{b}\pm0.03$	$34.10^{a}\pm0.06$	$30.20^{cb}\pm0.05$	0.17

Total Carotenoids

Carotenoids are the key pigments that contribute to yellow and orange coloration in fruits and function as antioxidants with health-promoting properties. In this study, Kaithli recorded the highest carotenoid content (21.11 µg/100 g), followed by Gola (20.13 µg/100 g), Umran (18.21 µg/100 g), and Apple Ber (14.13 µg/100 g), showing statistically significant differences ($p \leq 0.05$) (Table 1, Fig. 1). Kaithli's superior carotenoid content suggests its suitability for developing brightly colored, nutritionally enriched fruit-based products. Carotenoids, particularly β-carotene, serve as precursors to vitamin A and enhance both the visual appeal and nutritional value of processed foods. Carotenoid accumulation is influenced by cultivar, light exposure, and physiological maturity. A significant variability in carotenoid levels across jujube cultivars was reported by [10]. Additionally, [9] documented carotenoid concentrations ranging from 4.12 to 5.98 mg/100 g dry weight in several *Ziziphus* species, supporting the current findings.

Total Phenolic Content

A significant variation in total phenolic content was observed among the four ber cultivars namely Gola, Kaithali, Umran, and Apple ber. The total phenolic content in different ber cultivars ranged from 81.15±0.03 to 90.17±0.05 mg/100g. Among the cultivars Umran showed the highest total phenolic content of 90.17 mg/100 g, Kaithli (86.44 mg/100 g), Gola (82.30 mg/100 g), and Apple Ber (81.15 mg/100 g), with statistically significant differences ($p \leq 0.05$), suggesting inherent genetic variability (Table 1, Fig. 1).

A statistically significant difference in total phenolic content among the fruits of six jujube varieties, ranging between 18.11–21.45 mg GAE/g DW, was observed by [34]. Phenolic compounds are known for their antioxidant properties, contributing to the health benefits and shelf life of fruit products. The elevated phenolic content in Umran suggests its potential for producing health-promoting and shelf stable candies.

Multiple studies have reported variations in phenolic content among *Ziziphus mauritiana* cultivars.

A total phenolic content ranging from 48.69 to 196.34 mg/100 g across 28 Indian jujube varieties was reported by [14], with differences attributed to genetic and environmental factors. Similarly, [12] highlighted the influence of cultivar type and environmental conditions on the phenolic content of fruits.

Antioxidant Activity

The antioxidant activity between different ber varieties ranged from 29.20±0.07 to 34.10±0.06 %. Antioxidant activity is primarily attributed to phenolic compounds, which are crucial for health benefits and preservation of fruit products. Total antioxidant activity ranging from 7.41 to 13.93 and 8.01 to 15.13 μmol Trolox/g in FRAP and CUPRAC, respectively, was reported by [13]. It was found that different ber (Indian jujube) varieties showed significant variations in antioxidant activity. These differences are mainly attributed to variations in total phenolic content (TPC) and total flavonoid content (TFC), which are key indicators of antioxidant capacity [31]. Among different cultivars Umran demonstrated the highest antioxidant activity of 34.10%, followed by Kaithli (31.10%), Gola (29.20%), and Apple Ber (30.20%), with statistically significant differences ($p \leq 0.05$) (Table 1, Fig. 1). The strong correlation between total phenolic content and antioxidant activity observed in this study aligns with the findings of [29], who reported a direct relationship between phenolic compounds and antioxidant capacity in jujube cultivars. Additionally, [32] demonstrated that higher phenolic content in jujube peel and pulp correlates with increased antioxidant activity, emphasizing the importance of phenolics in determining antioxidant potential.

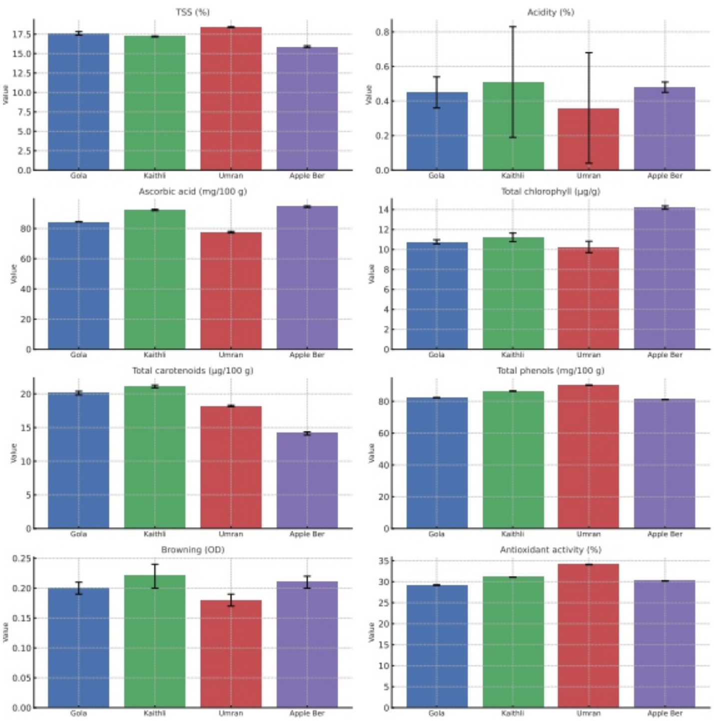

Fig. 1 Comparison of physicochemical attributes across different jujube cultivars

Browning Index

A significant variation in browning index was observed among the four *Ziziphus mauritiana* cultivars, which ranged from 0.18±0.01 to 0.22±0.02 OD. Among cultivars, Umran showed the lowest browning value (0.18 OD), followed by Gola (0.20 OD), Apple Ber (0.21 OD), and Kaithli (0.22 OD), with statistically significant differences ($p \leq 0.05$) (Table 1, Fig. 1). The minimal browning observed in Umran suggests a lower propensity for enzymatic discoloration during processing, making it favorable for maintaining product color and visual appeal in candy production.

Browning, measured as optical density (OD), is primarily attributed to the enzymatic oxidation of phenolic compounds by polyphenol oxidase (PPO), which leads to the formation of brown pigments such as melanins [28]. This reaction adversely affects the aesthetic and market value of fruit-based products. The extent of browning is influenced by phenolic content and PPO activity, which vary with cultivar and postharvest conditions [17].

The reduced browning index in Umran may reflect a lower PPO activity or a more stable phenolic profile, supporting its suitability for high-quality, visually appealing candy products. Similar trends have been reported by [27], who demonstrated that the browning index is a reliable indicator of visual degradation in processed fruit products and can guide cultivar selection for processing applications.

Conclusion

The comparative analysis of physico-chemical parameters of four *Ziziphus mauritiana* cultivars—Umran, Gola, Kaithli, and Apple Ber—revealed significant variability in their physicochemical and functional properties relevant to candy processing. Among all the cultivars, Umran stood out with the highest TSS, total phenol content, and antioxidant activity, along with the lowest browning index and acidity. These attributes underscore Umran's superior potential for producing visually appealing, sweet, and shelf-stable fruit-based candies with enhanced functional benefits. Conversely, Apple Ber recorded the highest ascorbic acid and chlorophyll content, suggesting its nutritional advantage and greener appearance, although its lower TSS may limit its appeal in sweet applications.

Kaithli showed the highest carotenoid levels, enhancing its prospects for producing brightly colored, vitamin A-rich products, while Gola maintained a moderate profile across most parameters. The observed differences among the cultivars can be attributed to genotypic variability and potential environmental influences. Overall, the findings emphasize that cultivar selection is critical in optimizing nutritional and sensory qualities of processed products. Among the tested cultivars, Umran emerged as the most promising ber variety for functional candy development, balancing sweetness, antioxidant potential, and color stability—key attributes sought by health-conscious consumers and the food processing industry. To select an appropriate ber cultivar is essential to enhance the quality, nutritional value, and consumer acceptance of ber-based confectioneries. These findings are significant for selecting optimal ber cultivars for processing industries focusing on value-added products like candies.

Future scope of the study

Future studies will be focus on optimizing the candy processing techniques for the selected cultivar and evaluating consumer acceptability, shelf-life stability, and nutritional retention in the final product.

Conflict of Interest

The authors declare no conflict of interest regarding this manuscript.

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AOAC Official Method 932.12 – Solids (Soluble) in Fruits and Fruit Products

AOAC Official Method 942.15 – Acidity (Titratable) of Fruit Products

AOAC Official Method 967.21 – Ascorbic Acid in Vitamin Preparations and Juices

AOAC Official Method 984.27 – Total Phenolics in Foods

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