

Harnessing the potential of underutilised *Buchanania lanzan* Spreng.: Review on processing, nutrition, and applications

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Buchanania lanzan Spreng., known as chironji, is an underutilised tree species native to the Indian subcontinent. This species is primarily recognised for its edible seeds. The seeds are rich in proteins (19–21.6%), fats (59.1%), carbohydrates (12.1%), minerals, and vitamins. These are also a valuable source of dietary energy and are utilised in various traditional foods and as energy bars. It is also known for its antioxidant, anti-inflammatory, and antimicrobial activities, making it an important source in traditional medicine. The significance of *B. lanzan* extends beyond its consumption and traditional dishes. Its seeds are used in the production of edible oils, and its gum and bark find various industrial applications, including cosmetics and pharmaceuticals. Despite these benefits, the species faces considerable threats due to deforestation, lack of efficient harvesting techniques, and inadequate awareness regarding its diverse uses. Promoting the conservation, cultivation, and sustainable use of wild *B. lanzan* can significantly contribute to food security, livelihoods, and the economy, particularly in arid and semi-arid regions. This review examines the multifaceted role of the traditional *B. lanzan* tree in enhancing nutritional diversity, providing therapeutic benefits, and its potential to drive economic development.

Keywords: *Buchanania lanzan*, Nutrition, Processing, Underutilised nut, Value addition

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Introduction

Buchanania lanzan (*B. lanzan*), often called chironji, is a member of the *Anacardiaceae* family. It is mostly found in mixed dry deciduous woods throughout India and is also known as "Char" or "Cuddaph almond"¹. Of the seven species of *Buchanania* known to exist in India, two species, such as *B. axillaris* (Syn. *B. angustifolia*) and *B. lanzan* (Syn. *B. latifolia*), produce edible fruits. The evergreen forests of Kerala are home to the endangered species *B. lanceolata*, *B. lucida*, *B. glabra*, *B. acuminata* and *B. platyneura* which are some of the other species in this genus². The most extensively dispersed and commercially important of these species in India is *B. lanzan*. Mr Hamilton, a forester, provided the species first recorded description in Burma in 1798. Currently, *B. lanzan* is found in various regions across India, predominantly in tropical dry deciduous and northern dry mixed deciduous forests. These include states such as Madhya Pradesh, Chhattisgarh, Jharkhand, Southeast Uttar Pradesh, as well as parts of Gujarat, Rajasthan,

Odisha, Andhra Pradesh, Karnataka, and Maharashtra. Notably, it is considered one of the major non-wood wild forest produce in Chhattisgarh and Uttar Pradesh³. As it is not cultivated on a plantation basis, information about the land area and actual production of *B. lanzan* in India is limited. India is capable of producing around 7000–10,000 metric tonnes of seeds annually.

According to a report produced by Chhattisgarh Minor Forest Produce Federation (CGMFPFed), Raipur as the highest producing state, Chhattisgarh alone has the potential of yearly production of 5000 metric tonnes of *B. lanzan* seeds valued at a price of Rs. 45 crores, which is more than 50% of the national production^{1,2}. Approximately 31.08% of Chhattisgarh's population consists of tribal communities, many of whom rely heavily on non-timber forest produce (NTFP) for their livelihood. *B. lanzan* naturally occurs throughout the state, with its distribution varying across different regions. In Uttar Pradesh, it is a significant tree species in the Bundelkhand region and Vindhyan Zone⁴.

The *B. lanzan* tree is a medium-sized species that typically reaches a height of 12 to 15 meters (40–50 feet), characterised by a straight trunk. It

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thrives on yellow sandy loam soils and is not suitable for waterlogged areas. It is recognised as an effective species for afforestation, particularly in barren hill slopes¹. Its bark is rough, dark grey to black in colour, and exhibits a distinctive fissured texture, measuring between 1.25 and 1.75 cm in thickness, with a reddish interior. The large, oblong, coriaceous leaves of the tree have a rounded base. It yields fruit which is valued as an edible nut and has a single seed (Fig. 1). The tree flowers during January and February, with its fruit ripening in the months of April and May¹. In the month of May, fruits are fully grown and, on turning black, are harvested, typically with a fruit width of 9 to 12 mm and a weight of 35 g per 100 fruits and 2700 to 2900 fruits/kg. The ripened fruit is divided into two components: the outer pulpy layer, which contains roughly 20-40% pulp and remaining 60-80% nut, respectively. The seed is obtained after the nut's decortication, mainly by traditional means and using mechanical methods such as decorticators in some parts of India. The physical characterisation of nuts varies due to diversity in varieties, which affects decortication efficiency to achieve edible seeds. This medicinally significant wild tree species serves as an important source of income for local tribal populations due to its rich content of antioxidants, essential nutrients, and bioactive compounds.

B. lanzan has been traditionally used by tribal communities for various food and medicinal purposes, such as treating cancer, skin diseases, body pain, and digestive disorders⁵. The seeds, with their sub-acidic flavour, similar to of pistachios and almonds, are consumed raw or roasted. The roots have cooling and astringent properties and are effective in treating diarrhoea. The fruit and gum are used as laxatives and to relieve pain, fever, and rheumatic conditions. Char

i.e., oil extracted from its seeds, is applied to skin and treat glandular swelling, while the extracts from its leaf are used to treat wounds, diarrhoea and ulcers. Furthermore, local people use *B. lanzan* leaves as fodder for animals due to scarcity of fodder during summer⁶. The termite-resistant and affordable wood of its tree is used as fuel and in making furniture, moulding, packing cases, and agricultural implements⁷. Moreover, the bark, rich in tannin, is utilised in varnish production and textile dressing, while the tree's seeds and gum are employed in skincare and as alternative hosts for the Kusmi lac insect.

In recent years, the lack of efficient harvesting techniques, limited awareness among tribal communities about its nutritional and therapeutic benefits, and increased deforestation has led to the decline in *B. lanzan* species. Consequently, it led to severe genetic erosion which is further intensified by deforestation-related activities. In Chhattisgarh, Uttar Pradesh, Bihar, Gujarat, and Maharashtra states, various seedling strains have considerable variation in traits such as fruit weight, total soluble solids, acidity and protein content. These provide promising opportunities for selecting superior varieties for large scale production of *B. lanzan*⁸. Although this plant grows in the wild and is frequently disregarded, yet its economic, therapeutic, and nutritional importance make its protection, cultivation, and promotion essential. Wild *B. lanzan* holds particular significance in wasteland development and dryland horticulture due to its resilience to harsh climatic conditions, offering valuable economic benefits to rural communities through its diverse uses, including food, fuel, fodder, timber, and medicine. Overall, this review compiles the reported studies on the processing, nutritional composition, uses, advancements and future potential of *B. lanzan* in food as well as in other sectors.

Post-harvest processing of *B. lanzan* nuts

Considering the high nutritional potential of *B. lanzan*, it is in high demand in Indian and international markets. Therefore, the government and corporate organisations have shown a strong interest in this growing industry by expanding its production and processing to generate foreign exchange⁵. Therefore, their engineering and physical characteristics are crucial in the development of *B. lanzan* processing machinery. Planting, harvesting, threshing, washing, sorting, and drying are some of

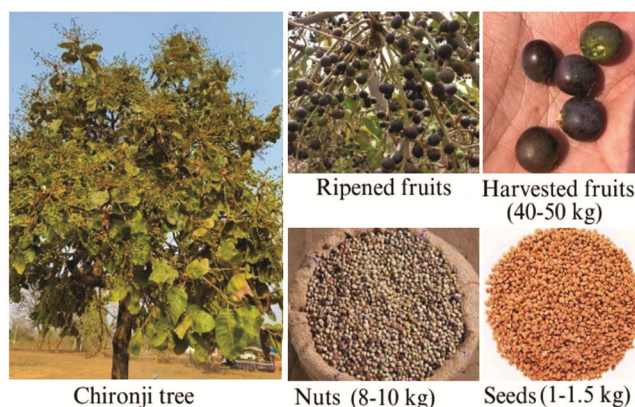


Fig. 1 — *Buchanania lanzan* tree, fruits, nuts and seeds.

the agricultural process operations where physical attributes are crucial to machine design and product behaviour research.

Deshmukh *et al.*⁹ determined the physical parameters of *B. lanzan* nuts and seeds having initial moisture content of 6.00–9.00% and 2.00–4.00% (db), respectively. The seed constituted 30.01% of the whole, and the remaining 69.99% was the shell. Nuts ranged in length, width, and thickness from 8.15 to 11.08 mm, 7.08 to 9.74 mm, and 5.63 to 7.01 mm, respectively, whereas seeds had equivalent values of 5.77 to 6.75 mm, 4.37 to 4.93 mm, and 3.57 to 3.82 mm. Nuts were found to have sphericity and porosity values ranging from 0.82 to 0.84 and 45.58 to 45.74%, respectively, whereas seeds had these values ranging from 0.74 to 0.78 and 43 to 44%, respectively. In another study by Nishad *et al.*¹⁰, the properties of *B. lanzan* nuts were evaluated at a moisture content of 8.34% (wb), and it was reported that the nuts were 9.38 mm long, 8.25 mm wide, and 6.35 mm thick. The arithmetic mean diameter and geometric mean diameters were found to be 7.99 and 7.89 mm, respectively, with a volume of 257.85 mm³ and an aspect ratio of 88.10%. These studies indicate coinciding properties with minor variations, which might be attributed to geographical and varietal differences.

Processing is carried out to obtain *B. lanzan* seeds from within the dried nuts. The seeds are small, delicate, light to dark brown in colour, and have a nut-like flavour. Its seeds have a very good demand in foreign markets and thus have become an important crop. Furthermore, the evolution of *B. lanzan* processing techniques reflects the growing interest in harnessing this valuable nut for various applications, including culinary, medicinal, and industrial purposes. Traditional methods of processing *B. lanzan* have been predominantly manual and labour-intensive, primarily focusing on the separation of nuts from the fruit and subsequent seed extraction. Over time, advancements in technology and the rising demand for *B. lanzan* in various sectors have led to the development of more efficient and refined processing techniques. The processing techniques have now emerged as fully mechanised systems from the manual processing in the past years, as discussed below.

Traditional techniques

Harvested *B. lanzan* fruits with green/purple skins are typically soaked in water overnight and rubbed between palms or with a jute sack to remove the skin

because they turn black when stored (Fig. 2). The obtained nuts after pulp removal are then washed, dried in the sun for two to three days, and then these nuts are decorticated to extract the seeds¹¹. Without harming the delicate inner seed, the hard shell of *B. lanzan* nuts breaks apart when they are decorticated⁹. Nuts are fed between two spinning discs in a grinding stone mill in the conventional processing method. Nuts and seeds are separated using impact and abrasive forces. These disks are composed of sun-dried clay, backed clay, or stone. Usually, the top disc is manually spun while the lower disc is fastened to the bottom. The disk on the top is guided by a steel or wooden axle that protrudes from the middle of the bottom disk. The top disk is used to feed the *B. lanzan* nuts⁸. After that, the seeds are kept in air-tight glass jars, plastic containers or polyethylene bags. On average, a tree produces 40–50 kg of fresh fruits, which reduces to 8–10 kg on drying and further yields 1.0–1.5 kg of finished produce per tree⁹.

During manual shelling of *B. lanzan* nuts, only 30–40% are recovered as whole seeds, and the rest are in broken forms, which are sold at a much lower price. The damaged seeds cause both excessive economic loss and nutritional losses. The seed is harmed during the separation stage by a fractured outer covering. A little crack in the seed also shortens the shelf life and encourages spoiling¹². Additionally, its conventional processing processes are labour-intensive, time-consuming, and exceedingly cumbersome, along with excessive financial and nutritional losses⁸.

Mechanised decortication

To save time and reduce drudgery, different *B. lanzan* nut decorticators have been developed to improve shelling efficiency and facilitate better quality seeds (Fig. 2). Singh *et al.*⁸ designed a *B. lanzan* decorticator comprising a hopper, cylindrical housing, emery black stones, electric motor, driving

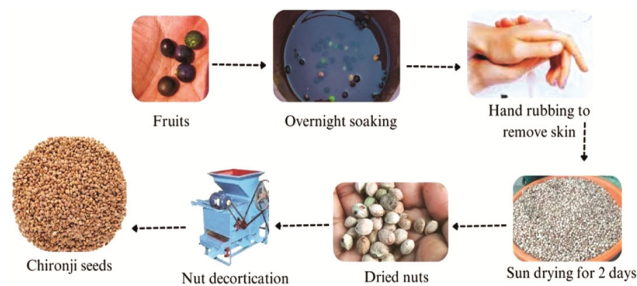


Fig. 2 — Processing of *Buchanania lanzan*.

systems, sieves, reciprocating grader, gap adjustment screw, grader stand, etc. It consisted of an iron ribbed (helical up to one-fourth and straight ribs for the rest of the length) cylinder mounted on a rotating shaft (240 rpm) fitted in a concentric cylinder housing. During seven passes of nuts in this decorticator, the maximum hulling efficiency (80%) was observed after the 7th pass, whereas passes 6th, 5th, 4th, 3rd, 2nd, and 1st had 78.78, 75.44, 68.06, 56.01, 39.38, and 21.2% hulling efficiencies, respectively.

In the same year, Deshmukh *et al.*¹³ optimised the process parameters for decorticating *B. lanzan* nuts. RSM was used to optimise the independent parameters for nut decortication, namely drying temperature, drying duration, and disc clearance. The ideal drying conditions were determined to be 69.61°C, 163.87 min, and 12 mm, respectively. At optimised independent parameters, the machine's capacity, unshelled nut, broken seed, and decorticating efficiency were 6.23 kg/h, 3.68%, 27.72%, and 85.29% respectively.

Nishad *et al.*¹⁰ developed another affordable decorticator with an efficiency of 93.90%. The percentage of whole seeds and fractured seeds on this system was 16 and 2%, respectively. Similar to this, Said and Jadhav¹⁴ standardised the procedure for separating seeds from nuts and developed a decorticator. Concave clearances (7.5 and 8 mm), cylinder speeds (150 and 300 rpm), different moisture levels (7 and 9%), cold water soaking, steaming, and sand roasting were used to optimise this machine. The decorticator worked best when sand-roasted nuts with 7% moisture were fed at a cylinder speed of 300 rpm and an 8 mm concave clearance. Under these circumstances, the whole seed recovery, decortication capacity and decortication efficiency were 12.60%, 64.15 kg/h, and 96.10%, respectively. From 1 kg of nuts, this decorticator generated 126 g whole seeds. The machine possessed less human drudgery, high efficiency, and easy operation; thus, the results will be a guide map for nut processing operations. This decorticator provided better efficiency compared to those developed in previous years.

However, processing raw *B. lanzan* nuts into seeds is a time-consuming and labour-intensive operation due to the hard outer layer. During *B. lanzan* nut shelling, the quality of yield in terms of whole seeds percentage still remains a major challenge⁸. Hence, pre-treatments such as drying, boiling and soaking of nuts are carried out to improve physical

characteristics. Said and Jadhav¹⁴ investigated various pre-treatment methods for nuts, focusing on their impact on processing efficiency and to optimise nut decortication. Nuts were steamed in an autoclave at a pressure of 0.15 kg/cm² for 1 minute and subsequently dried in the shade for 3 hours. The samples were also subjected to cold-water soaking pre-treatment for 12 hours and then shade-dried. Following this, sand roasting was performed which involved roasting the nuts at 60°C for 20 minutes and then shade drying. The pre-soaking in water led to crack development during the sand roasting process due to quick evaporation of absorbed moisture.

As reported by Nishad *et al.*¹⁵, drying of nuts was done in a tray dryer at 60°C temperature for 30 minutes and then immediately cooled under shade at room temperature. Further, nuts were boiled in a boiling pot at 80-100°C temperature for 20 min and then immediately dried in the shade for 12 h. For soaking, nuts were soaked in plain water for 24 h and then dried in the shade for 16 h. These pre-treatments led to an increase in dimensions after boiling and soaking, and a decrease with drying. The coefficient of friction was also affected by pre-treatments and the type of surface, with the lowest coefficient recorded when glass was used.

Limited studies on the processing of *B. lanzan* suggest that there is need for further scientific exploration in the future. The adoption of mechanised decortication of *B. lanzan* seeds plays vital role in enhancing processing efficiency, reducing labour expenses, and minimising seed damage compared to traditional manual methods. The mechanical decorticators with adjustable rollers, controlled pressure, and effective separation systems enable processors to achieve increased throughput while maintaining the quality and integrity of the oil within the seeds. The implementation of mechanised systems also facilitates large-scale uniform commercial production, and minimises post-harvest losses, which are essential steps for optimising the value chain of *B. lanzan*.

Nutritional composition

B. lanzan is an underutilised food source that is rich in both macro and micronutrients. Previous studies have reported essential nutrients and their corresponding contents present in its seed (Table 1). In the following sections, the nutritional composition is discussed in more detail.

Table 1 — Nutritional value of *Buchanania lanzan* seeds^{1,9,15,20,25,29}

Parameter	Amount
Proximate composition (%)	
Moisture	3.00
Protein	19.00-28.12
Fat	52.13-59.10
Carbohydrate	7.81-12.10
Fiber	3.80-9.24
Minerals (mg/100g)	
Calcium	279.00
Iron	8.50
Phosphorus	528.00
Vitamins (mg/100g)	
Ascorbic acid	5.00
Niacin	1.50
Riboflavin	0.53
Thiamine	0.69

Macronutrients

Macronutrients are nutrients that the human body needs in large quantities to function properly and maintain its structure and systems. In *B. lanzan*, the main macronutrients are lipids, carbohydrates, and proteins as discussed below.

Lipids

Fat is a crucial dietary component and performs a variety of bodily activities. Fat is a concentrated energy source that provides twice as much energy as either carbohydrates or proteins. Additionally, it makes food more palatable and slows down the emptying process of the stomach. A prominent dietary problem in low-income nations, particularly among rural tribal people, is fat. *B. lanzan* seeds, which are high in lipids, can become a great addition to a diet to help with these problems, as they offer a good supply of fats to promote general health and avoid shortages. *B. lanzan* seeds contain nearly 35-60% of fat¹⁶⁻¹⁸, while Rajput *et al.*¹ reported in their studies that dry *B. lanzan* seeds contain up to 65.6% of lipids. Additionally, the seeds are eaten raw or roasted, which form a substitute for almonds as the oil content in almonds ranges from 48 to 67% of the total seed dry weight, showing the similarity of the nutritional profile of these nuts¹⁹. Lipid analysis revealed that about 90.4% of the total lipids present in *B. lanzan* were neutral, 3.4% were glycolipids, and 6.2% were phospholipids. The majority of neutral lipids consists of free fatty acids (7.8%) and triacylglycerols (82.2%), with trace levels of sterols,

monoacylglycerols, and diacylglycerols. The phospholipids consisted of phosphatidylethanolamine, phosphatidylcholine, phosphatidylglycerol and phosphatidylinositol as major phospholipids and minor amounts of lysophosphatidylethanolamine and lysophosphatidylcholine²⁰.

Fatty acid composition

Nuts are an excellent source of healthy fats, primarily composed of unsaturated fatty acids, which offer numerous health benefits. *B. lanzan* contains 58.21% unsaturated fatty acids and 41.79% saturated fatty acids. The predominant fatty acid found in *B. lanzan* seed oil was oleic acid (55.17%), followed by palmitic acid, linoleic acid (ω -6), palmitoleic acid, lignoseric acid and stearic acid²¹. Cold-pressed seed oil analysis revealed a favourable fatty acid profile, including polyunsaturated fatty acids such as linolenic acid (ω -3) and linoleic acid (ω -6), and monounsaturated fatty acids such as oleic acid (ω -9)¹⁸. Similar results were reported by Sahu *et al.*¹⁶, and Hemavathy and Prabhakar²⁰ who illustrated that the major fatty acid was oleic, followed by palmitic acid, while the other acids were present to the extent of 3.90%. In a detailed study by Bothara and Singh²², the fatty acids found in *Buchanania lanzan* seed oil were oleic acid, vaccenic acid, cyclopropanoic acid, docosanoic acid, eicosanoic acid, heneicosanoic acid, hexadecanoic acid, and pentadecanoic acid. Heneicosanoic acid, pentadecanoic acid, and cyclopropanoic acid were the main fatty acids found in *B. lanzan*. In comparison to total lipids or neutral lipids, the fatty acid profile showed that glycolipids and phospholipids had minor levels of palmitic and oleic acids and large amounts of stearic, linoleic, and linolenic acids. These differences may be attributed to the climate and varietal variations among different geographical locations. These findings highlight the potential of *B. lanzan* seeds for the development of value-added products, dietary supplements, and phytotherapeutic formulations.

Protein

The key component of the body's tissues and cells is proteins. They are crucial parts of blood and other key bodily fluids, as well as healthy muscles. As antibodies, proteins aid the body in fending off diseases. As a result, proteins are among the most vital nutrients that the body needs and should be consumed in sufficient amounts. *B. lanzan* seeds, in addition to being rich in fats, also provide a significant amount of

protein. The protein present in seeds is 19.0-21.6% whereas fruits contain 2.2% protein²³. In some varieties of *B. lanzan*, the protein content was found to be up to 30%^{9,24}. The amount of protein present in it is almost similar to the content present in almonds, up to 16–23 g/100 g as reported in the studies of commercial California-grown almond cultivars²⁵. These findings signify the nutritional equivalency of both the nuts, indicating the potential of *B. lanzan* as an alternative to almonds in various food formulations.

Carbohydrates

A group of compounds that provide energy are called carbohydrates, and they generally include sugars and starches. Plant tissues, including seeds, contain carbohydrates in the form of sugar, starches, and non-starch polysaccharides, including cellulose and hemicellulose. Although *B. lanzan* is richer in protein and fat, it is lower in carbohydrates and dietary fibre. It contains nearly 12–13% of carbohydrate²⁶. The Fehling and Benedict test performed on *B. lanzan* by Dash *et al.*²⁷ also revealed a positive presence of carbohydrates.

Micro nutrients

Micronutrients are essential nutrients required by the body in small quantities to ensure proper growth, development, and physiological functions. They include vitamins and minerals that play vital roles in human nutrition.

Vitamins

Vitamins are organic compounds found in trace amounts in a variety of meals. They are necessary for the body to perform several essential functions, and many of them are involved in the utilisation of the main nutrients, such as proteins, fats, and carbohydrates. Water-soluble and fat-soluble vitamins are two basic categories for vitamins. Vitamins A, D, E, and K are fat-soluble vitamins, whereas B-complex vitamins and ascorbic acid belong to the former category. *B. lanzan* is a highly nutritious seed, rich in essential vitamins that support the body's energy requirement. According to Siddiqui²⁸ and Khatoon *et al.*¹⁸, it has significant amounts of niacin, vitamins C, B1, and B2. It is a good source of ascorbic acid (5.0 mg), riboflavin (0.53 mg), and niacin (1.50 mg)²⁵. Further demonstrating the nutritional significance of *B. lanzan*, Rajput *et al.*¹ found that it is rich in niacin (1.5 mg), thiamine (0.69 mg), riboflavin (0.53 mg), and ascorbic acid (5.10 mg).

Minerals

The minerals and trace metals play a major role in human body. Some of these triggers biological reactions, while others form the structural components of the body. Iron is a component of blood, while calcium, magnesium, and phosphorus are core components of bones and the skeleton. Minerals, including copper, magnesium, manganese, zinc, and molybdenum, help activate a variety of enzyme systems and provide structural support. *B. lanzan* seeds are known for their rich mineral composition, with significant amounts of essential nutrients. These are high in calcium, 279 mg per 100 g, along with iron (8.5 mg) and phosphorus (528 mg)²⁴. Additionally, other minerals such as copper, magnesium, potassium, sodium, and sulfur are also present, further boosting its nutritional profile. The combination of these minerals offers a beneficial addition our diets leading to the betterment of overall health^{29,30}.

Energy value

The energy from the food is crucial for proper body functions, and is derived from proteins, lipids and carbohydrates. According to Singh *et al.*²⁵, *B. lanzan* seeds provide 656 Kcal/100g of energy. Another studies also reported that calorie-dense *B. lanzan* satiates hunger and prevents overeating^{18,25}. It indicates that the seed is highly valuable for supporting the lives of region's tribal people.

Phytochemical constituents

Plants are packed with phytochemicals, which possess antibacterial, anti-inflammatory, and antioxidant properties. These compounds prevent chronic illnesses, lessen inflammation, and fight oxidative stress. *B. lanzan* being a rich source of bioactive compounds, particularly antioxidants (Table 2) contributes to the regulation of inflammation, enhanced immunity, and protection

Table 2 — Phytochemicals present in different parts of *Buchanania lanzan*

Compound	Plant part	Reference
Flavonoids	Leaves	1
Saponins	Leaves and barks	9
Alkaloid	Leaves	10
Dipalmitoolein	Seeds	21
Dioleopalmitin	Seeds	21
Triolein	Seeds	21
Tannin	Bark	49
Polyphenols	Leaves	50

against oxidative damage, thus, promoting overall health by preventing diseases.

Physicochemical characterisation of *B. lanzan* seeds was carried out by Khatoun *et al.*¹⁸ and they found high levels of phenolics, natural antioxidants, and essential minerals. The total phenolic content in petroleum ether extract (PEE), dichloromethane extract (DCME), methanolic extract (ME), and ethanol-water extract (EWE) was 5.78, 6.73, 10.05, and 13.42 µg Gallic acid equivalent (GAE)/mg, respectively, while total flavonoid content was 13.74, 7.08, 5.21, and 11.41 µg CE/mg, respectively. Antioxidant assessment using ferric reducing antioxidant power assay (FRAP) indicated EWE and ME had the highest activity (13.42 and 10.05 µg Butylated Hydroxytoluene BHT/g, respectively). Significant amount of fatty acids, plant sterols, and phenolic compound which are key agents in neutralising free radicals, such as peroxides and hydroperoxides, were also observed using GC-MS analysis. These compounds are indicative of lowering the risk of degenerative diseases.

A study by Suryawanshi *et al.*³⁰ found that both unripe and ripe fruits of *B. lanzan* had significant bioactive potential. Ripe fruits exhibited higher total polyphenols and peroxidase activity, while unripe fruits showed greater carotenoid content and catalase activity. Antioxidant assays 2,2-diphenyl-1-picrylhydrazyl (DPPH) and FRAP showed that methanolic extracts of both fruit stages had the highest activity. GC-MS profiling revealed a range of bioactive compounds, with the substantial quantities of tridemorph, 5-hydroxymethylfurfural, octadecanoic acid, n-hexadecanoic acid, methyl 5,11,14,17-eicosatetraenoate and 4H-pyran-4-one, 2,3-dihydro-3,5-dihydroxy-6-methyl in both unripe and ripe fruits.

The leaves and stem bark of *B. lanzan* are also abundant in phytochemicals, including triterpenoids, saponins, and tannins (2.64% in leaves and 13% in bark), further enhancing antioxidant potential¹. Leaves are particularly rich in flavonoids such as quercetin, kaempferol, and myricetin, known for strong antioxidant activities. Phytochemical screening by Jatav *et al.*³¹ in ethyl acetate, dichloromethane, and methanol extracts revealed alkaloids, flavonoids, phenols, and tannins with distinct R_f values. High-Performance Thin-Layer Chromatography (HPTLC) profiling of ethyl acetate extract confirmed a variety of phenolic compounds using toluene:ethyl acetate (7:3 v/v) as the mobile phase. The leaf juice contains

around 2.64% triterpenoids, flavonoids, saponins, reducing sugars, and tannins, supporting its role in preventive healthcare and applications in the pharmaceutical industry¹⁶.

Siddiqui²⁸ analysed gum exudates (20 and 10% concentrations) from different regions of India and found all samples contained flavonoids, saponins, amino acids/proteins, and carbohydrates, with tannins present only in black gum exudates from Madhya Pradesh and Chhattisgarh. The tannin-containing samples indicated antioxidant activity. Other studies, using *in vitro* assays such as DPPH and the Folin-Ciocalteu method, further confirmed the antioxidant efficacy of *B. lanzan*, highlighting its high polyphenolic content and strong potential for applications in food products, health supplements, and nutraceutical formulations.

Applications of *B. lanzan*

The *Buchanania lanzan* tree is versatile as its parts, like roots, leaves, fruits, seeds, and gums, are used for various food and other industrial uses (Fig. 3), as discussed below.

Food applications

The fruits of this plant are valuable food source for human consumption and are a key ingredient in the preparation of various traditional Indian sweets and aromatic products. Various products such as squash, ready-to-serve (RTS) drinks and nectar after juice extraction are prepared from the juicy and sweet *B. lanzan* fruits. The edible seeds in the powder form are used to flavour Indian dishes or thicken sauces and stews. The seeds are also commonly utilised in the traditional delicacies such as *chirongi ki burfi*, *halwa*, and *kheer*. Additionally, *B. lanzan* seeds are employed to garnish various desserts³². The oil extracted from *B. lanzan* seeds is occasionally used as an edible oil by indigenous communities²⁸.

Roasted *Buchanania lanzan* seeds

Value addition to *B. lanzan* seeds contributes to

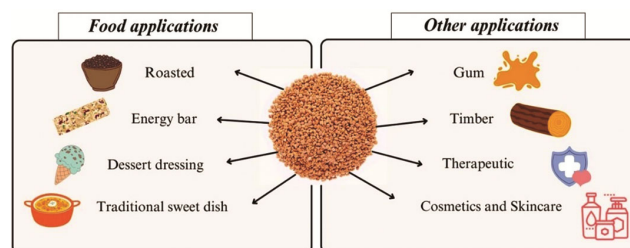


Fig. 3 — Food and other applications of *Buchanania lanzan*.

support the livelihoods of rural communities. Among the various value-added products, roasted seeds has a promising market potential. Roasting leads to key microstructural and chemical transformations, along with a reduction in moisture content, alterations in lipid composition, and colour changes. Furthermore, roasted seeds possess a characteristic taste, aroma, and crunchy texture. These sensory attributes primarily develop from the Maillard reactions during the roasting process, which produce flavour compounds essential for the distinct roasted nut profile. Hot air roasting is one of the simplest convective methods of heating, with low operating costs and is commonly applied for the roasting of nuts. Pradhan and Pradhan³² performed hot air roasting of *B. lanzan* seeds at 25 different combinations of temperature and time. Roasted seeds exhibit notable changes in their physicochemical properties, including a reduction in bulk density, hardness, and water activity, along with an increase in water absorption capacity, total phenolic content, antioxidant activity and browning index. Optimisation studies using an artificial neural network (ANN) model integrated with a genetic algorithm (GA) identified the optimal roasting conditions as a temperature of 146°C and a duration of 34 minutes. Under these conditions, the properties were recorded as bulk density of 537±1.21 kg/m³, hardness of 15.01±0.31 N, water absorption capacity of 1.33±0.11 g/g, water activity of 0.0059±0.007, browning index of 74.62±0.33, total phenolic content of 17.68±0.49 mg GAE/g dry weight, and antioxidant activity of 74.09±0.19%. However, the substantial thermal energy is used in hot-air roasting method with extended processing time. These conditions result in undesirable alterations in the final product's quality, primarily driven by Maillard reactions.

Another roasting technique *i.e.*, microwave roasting of *B. lanzan* seeds was carried out by Pradhan and Pradhan³³ using combinations of microwave power and roasting time. Roasting significantly influenced the physical and chemical properties and resulted in a significant reduction in bulk density, hardness, and water activity. Contrarily, a considerable enhancement was observed in water absorption capacity, browning index, total phenolic content, and antioxidant activity. The optimal roasting conditions were 700 W power for a roasting time of 5.5 minutes. Under these conditions, the parameters were: 8.02±0.15% bulk density, 16.63±0.17 N hardness, 1.02±0.06 g/g water absorption capacity,

0.054±0.0009 water activity, 76.79±1.23 browning index, 26.74±0.32 mg GAE/g total phenolic content, and 73.23±0.86% antioxidant activity. Scanning Electron Microscopy (SEM) analysis further revealed microstructural changes induced by roasting attributed to transformation of seed structure during the roasting process.

Impact of different roasting techniques, including pan (PR), microwave (MR), and hot air oven (HOR), on *B. lanzan* seeds, was observed by Bhanu *et al.*³⁴, on the nutritional profile, bioactive compounds, and anti-nutrients. A significant reduction was found in free sugars, with the most pronounced effects noted in microwave roasting. Roasting reduced total carotenoids and β-carotene levels by 52.2 and 22.7%, respectively, while enhancing the concentration of individual polyphenols. Minerals *viz.*, iron (Fe), calcium (Ca), copper (Cu), and zinc (Zn), were unaffected across all roasting methods. Similarly, the total saturated, monounsaturated, and polyunsaturated fatty acid profiles showed no noticeable changes after roasting. In raw seeds, total phenolic content and total flavonoid content were recorded as 1150 mg GAE/100 g and 113.12 mg Catechin equivalents (CE)/100 g, respectively. Notably, PR significantly enhanced the antioxidant activities. Overall, MR retained nutrient levels and PR demonstrated improvement in antioxidant potential.

Energy bars

Rich nutritional profile and versatility of *B. lanzan* contributes to its utilization in the development of energy bars. The healthy fats, proteins, and essential minerals in seeds make them an ideal base for energy bars to provide sustained energy and promote overall health. The pleasant flavour of *B. lanzan* seeds adds to the taste and texture of energy bars and appears more appealing to consumers. Moreover, antioxidants present in seeds contribute functional benefits to the energy bars. In energy bar formulations, seeds can be used as whole, ground into a powder, or processed into a paste, allowing for versatility.

Additionally, seeds also have an ability to thicken and bind ingredients, which can contribute to the structural integrity of the bars. Thus, it eliminates the need for artificial additives and provide consumers a natural and clean-label product. Safvi *et al.*³⁵ developed an energy bar using *B. lanzan* seeds and condensed milk, oats, puffed rice, dates (as a flavour

and binding agent), jaggery (as a sweetener), butter (as a preservative), raisins, and almonds. The prepared energy bars had a moisture content of $12.00 \pm 2.00\%$, fat content ranging from 24.00 to 27.33%, protein levels between 10.57 and 12.93%, and total soluble solids of 7.33 to 8.00° Brix. Sensory evaluation values were 8.17 to 8.83 based on 9-point hedonic scale, demonstrating high overall acceptability.

In a similar attempt, Verma *et al.*³⁶ also formulated an energy bar comprising various seeds including *B. lanzan* and dried fruits. The total carbohydrate content of energy bar was 72.59%, Iron 1.26 mg/100 g, Calcium 480 mg/100 g, and energy 431.71 kcal/100 g, along with antioxidants and phenolic compounds. Thus, *B. lanzan* based energy bars can also tap into the growing market for indigenous and traditional ingredients. It caters to the health-conscious consumers looking for unique and nutritious snack options and facilitates new

opportunities in the functional foods market.

Therapeutic applications

Traditionally, various parts of *B. lanzan* have been utilized to treat illness. The roots of its tree has expectorant, diuretic, and carminative properties commonly used in traditional medicine. The roots also exhibit wound healing, anticancer, antihypertensive, depurative, larvicidal, and antidiabetic properties, and are employed in the treatment of diarrhoea. The roots contain bioactive compounds such as tannins, saponins, and flavonoids, with tannins likely contributing to their antidiarrheal properties³¹. Moreover, the root extract is also utilised to treat blood disorders and biliousness³⁷. Methanolic extracts from the roots of *B. lanzan* also showed significant anti-inflammatory and analgesic activities. The therapeutic activities of different parts of *B. lanzan* are discussed in Table 3. In animal models, a dose of 400 mg/kg root extract markedly reduced paw oedema at both 1 and 3 hours

Table 3 — Therapeutic activities of *Buchanania lanzan*

Pharmacological Activity	Plant part & extract	Dose & Animal Model	Experimental Model/Assay	Key Findings	Reference
Anti-inflammatory & Analgesic	Root methanolic extract	200 & 400 mg/kg, oral, rats	Carrageenan-induced paw oedema; thermal and chemical pain assays	400 mg/kg markedly reduced paw oedema at 1 and 3 h; analgesic activity was significantly higher at 400 mg/kg vs. 200 mg/kg	38
Enzyme inhibitory (Anti-inflammatory)	Bark methanolic extract	50–200 µg (<i>in vitro</i>)	15-LOX & COX-2 enzyme inhibition assays	Complete 15-LOX inhibition at 200 µg; 73.58% COX-2 inhibition at 50 µg	39
Antigenotoxic & Antioxidant	Bark ethanolic extract	250, 500 & 1000 mg/kg/day, oral, mice	Cyclophosphamide-induced genotoxicity & oxidative stress	Reduced micronucleus frequency, LPO, and chromosomal damage; restored SOD, CAT, and GSH levels	40
Antidiarrhoeal	Leaf aqueous extract; Root alcoholic extract	200 & 400 mg/kg, oral, mice	Castor oil-induced diarrhoea	Reduced faecal output and delayed diarrhoea onset; phytochemicals include tannins, flavonoids, steroidal saponins	41
Adaptogenic (Antistress)	Leaf methanolic extract	10–50 mg/kg/day, oral, rats	Swim endurance test; Urinary VMA & ascorbic acid estimation	Dose-dependent prevention of stress-induced rise in urinary VMA and ascorbic acid without changes in unstressed controls	42
Antidiabetic & Antihyperlipidemic	Leaf methanolic extract	100 & 200 mg/kg/day, oral, diabetic rats	Streptozotocin-induced (Type I) and streptozotocin +nicotinamide-induced (Type II) diabetes	Significant reduction in fasting blood glucose and improvement in lipid profile	43
Anti-inflammatory (acute & chronic)	Seed methanolic extract	200 mg/kg, oral, rats	Carrageenan-induced paw oedema (acute), Formaldehyde-induced arthritis (chronic)	Significant reduction in paw volume in both acute and chronic inflammation models	44
Neuro-psychopharmacological (Memory enhancement)	Seed petroleum ether extract (PEB)	500 mg/kg, oral, rats	Elevated plus maze, Step-down apparatus; AChE assay	Decreased transfer latency and increased step-down latency; reduced AChE activity in brain regions, indicating improved learning and memory	45

post-carrageenan injection. Furthermore, in thermally and chemically induced pain models, analgesic activity at 400 mg/kg was significantly higher ($p < 0.01$) than that observed at 200 mg/kg³⁸.

The bark demonstrates anti-snake venom activity, as well as depurative, cardiogenic, and brain tonic properties, and is effective in treating constipation and glandular swelling¹⁷. In southern Bihar, tribal communities combine powdered stem bark of *B. lanzan* with *Syzygium cumini* (Myrtaceae) to treat infantile diarrhoea¹. Soxhlet-extracted methanolic bark extract was tested for its inhibitory effects on 15-lipoxygenase (LOX) and human cyclooxygenase-2 (COX-2) enzymes. The methanolic extract demonstrated a dose-dependent inhibition of LOX activity, with complete 15-LOX inhibition at 200 μg and 73.58% inhibition of the human COX-2 at a 50 μg concentration, indicating its potential as a natural anti-inflammatory agent through enzymatic pathway modulation³⁹. In another study on ethanolic bark extract of *B. lanzan*, it has shown protection against cyclophosphamide-induced genotoxicity and oxidative stress in mice. *In vivo* administration for 7 days significantly reduced micronucleus frequency in the bone marrow, lipid peroxidation (LPO), and chromosomal damage, while restoring hepatic antioxidant enzymes, superoxide dismutase, catalase and glutathione levels. The model involved cyclophosphamide-challenged mice, with biomarkers including LPO, glutathione (GSH), superoxide dismutase (SOD), and catalase (CAT) confirming attenuation of oxidative injury and enhancement of endogenous antioxidant defenses⁴⁰.

The juice from leaves treats digestive issues and has aphrodisiac, purgative, blood purifying, thirst-quenching, and expectorant properties. In addition to triterpenoids, flavonoids, and reducing sugars, it has 2.64% tannins (0.35% gallo-tannins). Traditionally, crushed or powdered leaves are used to treat wounds. To check the efficacy of *B. lanzan* Spreng for managing diarrhoeal disorders, a study by Kodati *et al.*⁴¹ evaluated aqueous leaf extract and an alcoholic root extract of *B. lanzan* in mice models. The castor oil-induced diarrhoea assay assessed antidiarrhoeal activity. Oral administration of the alcoholic root extract markedly reduced faecal output and delayed diarrhoea onset. The presence of compounds (tannins, flavonoids, and steroidal saponins) having gastrointestinal protective and motility-modulating properties was evident from phytochemical screening.

The findings suggest that tannins may play a key role in mediating the observed antidiarrhoeal effect. The methanolic leaf extract was further explored for adaptogenic potential using a rat model in both normal and stressed groups. Urinary vanillylmandelic acid (VMA) and ascorbic acid, determined spectrophotometrically, served as non-invasive biomarkers of antistress activity. Oral administration of the extract before stress induction significantly attenuated stress-induced elevations in urinary VMA and ascorbic acid in a dose-dependent manner, without affecting levels in unstressed controls⁴².

Diabetes mellitus is a chronic metabolic disorder characterised by absolute or relative insulin deficiency and/or impaired insulin action, often accompanied by hyperlipidemia as a metabolic complication. Elevated low-density lipoprotein (LDL) levels in diabetic individuals contribute to abnormal lipid metabolism, increased very-low-density lipoprotein (VLDL) secretion, impaired VLDL catabolism, and subsequent atherosclerotic plaque formation. In a study⁴³, Wistar rats were rendered diabetic by intraperitoneal administration of streptozotocin (40 mg/kg) alone (Type I) or in combination with nicotinamide (Type II). Animals exhibiting fasting blood glucose $> 190 \pm 8$ mg/dL were treated orally with methanolic *B. lanzan* leaf extract or standard drug for 21 days. Diabetes induction elevated fasting glucose to 327.7 ± 47.4 mg/dL (vs. 91.0 ± 3.2 mg/dL in controls). Extract administration significantly ($p < 0.05$) reduced blood glucose levels and improved serum lipid profiles, indicating potent antidiabetic and antihyperlipidemic effects.

The fruits of *B. lanzan* have laxative effects and alleviate thirst, body heat, fever, cough, and asthma. An ointment from the seeds is used to treat prickly heat and itching. Additionally, seed oil, referred to as "char", is utilised for skin related issues such as facial blemishes. This oil alone or in combination with other oils is also applied to address glandular swellings in the neck¹⁰.

The current research on *B. lanzan* has demonstrated promising anti-inflammatory and analgesic effects across various experimental models. Inflammation is a key physiological defence mechanism that enables the body to respond to infection, burns, toxic chemicals, allergens, or other harmful stimuli. The *in vivo* anti-inflammatory potential of *B. lanzan* has been extensively evaluated using various experimental

models. *In vivo* animal study, the methanolic extract of *B. lanzan* seeds (200 mg/kg body weight) administered orally produced a significant reduction in paw volume⁴⁴.

A memory boosting effect, i.e., neuro-psychopharmacological potential of petroleum ether extract of *B. lanzan* seeds, was also evaluated in rats by Neelakanth *et al.*⁴⁵. Memory acquisition and retention were assessed using the elevated plus maze and step-down apparatus, while acetylcholinesterase (AChE) activity was quantified in specific brain regions. Extract application produced a significant decrease in transfer latency in the elevated plus maze and an increase in step-down latency, indicating enhanced learning and memory performance. Overall, considering these available studies, thorough pharmacological studies, toxicological assessments, and clinical validations are necessary to convert traditional knowledge into evidence-based applications in pharmaceuticals and nutraceuticals, even though initial reports emphasise its antioxidant, anti-inflammatory, and antimicrobial properties.

Industrial applications of *B. lanzan*

Gums

Gums are natural exudates, typically in the form of tears or flakes, derived from the sap of various trees and shrubs, often following either natural or artificial damage to the woody stems and branches. These substances are ionic, complex polymers composed of glycopeptides, along with other compounds and mineral salts. Notably, many gums, particularly those sourced from species within the *Fabaceae* family, such as *Acacia*, *Sterculia*, *Astragalus*, *Balanites*, *Buchanania*, and *Anogeissus*, are edible. Historically, gums have been utilised for their nutritional, culinary, and therapeutic properties in food, pharmaceuticals, and refining industries.

B. lanzan gum exhibits a colour range from yellow to dark yellow and is characterised by its odourless nature and rough texture. The highest-quality gum is primarily utilised in the food and beverage industry, particularly in soft drinks and edible products, where it serves as a colouring agent¹. Dash *et al.*²² carried out a study on the isolation and characterisation of *B. lanzan* gum. The results showed that the *B. lanzan* gum possessed a total ash content of $3.54 \pm 0.69\%$, loss on drying of $6.8 \pm 0.50\%$, viscosity (4% w/v aqueous solution) of 38 ± 0.61 cps, a Swelling index of $89.42 \pm 1.93\%$, a Hausner's ratio of 1.18 ± 0.05 , a compressibility index of $15.73 \pm 0.96\%$, an angle of

repose of $16.04 \pm 0.15^\circ$, and a pH range of 4.20 to 5.05, respectively. *B. lanzan* gum is water-soluble and is traditionally used for the treatment of intercostal pain and diarrhoea. When combined with goat's milk, it is believed to provide analgesic effects and effectively alleviate intercostal pain. In some tribal communities of Andhra Pradesh, a mixture of the gum dissolved in cow's milk is consumed to treat rheumatic pain. The gum is reported to be produced and collected in significant quantities, with an estimated annual output of around 175 metric tons from the Mandla, Dindori, Umaria, Shahdol, Katni, and Chhindwara districts of Madhya Pradesh, India.

In addition to this, its gum is generally mixed with guggul (*Commiphora wightii*) along with perfumes or scents to be used as incense. *B. lanzan* gum is also used in the refinement process in the tobacco industry. Natural gums, including *B. lanzan* gum, are commonly utilised as excipients in pharmaceutical formulations due to their non-toxic, biocompatible, biodegradable, and inert characteristics. Furthermore, they are easily available and cost-effective which makes gums ideal for use in various pharmaceutical dosage forms. Ionic gums, such as acacia and tragacanth, are generally used in the food and pharmaceutical industries for their stabilising and texture-enhancing properties. However, their low viscosity limits the stabilising efficacy of these gums.

In this context, Samajdar and Kumar⁴⁶ conducted a research on *B. lanzan* gum and its thermally modified form in relation to the emulsifying properties of acacia and tragacanth. Gums were obtained by heating *B. lanzan* gum (CG) at 110°C for 24 h, 48 h and 96 h. These formulations indicated better stabilising properties than natural CG emulsions. The natural gum formulations exhibited droplet sizes ranging from 9.77 to 26.55 μm , with zeta potential values between -14.8 and -23.2 mV. In comparison, the heat-treated gums displayed a smaller droplet size range of 1.42 to 17.5 μm and a more negative zeta potential, from -17.2 to -40.6 mV. These formulations were stable even after seven days of storage at room temperature and showed no phase separation over a period of more than one month. These types of gum formulations has the potential to enhance the functional properties of ionic gums, which leads to extension of their applicability as pharmaceutical emulsifiers, stabilisers in lotions, and thickeners, among other applications.

Timber

The timber from the *B. lanzan* tree is used to make furniture, boxes and crates, match boxes, mouldings, packing cases and agricultural instruments. It also has a small degree of termite resistance¹. Over-exploitation and careless harvesting practices have contributed to reduction in the population of *B. lanzan* in recent years. These situations pose a severe risk of extinction and calls for immediate conservation interventions².

Cosmetics and skincare applications

The global market for cosmetic-based biomass continues to experience significant growth and is projected to expand at a compound annual growth rate (CAGR) of 4.2% through 2030⁴⁷. The increasing demand from customers for safe and eco-friendly products has encouraged further research in the development of green cosmetics. These cosmetics aim to diminish the negative environmental impacts of non-renewable resources, such as fossil oils.

Bioactive chemicals found in wild plant species have many advantages when used as ingredients in cosmetics. For example, *B. lanzan* seed oil is frequently used in cosmetic compositions as an alternative to olive and almond oils²⁸. Its increasing popularity in the cosmetics sector can be attributed to the emollient qualities of the oil that is derived from its seeds. It can be used in cream, lotion, and face oil formulas to relieve dry, irritated skin, lower inflammation, and encourage healing⁴⁸. *B. lanzan* oil's rich antioxidants also aid in anti-aging skincare products by shielding the skin from oxidative stress brought on by environmental elements like pollution and UV radiation³³. In the Indian market, *B. lanzan*-based lip balms are well-known under the Chatura Ayurveda brand.

Furthermore, *B. lanzan*'s exfoliating properties make it a valuable addition to scrubs and masks as a natural exfoliant to remove dead skin cells and impurities. Its anti-inflammatory and antibacterial properties also make it suitable for products targeting acne-prone skin, helping to reduce breakouts and soothe redness. Thus, *B. lanzan* offers a considerable ingredient choice for cosmetic formulations aimed at complete skin health due to its diverse phytochemical composition, which includes phenolics, flavonoids, tannins, and saponins, all of which demonstrate powerful antioxidant, anti-inflammatory, and antimicrobial effects.

Conclusion

B. lanzan is traditionally known for its rich nutritional profile comprising of protein, fats, minerals, and bioactives, including antioxidants, tannins, and essential fatty acids. These attributes extend its applications in food formulations, nutraceuticals, cosmetics, and pharmaceuticals. The present review highlights the documented studies on processing operations, physicochemical properties, nutritional and bioactive composition and functional applications. However, a gap has been observed in context to advanced characterisation techniques to further explore its composition and functional benefits. Additionally, future research on post-harvest handling, value-added processing, and market feasibility would be pivotal to bridge the gap between its traditional uses and large-scale commercial adoption. With an integration of comprehensive quality evaluation and product development, *B. lanzan* could evolve from an underutilised forest produce into a multipurpose, economically significant crop, promoting both rural livelihoods and sustainable industrial growth. Thus, an underutilised traditional nut, *B. lanzan*, has a potential to become a commercially significant crop especially in culinary, health, and industrial sectors if research gaps in composition, processing technology, pharmacological evaluations, and sustainability are addressed in the future.

Conflict of interest

The authors have no conflicts of interest to declare.

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References

- 1 Rajput B S, Gupta D, Kumar S, Singh K and Tiwari C, *Buchanania lanzan* Spreng (Chironji): A vulnerable multipurpose tree species in Vindhyan region, *J Pharmacogn Phytochem*, 2018, 7(5), 833-836.
- 2 Chauchan P S, Singh J and Kavita A, Chironji: A promising tree fruits of dry subtropics, *Hort Flora Res Spectr*, 2012, 1, 375-379.
- 3 Niratker C and Sailaja D, Evaluation of genetic diversity of Chironji (*Buchanania Lanzan*) in Chhattisgarh, *Int J Res Anal Rev*, 2018, 5(4), 922-925.

- 4 Meena V S, Gora J S, Singh A, Ram C, Meena N K, *et al.*, Underutilised fruit crops of Indian arid and semi-arid regions: Importance, conservation and utilisation strategies, *Hortic*, 2022, **8**(2), 171, doi: 10.3390/horticulturae8020171.
- 5 Malaka A, Sahoo H, Sinha A and Kumar A, Necessity of genetic diversity study and conservation practices in Chironji (*Buchanania cochinchinensis* (Lour.) MR Almedia), *Environ Conserv J*, 2023, **24**(1), 253-260, doi: 10.36953/ECJ.12802358.
- 6 Avani P, Bauri F K and Sarkar S K, Chironji: A golden nut fruit of Indian tribes, *Acta Hort*, 2019, **1241**, 37-42, doi: 10.17660/ActaHortic.2019.1241.6.
- 7 Rai P K, Sharma D R and Sharma A, Chironji is a pharmacognostic miracle herb, *Res J Pharmacol Phytochem*, 2015, **7**(3), 182-188, doi: 10.5958/0975-4385.2015.00029.1.
- 8 Singh J, Naik R K, Patel S and Mishra N K, Design and development of Chironji (*Buchanania lanzan*) decorticator, *Int J Eng Res Technol*, 2016, **5**, 46-51.
- 9 Deshmukh S D, Dange M M, Pardeshi I L and Borkar P A, Physical properties of Chironji nut (*Buchanania lanzan* L.) as potential for development of processing machines, *J Ready Eat Food*, 2017, **4**, 6-10.
- 10 Nishad P K, Patel S, Naik R K and Mishra N K, Chironji nut decorticator developed by IGKV Raipur India, *Bhartiya Krishi Anusandhan Patrika*, 2018, **33**(4), 271-274, doi: 10.18805/BKAP132.
- 11 Vijay M K, Sharma R S, Maloo S R, Jain V and Sharma A, *Buchanania lanzan* Spreng (Chironji): An endangered socio and-economic forest tree species of Central India, *J Pharma Innov*, 2022, **11**, 336-342.
- 12 Thounaojam A S and Dhaduk H L, Enhancement of seed germination in Chironji (*Buchanania lanzan* Spreng) through physical and chemical treatments, *J Pharmacogn Phytochem*, 2020, **9**, 1354-1359.
- 13 Deshmukh S D, Dange M M and Gawande A B, Optimisation of process parameters for Chironji nut (*Buchanania Lanzan*) decortication, *Int J Res Eng Sci Technol*, 2016, **1**(6), 39-50.
- 14 Said P P and Jadhav V S, Development of a decorticator for *Buchanania lanzan* nuts and its process optimisation, *J Food Process Eng*, 2021, **44**(1), e13591, doi: 10.1111/jfpe.13591.
- 15 Nishad P K, Naik R K, Patel S and Mishra N K, Effect of pre-treatment on physical properties of Chironji (*Buchanania lanzan*) nuts, *Agric Res J*, 2017, **54**(4), 603-606, doi: 10.5958/2395-146X.2017.00118.1.
- 16 Sahu S N, Jaiswal S G and Naik S, Physico-chemical thermal and oxidative properties of wild Chironji (*Buchanania lanzan* Spreng.) seed oil, *J Lipid Sci Technol*, 2015, **47**(1), 3-9.
- 17 Mishra N, Dubey A D, Mishra M and Barik N, Study on antioxidant activity of common dry fruits, *Food Chem Toxicol*, 2010, **48**(12), 3316-3320, doi: 10.1016/j.fct.2010.08.029.
- 18 Khatoun N, Gupta R K and Tyagi Y K, Nutraceutical potential and phytochemical screening of *Buchanania lanzan*, an underutilised exotic Indian nut and its use as a source of functional food, *J Pharmacogn Phytochem*, 2015, **4**(1), 87-94.
- 19 Yada S, Lapsley K and Huang G, A review of composition studies of cultivated almonds: Macronutrients and micronutrients, *J Food Compos Anal*, 2011, **24**, 469-480, doi: 10.1016/j.jfca.2011.01.007.
- 20 Hemavathy J and Prabhakar J V, Lipid composition of Chironji (*Buchanania lanzan*) seed, *J Food Compos Anal*, 1988, **1**, 366-370, doi: 10.1016/0889-1575(88)90037-3.
- 21 Kumar J, Prabhakar P K, Srivastav P P and Bhowmick P K, Physical characterisation of chironji (*Buchanania lanzan*) nut and seeds, *Food Sci Res J*, 2014, **5**(2), 148-153.
- 22 Bothara S B and Singh S, Fatty Acid profile of *Buchanania lanzan* Spreng. seed oil by gas chromatography-mass spectrometry, *Inventi Rapid Pharm Anal Qual Assur*, 2011, **4**, 241.
- 23 Srivastava A K, Gupta D, Tiwari C, Kumar S and Rajput B S, *Buchanania lanzan* spreng. (Chironji) a potential wild fruit tree of peninsula India: A review, *J Progress Agric*, 2021, **12**(1), 1-8.
- 24 Kumar J, Vengaiah P C, Srivastav P P and Bhowmick P K, Chironji nut (*Buchanania lanzan*) processing, present practices and scope, *Indian J Tradit Knowl*, 2012, **11**(1), 202-204.
- 25 Singh R K, Mandal J and Das B, Study on present practices of Chironji nut (*Buchanania lanzan*) processing in Chotanagpur Plateau Region, *Int J Curr Microbiol Appl Sci*, 2018, **7**, 4680-4684.
- 26 House J D, Hill K, Neufeld J, Franczyk A and Nosworthy M G, Determination of the protein quality of almonds (*Prunus dulcis* L.) as assessed by *in vitro* and *in vivo* methodologies, *Food Sci Nutr*, 2019, **7**(9), 2932-2938, doi: 10.1002/fsn3.1146.
- 27 Dash S K, Behera B C and Mohanty B, Isolation, characterization and acute toxicity study of *Terminalia elliptica* (Saj) gum, *Buchanania lanzan* (Chironji) gum and *Albizia lebbek* (Siris) gum, *Int J Health Sci*, 2022, **6**, 3597-3615, doi: 10.53730/ijhs.v6nS8.12903.
- 28 Siddiqui M Z, Chironji: A species of enormous potentials, *World J Pharm Sci*, 2014, **2**, 374-379.
- 29 Banerjee A and Jain M, Investigations on *Buchanania lanzan* seed oil, *Fitoterapia*, 1988, **59**, 406.
- 30 Suryawanshi M, Patil V and Jadhav (Rathod) V, Biochemical composition, nutritional analysis and antioxidant activity of *Buchanania lanzan* Spreng fruits, *Curr Bot*, 2021, **12**, 180-187, doi: 10.25081/cb.2021.v12.6852.
- 31 Jatav P and Tenguria R K, Determination of total alkaloids and tannins contents in leaves of *Buchanania lanzan*, *J Coast Life Med*, 2022, **10**(3), 693-700.
- 32 Pradhan D and Pradhan R C, Application of a neural network mathematical model in the development of hot air roasting process technology for Chironji (*Buchanania lanzan*) seeds, *J Food Process Preserv*, 2022, **44**(12), 14907, doi: 10.1111/jfpp.14907.
- 33 Pradhan D and Pradhan R C, Optimisation of process parameters using a hybrid intelligent system model and evaluation of physicochemical properties of microwave roasted Chironji (*Buchanania lanzan*) seeds, *J Food Meas Charact*, 2020, **14**(6), 2956-2969, doi: 10.1007/s11694-020-00537-7.
- 34 Bhanu L, Goudar G, Gogoi P, Mahajan A, Subhash K, Chandragiri A K and Longvah T, Effect of roasting on nutritional composition, polyphenols and antioxidant properties of Chironji (*Buchanania lanzan* Spreng.) seeds, *J Food Meas Charact*, 2024, **18**, 1-16, doi: 10.1007/s11694-024-02710-8.

- 35 Safvi A F, Ahmad A, Younis K and Yousuf O, Development of energy bar by adding underutilised Chironji (*Buchanania lanzan*) seeds, *Food Humanity*, 2023, **1**, 44-50, doi: 10.1016/j.foohum.2023.04.003.
- 36 Verma A, Singh D and Mitra A, Development of gluten free energy bar and its proximate analysis, *Pharma Innov J*, 2022, **11**, 569-576.
- 37 Mondal M, Konar A, Halder S, Roy A, Dalal D D and Ghosh P, An insight into the morphological, ethno medicinal, phytochemical and pharmaceutical properties of *Buchanania lanzan*, *J Med Plants Stud*, 2024, **12**(1), 11-17, doi: 10.22271/plants.2024.v12.i1a.1620.
- 38 Patsnaik A K, Kodati D, Pareta S K, Patra K C and Harwansh R K, Analgesic and anti-inflammatory activities of *Buchanania lanzan* Spreng. Roots, *Res J Pharm Biol Chem Sci*, 2011, **2**(1), 419-425.
- 39 Sekhar S, Karmakar R and Harishchandra S P, Curative properties of *Buchanania lanzan*: As evaluated by its antioxidant, anti-inflammatory and DNA protective properties, *J Nat Pharm*, 2012, **3**(2), 71-77.
- 40 Jain R and Jain S K, Effect of *Buchanania lanzan* Spreng. Bark extract on cyclophosphamide induced genotoxicity and oxidative stress in mice, *Asian Pac J Trop Med*, 2012, **5**(3), 187-191.
- 41 Kodati D, Pareta S K and Patnaik A, Antidiarrhoeal activity of alcoholic extract of *Buchanania lanzan* Spreng. Roots, *Pharmacol Online*, 2010, **3**, 720-726.
- 42 Mehta K S, Nayeem N and Bains N, Adaptogenic activity of methanolic extract of *Buchanania lanzan* leaves an experimental study in rat model, *Pharm Sinica*, 2011, **2**(3), 107-112.
- 43 Sushma N, Smitha P V, Venu Gopal Y, Vinay R, Reddy N S, *et al.*, Antidiabetic, antihyperlipidemic and antioxidant activities of *Buchanania lanzan* Spreng methanol leaf extract in streptozotocin induced Types I and II diabetic rats, *Trop J Pharm Res*, 2013, **12**(2), 221-226.
- 44 Warokar A S, Ghante M H, Duragkar N J and Bhusari K P, Anti-inflammatory and antioxidant activities of methanolic extract of *Buchanania lanzan* Seed, *Indian J Pharm Educ Res*, 2010, **44**(4), 363-368.
- 45 Neelakanth M J, Bhat M R, Taranalli A D and Veeresh B, Effect of *Buchanania lanzan* seeds on learning and memory in normal and memory deficit rats, *J Res Pharm Biomed*, 2012, **22**(1), 33-38.
- 46 Samajdar S and Kumar K J, Impact on stabilisation of ionic gum emulsions by natural and thermally modified Chironji gum, *Int J Boil Macromol*, 2020, **156**, 233-238, doi: 10.1016/j.ijbiomac.2020.04.042.
- 47 Fatriasari W, Anwar Y, Putri A S and Arung E T, Potential of tropical biomass for the bioactive ingredients in cosmetics. In *Biomass-based Cosmetics*, edited by E T Arung, W Fatriasari, I W Kusuma, H Kuspradini, K Shimizu *et al.*, (Springer, Singapore), 2024, 1-26, doi: 10.1007/978-981-97-1908-2_1.
- 48 Desai S N, Jadhav A J and Holkar C R, Extraction and microencapsulation of *Buchanania lanzan* Spreng seed oil, *Chem Pap*, 2022, **76**, 3521-3530, doi: 10.1007/s11696-022-02116-0.
- 49 Srivastav A, Prakash S, Barman P K and Kumar D, Contribution of agroforestry tree species in Vindhyan region of Uttar Pradesh India, *Int J Environ Agric Res*, 2024, **10**(10), 28-39.
- 50 Sharma V, Pradhan R, Naik S, Bhatnagar N and Singh S, Evaluation of a centrifugal impaction-type decorticator for shelling tung fruits, *Ind Crops Prod*, 2013, **43**, 126-131, doi: 10.1016/j.indcrop.2012.06.046.