Journal of Research in Chemistry

E-ISSN: 2709-9423
P-ISSN: 2709-9415
JRC 2023; 4(1): 17-25

www.chemistryjournal.net
Received: 13-10-2022
Accepted: 16-11-2022

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Review on the therapeutic properties of jamun (*Syzygium cumini* L.) seed and their utilization in dairy product

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Abstract
Jamun seed powder is used as a detoxifying herb which consists of moisture, crude protein, crude fat, crude fiber, ash, and nitrogen free extract. Jamun seed powder has been used as a natural remedy to treat gastrointestinal and cardiovascular conditions while maintaining a healthy blood sugar level since ancient times. For generations, jamun seed powder has been used as a natural supplement to maintain a healthy blood sugar level. Here in this review the jamun seed powder will be added in khoa, which will help to increases the nutritional value of our product, it will also have ability to regulate blood sugar level, blood pressure and boosts stomach health and immunity. Khoa is an indigenous milk product which is protein rich food, high in calcium and phosphorus. It is good for bone health, muscle development and boosts cardiovascular health. In this review we are doing the extraction of jamun seed powder and adding in khoa as we found that jamun seed powder has lot of health benefits especially to the diabetic patients.

Keywords: Jamun seed, khoa, fortification, antioxidant, anticancer, antidiabetic activity

1. Introduction

Milk has been consumed as sustenance from ancient times. It has a significant impact on the diet. Milk and its products make up (16%) of all food expenses in India, ranked second position after cereals (Aneja *et al*. 2002, Gupta 2007, Kanawjia 2008) [3, 38, 44]. In India, numerous traditional milk products are created using roughly half of the nation's total milk production (132.4 million tonnes in 2013) (Rao and Raju 2003, Bhasin 2010) [74, 16]. According to the manufacturing concept, there are six categories of traditional Indian dairy products. Heat - products, heat and acid coagulated products, fermented products, products made with addition of cereals, clarified butter fat (ghee), frozen products. With an annual growth rate of about (5%), India produces (15%) of the world's total milk production (Rao and Raju 2003) [74]. It has been estimated that khoa makes up about (7%) of the entire milk production due to its widespread usage (Rajarajan *et al*. 2007) [72]. Khoa is a well-known dairy product that is produced locally. Traditional dairy products not only have a strong market in India, but they also have a lot of potential for export due to the huge Indian diaspora that exists around the world (Rao and Raju 2003) [74]. Due to the production of traditional milk products, which have a far larger market than dairy products made in the western style, India's organized dairy industry has a special opportunity. Traditional dairy product consumption is increasing at a level of more than (20%) annually, but growth rates for western dairy products are substantially lower (5–10%) (Patil 2009) [67]. The traditional Indian dairy products provide roughly (200%) value to milk, compared to the western dairy products (50%) addition with the exception of malted milk and milk chocolates (Aneja 1997) [4]. Additionally, the prices of various traditional dairy products from India, including shrikhand, rasogolla, gulabjamun, khoa-based sweets (peda, burfi, kalakand), and sandesh, paneer, are (29%, 33%, 34%, 35% and 65%) of the selling price, respectively. Comparative expenses range from (70-80%) higher for western dairy products (Prakash and Devaraj 2019) [98].

The Prevention of Food Adulteration Act, as revised up to March 2006, defines khoa as a product made from cow, buffalo, goat, or sheep milk, or a combination of those milks, that is rapidly dried and has a milk fat content of at least (30%) on a dry weight basis for the finished product (Reddy 2007) [78]. Eugenia jambolana or *Syzygium cumini*, a member of the Myrtaceae family, are its scientific names.

Common names for jamun include Jambul, Java plum, Indian blackberry; black plum, Portuguese plum, Malabar plum, purple plum, Jamaica and damson plum (Ali *et al*. 2013) [2]. The species *Syzygium* belongs to the myrtle family Myrtaceae, which is native to the tropics, particularly tropical Australia and America. Though rather unevenly, it is extensively dispersed around the planet in tropical and subtropical regions. It is widely distributed around the world in tropical and subtropical areas, though quite unevenly. The genus contains over 1100 species, and its native range stretches from southern Asia east to the Pacific to Africa and Madagascar. From Malaysia to northeastern Australia, where many species are very poorly known and many more have not yet been defined taxonomically, is where it is most diverse. Plants in this family are known to contain a lot of volatile oils, which have been used in claimed medical applications (Mahmoud *et al*. 2001) [59]. The tropical tree *Syzygium cumini*, sometimes known as Jamun, is a purple, ovoid, freshy fruit. The ripe berries taste sweetish-dry and can be used to make wine, jellies, juices, squash, and health beverages. In India, its seed has traditionally been used to treat a variety of illnesses. The majority of jamun is produced in India. India produces roughly (15.4%) of the 13.5 million tonnes of jamun produced globally. The jamun fruit has a lot of iron and is used as a potential treatment for diabetes, liver illness, and heart disease. Fruit with strong antioxidant properties also contains a significant amount of anthocyanins (AOAC 2006) [7]. Traditionally; jambul fruits, leaves, seeds, and bark have been employed in ayurvedic treatment. For many years, people have utilised jamun seed powder as a natural means of maintaining balanced blood sugar levels. It is helps with cleansing effects that supports maintaining normal sweating and urine. Additionally, it serves as a digestive aid, a cooler, and a blood purifier. Jamboline, a glycoside found in jamun seeds, aids in keeping blood glucose levels within acceptable ranges.It possesses an immunomodulatory hypolipidemic and cardioprotective function (Ranjan *et al*. 2011) [73]. In the past 20 years, research has examined the exceptional complex of naturally occurring antioxidant chemicals found in jamun (Banerjee 2005) [13].

2. Composition of jamun seeds

Along with albumen, fat, glycosides, an alkaloid called jambosine3, resin, ellagic acid, quercetin, gallic acid, and minerals like zinc, vanadium, chromium, salt, and potassium, jamun seeds also include other substances. Unsaponifiable seed fat substance contains $-sitoterol (Ali *et al*. 2013) [2]. The following substances have been found in *Syzgium cumini* seeds: protein, fat, crude fibre, ash, (0.41%) calcium (0.17%) phosphorus, fatty acids (palmitic, stearic, oleic, and linoleic),consisting of lauric (2.8%), myristic (31.7%), palmitic (4.7%), stearic (6.5%), and oleic (32.2%), linoleic acid (16.1%), malvalic (1.2%), stercu-lic acid (1.8%), and vernolic acid (3%), dextrin (6.1%) and (41%) starch. Dextrin contains traces of -sitosterol, corilagin, ellagitannins, ellagic acid, gal-loyl-galactoside, and gallic acid, which together make for (6–19%) of the total tannin content (Ranjan *et al*. 2011) [73]. As well as jamun fruit, which contains lauric (2.8%), myristic (31.7%), palmitic (4.7%), and stearic acids, all play a significant role in the management of diabetes (6.5%) when the body produces too much glucose; the jamun seeds contain Glucoside, Jamboline and Ellagic Acid, which can stop the conversion of starch into sugar (Giri *et al*. 1985) [35]. However, the bioactive components of jamun known as ellagic acid and glucoside jamboline have antioxidant action and have the ability to turn starch into sugar (Benherlal and Arumugham 2007) [15].

2.1 Nutritional composition of jamun seed

2.1.1 Carbohydrates

The main nutritional component of jamun seeds is carbohydrates (Benherlal and Arumugham 2007, Giri *et al*. 1985, Indrayan *et al*. 2005) [15, 35, 40]. With a concentration ranging from 23 g/100 g to 60 g/100 g dm of seed, starch predominates among digestible carbohydrates, which supply the energy required to support numerous metabolic activities in the human body (Benherlal and Arumugham 2007, Gajera *et al*. 2018) [15, 33]. Jamun seeds are a well-known source of dietary fibre. Non-digestible carbohydrates, which included lignin, are nutritionally important, health-promoting food ingredients. The total amount of dietary fibre in jamun seeds was calculated to be 27.7 g/100 g, with insoluble fibre accounting for a substantially higher percentage 24.9 g/100 g than soluble fibre 2.8 g/100 g. The percentage of insoluble dietary fibre was much higher than that of soluble dietary fibre, which was measured at 24.9 g/100 g and 2.8 g/100 g, respectively, in the study of jamun seeds. (Kaur *et al*. 2011) [48]. With a composition of 40 g/100 g of fresh matter, fm moisture content of 5.9 g/100 g, and water-soluble gums make up the majority of the non-digestible carbohydrates in jamun seeds. The second non-digestible seed carbohydrate fraction was water-insoluble neutral detergent fibre 15 g/100 g fm, which contained cellulose 6.9 g/100 g fm, hemicellulose 5.9 g/100 g fm, lignin 1.0 g/100 g fm, cutin 0.76 g/100 g fm, and silica 0.44 g/100 g fm. The health effects of dietary fibre may depend on its composition (Pandey 2002) [65].

2.1.2 Proteins

Jamun seed contains up to (8%) protein (Benherlal and C Arumugham 2007, Indrayan *et al*. 2005) [15, 40]. Despite the fact that certain reports in the literature suggest substantially greater protein content - 19.96 g/100 g fm (Santos *et al*. 2020) [81]. Free amino acids were recorded in *S.cumin* seeds in addition to crude protein. Cumini seeds have a 4.84–9.90 mg/100 g concentration; however their profile has not been analyzed (Gajera *et al*. 2018) [33].

Jamun seeds' protein profile was recently attempted to be ascertained utilizing two-dimensional gel electrophoresis and matrix-based-assisted laser desorption/ionization time-of-flight mass spectrometry and identified 15 functional proteins, including lactoferrin, chitinase1, sulphate transporter like protein, pectate lyases, β-tubulin, ABC transporter, phosphate binding protein, 1-aminocyclopropane-1-carboxylate oxidase, G protein coupled receptor, ADP-glucose pyrophosphorylase, and glutamate-ammonia ligase adenylyltransferase, which play significant roles in the metabolic, transport, and defence processes of plants.

2.1.3 Lipids

Jamun seeds have low total lipid content less than 1.5 g/100 g (Benherlal and Arumugham 2007, Ghosh *et al*. 2017) [15, 34]. Although lipids have a healthy, balanced fatty acid make up. Unsaturated fatty acids, such as monounsaturated fatty acids and polyunsaturated fatty acids, make up (14%) and

(36%), respectively, of the total fatty acids, whereas saturated fatty acids account for (50%) (Bhaskar *et al*. 2021) [17]. The nutritional value of jamun seed is low, reaching only 267 kcal/100 g, which can be considered nutritionally advantageous in the context of the current global problem of overweight and obesity in humans. This is because jamun seeds are high in dietary fibre and low in fats (Indrayan *et al*. 2005) [40].

2.1.4 Micronutrients

Jamun seeds provide significant levels of ascorbic acid. Its mineral content makes it a popular product among dietitians (Ghosh *et al*. 2017, Indrayan *et al*. 2005) [34, 40]. Nine dietary macro- and microelements are relevant to the mineral makeup of jamun seeds. Manganese, potassium, and iron were dominating as well as chromium. While sodium, zinc, and magnesium were found to have moderate levels, calcium and copper were only found in minimal amounts **(**Ravi *et al*. 2004a**)** [77]. The components were different, and the content was reducing for the following minerals potassium 606 mg/100 g, Magnesium 112 mg/100 g, sodium 43.9 mg/100 g, calcium 136 mg/100 g, copper 2.13 mg/100 g, iron 4.20 mg/100 g, zinc 0.46 mg/100 g, manganese 0.40 mg/100 g, and chromium 1.40 mg/100 g. There may be changes in the mineral composition as a result of several environmental factors. It was discovered that the ripening process directly impacted the minerals in *S.cumini* during plant growth and their soil-climate adaptation, varietal differences, and harvest time. When compared to fruits at the intermediate ripe stage, the potassium and calcium levels of cumini fruit pulp and ripe fruits were significantly higher **(**Granado *et al*. 2021, Moussa *et al*. 2020**)** [36, 62].

Ascorbic acid was the only vitamin and pro-vitamin that was determined in jamun seeds **(**Gajera *et al*. 2018, Ghosh *et al*. 2017) [33, 34]. Its concentration varied from 90 mg/100 g to 137 mg/100 g which was higher compared to various genotypes and was greater than each genotype's fruit pulp **(**Ghosh *et al*. 2017**)** [34]. Ascorbic acid levels in jamun seeds were reported to be a little lower it was 49.8 mg/100 g in a study by (Giri *et al*. 1985) [35]. While β-carotene and other carotenoids have been reported in pulp (Faria *et al*. 2011) [31]. The presence (as well as other fat-soluble vitamins) has not been verified in the seeds by (Gupta and Agrawal 1970) [37]. Only recognized β-sitosterol in the portion of jamun seed oil that is not Unsaponifiable.

2.1.5 Phytochemicals

Jamun seeds contain a range of phytochemicals, including terpenes and terpenoids, sterols, saponins, and phenolic compounds. In jamun seeds Phytochemicals have only been described on a qualitative basis. Jamboline, gallic acid, ellagic acid, corilagin, 3, 6-hexahydroxydiphenoyl glucose, 4, 6-hexahydroxydiphenoyl glucose, quercetin, and - sitoterol have all been found to be present in the seed (Modi *et al*. 2010, Sagrawat *et al*. 2006, Menon and Prince 2006, Rastogi and Mehrotra 1990, Bhatia and Bajaj 1975) [61, 80, 60, 76, 18]. Fatty oils like oleic acid, myristic acid, and linoleic acid are also the primary components of *S.cumini* seeds.

However, trace amounts of stearic acid, palmitic acid, lauric acid, vernolic acid, stercu-lic acid, and malic acid were found (Daulatabad 1988) [28]. In separate tests, the alcoholic extract of the seed contained alkaloids, flavonoids, glycosides, phytosterol, saponins, tannins, and triterpenoids (Modi *et al*. 2010, Sagrawat *et al*. 2006, Menon and Prince 2006, Rastogi and Mehrotra 1990, Bhatia and Bajaj 1975, Kumar *et al*. 2016) [61, 80, 60, 76, 18, 51].

2.1.6 Phenolic compounds

Phenolic compounds are the most frequently identified in jamun seeds and they are the most prevalent group of bioactive compounds. The amount of total phenolic content in jamun seeds was found to be 55.54 mg of gallic acid equivalents GAE/g dm and 22.59 mg GAE/g fresh seeds at 62.25 g/100 g moisture content **(**Balyan and Sarkar 2017, Shrikanta *et al*. 2015) [12, 92]. Lower TPC was 26.9 mg GAE/g dry powdered seeds which was discovered by (Aqil *et al*. 2012) [9]. Higher values between 79.89 and 108.7 mg GAE/g dry seeds were reported by **(**Mahindrakar and Rathod 2020, Bajpai *et al*. 2005) [57, 11]. The profile of the phenolic components in jamun seeds includes phenolic acids, flavonoids (flavones, flavan-3-ols, flavonols, and dihydrochalcones), stilbenoids, coumarins, lignans, hydrolysable tannins, and phloroglucinol derivatives. Two phenolic acids (Gallic and ellagic acids) are the simple derivatives, and their polymeric forms are gallotannins and ellagitannins, respectively which are most frequently characterized and quantified **(**Bajpai *et al*. 2005, Balyan and Sarkar 2017, Bhatia and Bajaj 1975, Liu *et al*. 2018, Omar *et al*. 2012, Sawant *et al*. 2015) [11, 12, 18, 54, 56, 64, 82]. Nuclear magnetic resonance spectroscopy and liquid chromatography with tandem mass spectrometry methods were used to detect 9 gallotannins, 17 ellagitannins, and further ellagic acid derivatives in jamun seeds (Bhatia and Bajaj 1975, Liu *et al*. 2018, Elhawary *et al*. 2022, Omar *et al*. 2012, Sawant *et al*. 2015) [18, 54, 56, 30, 64, 82]. It is widely known that hydrolysable tannins have potent antibacterial and antioxidant properties **(**Karamac 2009, Puljula *et al*. 2020) [45, 70]. The digestive system's functionality may also be impacted (Zary *et al*. 2021) [97]. The ellagitannin-rich fraction of jamun seeds was discovered to inhibit the canonical Wnt signaling pathway in a human 293T cell line, indicating their potential against colon cancer (Sharma *et al*. 2010) [89]. Additionally, it was observed that the antioxidant activity of the jamun seed fraction, which contains ellagitannins and ellagic acid, was higher than that of the pulp, which mostly contains anthocyanins (Aqil *et al*. 2012) [9]. Myricetin and its derivatives, such as myricetin 3-O-glucoside, O-methylated forms (syringetin, syringetin 3-O-glucoside, laricitrin), and dihydroxy derivatives (dihydromyricetin), have been found to be the most prevalent compounds in jamun seeds (Elhawary *et al*. 2022, Liu *et al*. 2018) [30, 54, 56]. The different bioactivity of the standardized flavonoid-rich extracts of jamun seeds was due to the presence of rutin, quercetin, and kaempferol (Sharma *et al*. 2008b, Sharma *et al*. 2008a, Jasmine *et al*. 2010) [87, 86, 82]. The extracts were discovered to have hypoglycemic, hypolipidemic, and anti-atherogenic properties. Jamun seeds have also been found to contain flavone C-glycosides (Swertisin, schaftoside, and apigenin 6, 8-di-C-d-glucopyranoside), which are rare in natural sources (Liu *et al*. 2018, Nagaraju *et al*. 2006) [54, 56, 63].

2.1.7 Terpenes and terpenoids

Jamun seeds contain 45 terpenes and terpenoids that have been categorized as monoterpenes, monoterpenoids, sesquiterpenes, sesquiterpenoids, norsesquiterpenoids, and triterpenoids (Elhawary *et al*. 2022, Liu *et al*. 2017a, Sawant *et al*. 2015, Scharf *et al*. 2016) [30. 53, 82, 83]. It was discovered that some jamun seed sesquiterpenoids were biologically active (Liu *et al*. 2018) [54, 56]. Two sesquiterpene hydrocarbons, E-caryophyllene and -humulene, accounted for (42.5%) and (22.2%) of the total essential oil in the fresh jamun seeds essential oil, respectively (Scharf *et al*. 2016) [83].

2.1.8 Other phytochemicals

Using NMR, the pentacyclic triterpene glycoside (saponin) vitalboside A was identified (Thiyagarajan *et al*. 2016) [95]. B-Sitosterol has also been found in S. cumini seeds as a bioactive phytochemical. It was found in the jamun seed oil's unsaponifiable fraction (Gupta and Agrawal 1970, Sharma *et al*. 2011b, Sharma *et al*. 2011) [37, 91, 90] discovered the presence of a sterol with an unknown structure in the Sephadex LH-20 fraction of the ethanolic jamun seed extract.

2.2 Health benefits of jamun seeds

Jamun fruit seeds have been shown to help diabetic patients with a variety of issues, including lowering blood glucose levels and delaying the development of complications like neuropathy and cataracts. Jamun fruit also lowers blood sugar levels, which makes it a key component in the management of diabetes. People have long used jamun seed powder as a natural way to maintain their blood sugar levels. It cleanses the body and has properties that control natural urination and sweating. It performs cardioprotective, hypolipidemic, and immunomodulatory functions. The fruit lessons the sugar in blood. Additionally, it serves as a blood purifier, digestive aid, liver stimulant, and cooling. Jamboline, a glycoside found in jamun seeds, aids in keeping blood glucose levels within acceptable ranges (Helmstadter 2008) [39]. The use of seed extract in the treatment of diabetes is advantageous since it lessens symptoms like frequent urination and thirsting (Joshi *et al*. 2019) [43]. Because of its saponins, tannins, and flavonoids, *Syzygium cumini* seeds have been discovered to have anti-diabetic, anti-inflammatory, and anti-dyslipidemic properties (Karthic *et al*. 2008) [46]. It has been claimed that powdered seeds can treat diabetes (Moussa *et al*. 2020) [62]. The seeds have anti-HIV, anti-diarrheal, anti-hyperglycemic, and antibacterial effects. Jamboline or antimellin, an alkaloid found in the seeds, prevents the diastatic conversion of sugar to starch (Chaudhary and Mukhopadhyay 2012) [21]. Diabetes, allergies, viral infections, inflammation, and gastric ulcers can all be treated with jamun seeds (Dagadkhair *et al*. 2017) [27]. Additionally, it has a diuretic, anti-nociceptive, hypothermic, chemo-protective, and cardio-protective action (Katiyar *et al*. 2016, Anjali *et al*. 2017) [47, 5]. Myricetin, oxalic acid, gallic acid, citronellol, cyanidin diglucoside, hotrienol, phytosterols, flavonoids, carotenoids, and polyphenols are among the bioactive compounds that have been linked to a number of health advantages (Chhikara *et al*. 2018) [23].

2.3 Biological activities of jamun seed extract

2.3.1 Antidiabetic activity

Many natural compounds have an anti-diabetic effect by inhibiting the enzymes -amylase and -glucosidase, which slow down the digestion of starch and lower blood sugar levels (Alam *et al*. 2019, Lee and Yoon 2022) [1, 52]. Extracts from black jamun seeds decreased the activity of the enzyme by (59.1-90.6%) (Gajera *et al*. 2017) [32]. Hyperglycemia enhances glucose metabolism through the polyol pathway in the diabetic state. Glucose is converted to sorbitol by aldose reductase. When polyol is produced in high quantities, it cannot pass through cell membranes and either accumulates or is changed into fructose. The insulin signaling pathway is negatively regulated by protein tyrosine phosphatase B1 (PTP1B), which is linked to both type 1 and type 2 diabetes risk (Alam 2019) [1]. The anti-diabetic properties of jamun seeds, their extracts, and phytochemicals were demonstrated in a number of *In vivo* investigations. According to research, jamun seed extract favorably enhances several biochemical processes, including glucose tolerance and glucose uptake, keeps blood sugar levels stable in diabetic mice, and has advantages for repairing β –cells (Sharma *et al*. 2008a) [86]. A long-term human study that lasted a year and involved 99 patients with type 2 diabetes mellitus who had problems controlling their blood sugar levels showed a reduction in fasting plasma glucose and postprandial blood sugar, demonstrating the usefulness of jamun seed powder in managing type 2 diabetes mellitus (Sidana *et al*. 2017) [93].

2.3.2 Antihyperlipidemic and antihypercholesterolemic activity

Jamun seeds have a number of bioactive substances that help to control the blood lipid profile (Prince *et al*. 2004) [69]. Jamun seeds have been shown to have antihyperlipidemic effects in human studies. When jamun seed capsuled powder 4.5 g/day was added to the diet of patients with prediabetes, their levels of total cholesterol and LDL-cholesterol decreased dramatically, from 266 to 216 mg/dL and from 189 to 139 mg/dL, respectively (Parveen *et al*. 2020) [66].

2.3.3 Anticancer activity

Discovered that the jamun seed extract caused human hepatoma cells to undergo apoptosis. In this study, the mitochondrial potential and a hepatocyte nuclear factor-1 were both down regulated when varied extract concentrations 10, 20, and 40 g/mL were used. The Western blotting test confirmed it, evaluated the impact of crude and hydrolyzed jamun seed extracts on cancer cell viability using a mmt assay (Prakash and Devaraj 2019) [98]. Both extracts significantly reduced the proliferation of human non-small-cell lung carcinoma A549 (Aqil *et al*. 2012) [9]. When expressed as IC50, the activity of the crude and hydrolyzed extracts achieved values of 64 and 38 g/mL, respectively. With an IC50 value of 1.24 g/m, the methanolic extract of jamun seeds demonstrated cytotoxic action against the colon cancer cell line. With an IC50 value of 1.24 g/m, the methanolic extract of jamun seeds demonstrated cytotoxic action against the colon cancer cell line (Elhawary *et al*. 2022) [30].

2.3.4 Antiinflammatory activity

Since it includes a number of bioactive compounds, the jamun seed's powder or extract can function as an anti-inflammatory agent, lowering both acute and chronic inflammation. This was supported by numerous *In vivo* experiments (Kumar *et al*. 2008) [50]. Adenosine deaminase and DPP-4 can both be inhibited by the jamun seed extract in human lymphocytes. Most likely, the bioactive substances in the extract will interact with the DPP-ADA complex and alter purinergic signaling (Belle *et al*. 2013) [14].

2.3.5 Antioxidant activity

Several *In vitro* approaches were used to examine the antioxidant capacity of jamun seeds, employing different methods for the extraction of bioactive substances. DPPH was significantly inhibited by the phenolics (gallic acid, ellagic acid, ferulic acid, catechin, and quercetin) present in seeds from underutilized native black jamun landraces discovered in the Gir forest region of India (Gajera *et al*. 2017) [32].

2.3.6 Antimicrobial activity

The jamun seed extract demonstrated antibacterial potential against human bacterial infections that were multidrug resistant. The agar well diffusion and microbroth dilution experiments provided evidence that the jamun seed extract might be used as a novel antibacterial agent (Bag *et al*. 2012) [10]. It was demonstrated that the crude extracts of jamun seeds might combat isolated bacteria that produced -lactamase, a drug-resistant enzyme (Jasmine *et al*. 2010) [82]. *Aeromonas hydrophila, Chromobacterium violaceum, E. coli, Pseudomonas aeruginosa, Salmonella enterica serovar Typhimurium, Serratia marcescens, Listeria monocytogenes*, and *S. aureus* were all susceptible to phenolic extracts from jamun seeds (Santos *et al*. 2020) [81]. Bioactive chemicals isolated from jamun seeds using water and methanol demonstrated antifungal efficacy in the study by **(**Chandrasekaran and Venkatesalu 2004**)** [20]**,** *Aspergillus Niger, Candida albicans, Tricophyton rubrum, T. mentagrophytes, and Microsporum gypseum* were among the dermatophytic fungus that extracts were effective against.

3. Khoa

Khoa is a traditional Indian dairy product that is heat-desiccated. It is made by continuously boiling milk until the necessary concentration of milk solids (60–70%) is reached. It is also referred to as mava, kava, khoya, and khova (Kumar *et al*. 2016) [51]. It must have atleast (30%) fat on a dry matter basis, free of added flour, sugar, and coloring, and contain no more than (0.1%) citric acid by weight, according to the FSSAI 2011 standards. For three types of khoa, Pindi, Danedar, and Dhap, the Bureau of Indian Criteria (BIS) has defined standards for total solids, fat, ash, acidity, coliforms, and yeast and mould counts (IS 1980). These are used to create high-value khoa-based goods such burfi, peda, kalakand, and gulabjamun **(**Choudhary 2015, Choudhary *et al*. 2017a**)** [15, 25]**.** The desiccation conditions, kind of milk, fat/SNF ratio, lactose level, etc. are all factors that determine the quality of khoa. Cow milk khoa is sticky because the free fat isn't released enough, whereas buffalo milk khoa has a soft, smooth body and is ideal for khoa-based sweets due to its high fat content. Khoa made from buffalo milk has a slightly granular or greasy texture, a mildly cooked, rich nutty flavour, and a sweet taste (Vogra and Rajorhia 1983) [96]. The compositional and physico-chemical parameters of Khoa during storage have been examined in relation to the quality of buffalo milk; however the impact of lactose hydrolysis on these parameters has never been identified.

As a result, research was intended to produce relevant information on how low lactose Khoa's physico-chemical characteristics changed after storage at 5°C (Choudhary *et al*. 2019) [26]. Due to the high lactose content, khoa has a uniformly pale colour with just a hint of brown, a little greasy or granular texture, and a rich nutty flavour that is connected to a mildly cooked and sweet taste (Aneja 1997) [4]. Usually, (17–19%) of khoa by weight is produced from cow milk. According to reports, the yield from buffalo milk is (21-23%) by weight (Elhawary *et al*. 2022) [30]. Buffalo milk fat is easier to emulsify than cow milk because it contains a higher proportion of butyric acid-containing triglycerides and releases more free fat as a result. This may account for the Khoa's smooth and mellow texture (Sindhu 1996) [94].

3.1. Types of khoa

According to its intended usage, khoa is divided by the Bureau of Indian Standards into three principal types: pindi, danedar, and dhap **(**Aneja *et al*. 2002) [3].

3.1.1 Danedar: granular khoa known as danedar type is produced by milk with a high acidity level. Danedar khoa is distinguished by its uneven body and granular texture. The quantity of coagulant applied and the quality of the milk used both affect the size of the grains. This particular variety of khoa is utilised as a base for the creation of kalakand, cakes, and pastries where granulation is valuable **(**Aneja *et al*. 2002) [3].

3.1.2 Pindi: Is defined as a hemispherical, circular ball with a smooth, homogenous body and texture that is free of burnt particles and other browning flaws. It works best for preparing peda (Aneja *et al*. 2002) [3].

3.1.3 Dhap: The body of dhap khoa has a loose, sticky consistency and a silky texture. It has a lower mass percentage of total solids than pindi and danedar and has higher moisture content. After frying and soaking in sugar syrup, uniform balls with the proper rheological properties must be produced. It is recommended for making gulabjamun (Aneja *et al*. 2002) [3].

Table 1: Types of khoa and its preferred applications

Types of khoa	TS (%)	Fat (%)	Applications
Dhap	56-63	20-23	Gulabjamun, Pantua
Pindi	67-69	21-26	Barfi, Peda
Danedar	60-65	20-25	Kalakand, Milk cake

(*Source*: Aneja *et al*. 2002) [3]

3.2. Microbiology of khoa

Due to its nutritious richness and moisture content, khoa is an ideal medium for the growth of microorganisms. Poor shelf life is caused by the typically inferior methods used in its manufacture, handling, and storage in the unorganized sector (Sharma *et al*. 2008b) [87]. Although milk undergoes extreme heat treatment when making khoa, aerobic spore formers are known to withstand this heat treatment and may outnumber other types of microorganisms, suggesting that the survivors may grow during later storage. Furthermore, it is not impossible that these products could get contaminated during later handling (Rudreshappa and De 1971) [79].

Studied how antifungal medications affected maintaining khoa quality. (Rajarajan *et al*. 2006) [71]. They administered potassium sorbate (0.3%) and natamycin (0.5%) to the samples. When stored at 30°C and also at 5°C, the yeast and mould levels were decreased (Chavan and Kulkarni 2006) [22]. They made attempts to enhance the Khoa's microbiological quality using microwave and solar heating. In terms of lowering the overall bacterial count, yeast and mould count and spore count, microwave heating was found to be rather superior. Additionally, during a week of storage, it increased at a very modest rate. Utilizing solar radiation through a convex lens demonstrated encouraging outcomes in lowering microbial numbers, especially more successfully on YMC.

4. Fortification

The addition of one or more essential nutritional components to a food product, whether or not they are typically present in foods, is referred to as fortification. This is done to prevent or correct known nutrient deficiencies in either the general population or in certain target populations. The General Principles Codex also specifies that the initial proof of the need for an increase in the nutrient intake necessary to the population or to the target group is the key criterion indicated in the accomplishment of any such fortification programme. This demonstration may rely on actual clinical or subclinical deficiency investigations, assessments of inadequate nutrient intake, or potential deficiencies brought on by modifications to common food products (Codex Alimentarius Commission). Food fortification has been used for a very long time to successfully regulate the deficiency of a number of B vitamins, including thiamine, riboflavin, and niacin, as well as iodine and iron (Burgi *et al*. 1990) [19]. In order to reduce the deficiency rate in populations on a large scale, government organizations and food policy makers support food enrichment and fortification to varying degrees, and this has proven to be an effective strategy (The World Health Report). It is estimated that 2 billion people worldwide suffer from micronutrient malnutrition (Liu *et al*. 2018) [54, 56]. The most crucial elements used for food fortification are: iron, iodine, folate (vitamin B9), vitamin B12, other B vitamins (thiamine, riboflavin, niacin and vitamin B6), vitamin C, vitamin D, calcium, selenium, fibers, proteins, fatty acid.

5. Conclusion

Jamun seeds appear to be a low-cost source of a natural antidiabetic agent, although their antioxidant, anti-inflammatory antimicrobial potential is becoming more appreciated. The seed of the jamun fruit has a richly-varied composition of bioactive compounds, including terpenoids, phenolic compounds and saponins with high contents of gallic acid, ellagic acid and hydrolysable tannins. Their use has been rediscovered as antidiabetic, antiinflammatory, anticancer, antioxidant and antimicrobial in many products. After fortification of jamun seed powder with khoa, a nutritive and health-beneficial product will be formed. In this review we found that jamun seed has a lot of health benefits so if we add the extracted seed powder in khoa it will be more beneficial for our health, mainly to the diabetic patients.

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