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Unlocking the Bioactive Potential of Indian Jujube: A Key Ingredient for Functional Food Innovation

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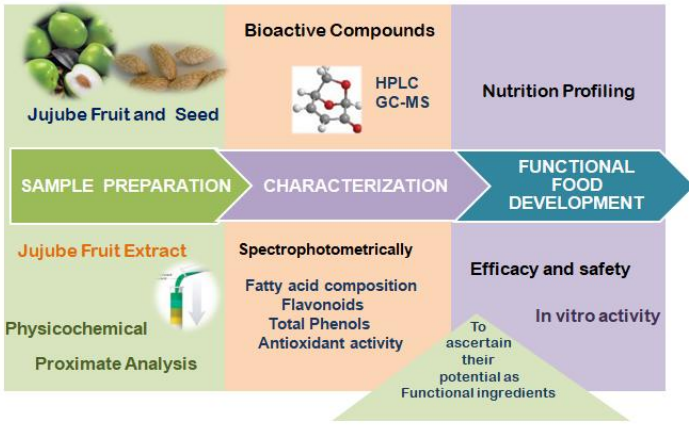
Indian Jujube (*Zizyphus mauritiana* Lam), belonging to the family Rhamnaceae, is a fruit commonly known as Ber in India and Pakistan. It holds the status of an ancient and indigenous fruit across the regions of India, China, and Malaysia. The fruits boast high nutritional value, being notably rich in vitamin C, A, and B complex. Ber stands as one of the most ubiquitous fruit trees in India, cultivated extensively throughout the country. Accessible to people of limited means, Ber has earned the moniker of the "poor man's fruit." Across India, a myriad of horticultural varieties of ber flourish, with notable ones including Umran, Karaka, Gola, Seb, Chhuhara, Sanaur-2, Ilaichi, and Mehrun. In Haryana, prominent varieties cultivated are Gola, Kaithli, Banarasi Karaka, Umran, and Seb. India proudly holds the title of the largest producer of Ber. In Haryana alone, Ber finds itself planted across 4318 hectares, yielding an annual production of 27634 MT, as per the data from the Horticulture Department Haryana, Statistical Data 2022-23. Presently, the market for Indian jujube/ber fruits remains confined to producing regions. One of the contributing factors to the sluggish growth in export, among other marketing challenges, is the lack of awareness regarding the fruit and its nutritional benefits.

Botanical Information	Indian Ber (*Zizyphus mauritiana* Lamk) Chinese Ber (*Zizyphus mauritiana* Mill) Common name Jujube/ Ber Family Rhamnaceae
Jujube varieties	Fruit Type: Ripe/Unripe Minor Underutilized Poor man's Fruit Ber varieties grown in Haryana : Gola, Kaithli, Banarasi Karaka, Umran, Seb
Fruit Nature	Short fruiting season, Highly perishable in nature (Low temp storage)
Harvesting Season	February-March-April
Producing Regions	Maharashtra, Gujarat, Madhya Pradesh, Punjab, Haryana, Rajasthan, Bihar, Karnataka, Andhra Pradesh, Tamil Nadu, West Bengal and Assam.
Consumption pattern	As Fruit, Candy

Nutraceutical Properties of Indian Jujube/Ber (*Zizyphus mauritiana*)

The fruits of *Zizyphus mauritiana* Lam, commonly referred to as Indian jujube or Ber, are endowed with significant nutritional and medicinal worth. Extensive investigations have unveiled a diverse array of phytochemicals within, encompassing amino acids, ascorbic acid, flavonoids, phenolic acids, as well as vitamins A and C, phosphorus, calcium, and iron (Choi *et al.*, 2011). Consequently, the antioxidants and organic compounds found in this remarkable fruit proffer an extensive range of health advantages. Given its phytoconstituents, much of the research pertaining to the fruit centers on evaluating total antioxidant activity (Krishna and Parashar, 2013). Indian jujube fruits have been noted to manifest various pharmacological activities, including antispastic, antifertility, hypotensive, antinephritic, cardiotonic, immunostimulant, anticancer, antibacterial, and antidiarrheal properties (Preeti and Tripathi, 2014). Several studies validating the nutraceutical attributes of Indian jujube are expounded upon below: Koley *et al.* (2016) documented that Indian jujube fruit represents a rich reservoir of ascorbic acid and total phenolics, ranging from 19.54 to 99.49 mg/100 g and 172 to 328.6 mg GAE/100 g, respectively. Memon *et al.* (2012) scrutinized the antioxidant activity, phenolic compounds, seed oil composition, and diverse value-added phytochemicals in seed waste from *Ziziphus mauritiana* L. fruit. Rajopadhye and Upadhye (2016) explored the antioxidant potential of the fruit pulp from eight cultivars of jujube. Additionally, they determined the bioactive compound maslinic acid using the High-Performance Thin-Layer Chromatography (HPTLC) method and evaluated the in vitro antioxidant and hepatoprotective activities of eight cultivars of Indian jujube. Rekha *et al.* (2021) also noted promising anticancer activities in *Ziziphus jujube*.

Extraction and Characterization of bioactive compounds



"Bioactive compounds" are naturally occurring extra-nutritional constituents typically found in small quantities in foods. They are under intensive study to evaluate their effects on health, including their protective effects in disease prevention and potential medicinal benefits. *Ziziphus mauritiana* fruit, commonly known as the poor man's fruit, is highly nutritive and favored by consumers. In India, ripe Ber fruit is predominantly consumed raw with minimal processing. Numerous scientific reports detail the phytoconstituents and bioactive compounds present in Indian Jujube fruits. For instance, Al-Saeedi *et al.* (2016) evaluated the total phenols, flavonoid content, and antioxidant potential of leaf and fruit extracts from the Omani *Ziziphus jujuba L* fruit variety. Han *et al.* (2015) optimized extraction conditions for jujube pulp and seeds to maximize active ingredient yield and antioxidant activity, and also prepared chitosan nanoparticles loaded with jujube pulp and seed extracts for enhanced stability. Kou *et al.* (2015) likewise assessed bioactive compounds and studied antioxidant properties across five different cultivars of Ziziphus. Sathyadevi and Subramanian (2015) extracted, isolated, and characterized major bioactive flavonoids from the fruits of Indian *P. peruviana Linn.*, commonly known as golden/cape berries. Additionally, investigations into seed oil extraction and characterization from *Ziziphus mauritiana* fruit seeds, which are often discarded, have revealed their nutritional and therapeutic potential. There is also ongoing exploration of the development of functional foods with in-vitro/in-vivo studies. Bridging the technological gap involves determining total flavonoid and phenolic content (including potential anti-cancer bioactive compounds) through extraction and characterization of fruits, leading to further development of functional foods. Ultimately, fruit processing has yielded consumer products rich in bioactive compounds.

Identified Bioactive compounds present in Indian Jujube	
Phenolics compounds	Rutin, Quercetin, Quercitrin, Phlorizin, Catechol, Gallic acid, Catechin, Chlorogenic, Caffeic acid, Epicatechin, Coumaric acid, Ferulic acid, Protocatechuic acid
Total Flavonoids	Flavones (Apigenin, Diosmin, Luteolin), Flavanone (Naringenin, Eriodictyol, Pinocembrin), Isoflavone (Genistein, Tectorigenin, Daidzein, Formononetin)
Flavonols	Quercetin, Kaempferol, Procyanidin, Epicatechin

Development of Fruit based Functional Food

In recent times, there has been a key role of fruits in disease prevention and treatment. Thus, the production and consumption of fruit-based functional foods have gained much importance as they provide several health benefits beyond the basic nutritional functions. Nowadays, the range of functional foods includes products such as baby foods, baked goods, and cereals, dairy foods, confectionery, ready meals, snacks, meat products, spreads, and beverages. Silva *et al.*, 2016, reviewed the scope of different bioactive ingredients as potential sources for functional food development. Paz *et al.*, 2015, used Brazilian fruit pulp as a source of bioactive compounds for the development of functional food. Similarly, Sun-Waterhouse *et al.*, 2010, developed functional fruit smoothies with enhanced polyphenols and fibers. The unique combination of Indian Jujube (Ber) polyphenols, including flavonoids, flavanols, and triterpenic acids, makes it a promising source for the development of novel functional food/nutraceutical products. This includes juice production along with several Indian Jujube skin or seed extracts, skin

powder, dry seed powder (capsulated or bulk), and pomace powder.

Extraction and characterization of valuable components with different biological properties from raw agricultural commodities, agricultural wastes, and food processing wastes thus have good potential applicability. It is mainly done through different extraction techniques, retaining the quality of extracts, which is an important endeavor for the development of functional foods.

Identified Bioactive Compounds	Extraction Techniques/Analysis	Values (Quantification)	Biological Property
Free amino acids	Mass spectroscopy	---	Antioxidant and Cancer cell Inhibitory effect Anti-inflammatory Anti-obesity, Immunostimulating, Hepatoprotective and Gastrointestinal protective activity
Protein	HPLC	---	
Flavonoids	Mass spectroscopy	60.32-173.11 mg/100 g	
Total flavonols	Colorimetry	25.21-70.59 mg rutin /100 g	
Total Phenolics	Spectrophotometrically Using Folin-Ciocalteu reagent (expressed as mg GAE/100 g FW)	48.69-196.34 mg GAE /100 g	
Antioxidant activity	Colorimetry, Cupric reducing antioxidant capacity (CUPRAC), Ferric reducing antioxidant powder (FRAP)	1.6-6.33 µM Trolox Eq. /g (CUPRAC assay) 1.22-5.49 µM TE/g (FRAP assay)	
Polysaccharides	Column chromatography		
Triterpenic acids	Spectrophotometrically Vanillin- perchloric assay acid	7.52-15.20 mg Ursolic acid eq. UAE/g	

In summary, the development of fruit-based functional foods utilizing bioactive compounds from Indian Jujube (Ber) holds promise for enhancing overall health and well-being while also mitigating the risk of chronic diseases, including potentially anti-cancer properties. Effectively harnessing the fruit, both its pulp and seed, will bolster its position in the market and ensure better returns for small-scale farmers. It underscores the demand for fruit-derived products and the integration of fruit goodness into commonly consumed foods, offering significant opportunities to diversify product profiles with higher value-added ingredients applicable across various food processing sectors and industries. Furthermore, it targets specific health demographics, addressing the growing population afflicted by diseases. Fruit-based functional foods not only promote general health and well-being but also underscore the significance of bioactive compounds in human health through the intervention of bioprocesses, delivering safe and nutritious options based on the Ber fruit to consumers. Moreover, natural biomolecule extracts from fruits and their seeds could potentially serve as nutraceuticals and dietary supplements, providing enhanced returns to farmers and potentially popularizing this lesser-known fruit. Ultimately, this initiative aims to promote the utilization of not only jujube pulp but also the seeds, maximizing the value of the entire fruit by-product.

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