# Function and Nutritional fortification of different products with Syzygium Cumini seeds; Mozzarella Cheese

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Jamun seed powder is utilized as a detoxifying herb that contains moisture, crude protein, crude fat, crude fiber, ash, and nitrogen-free extract. Historically, people have used jamun seed powder as a natural medicine to manage gastrointestinal and cardiovascular ailments, as well as to regulate blood sugar levels. Throughout many centuries, jamun seed powder has been utilized as a natural supplement to balanced blood sugar level. This comprehensive review aims to investigate the use of Syzygium cumini seeds, in different products, specifically concentrating on its addition to mozzarella cheese (a dairy product), thereby enhancing the nutritional value of our product for diabetic patients. Additionally, jamun seed powder has the capacity to manage blood sugar levels and blood pressure and improve gastrointestinal health and immunity. Cheese is a dairy product, a highly nutritious food that contains a significant amount of protein, calcium, and phosphorus. It promotes bone health, enhances muscle development, and improves cardiovascular health. This review focuses on the process of extracting jamun seed powder and incorporating it into cheese. Research data has revealed that jamun seed powder has numerous health benefits, particularly for individuals with diabetes.

## Introduction

Function foods are defined by the Food and Nutrition Board (FNB) of the National Academy of Sciences as "any modified food or food ingredient that may provide a health benefit beyond that of the traditional nutrients it contains" (Thomas and Earl et al., 1994), which imparts potentially healthy impacts. Despite being a common term, the scientific and health communities have not quite accepted the concept of functional food (Hasler., 1996). There is a widespread belief that classifying food as either "good" or "bad" is improper without scientific justification. Moreover,

numerous researchers firmly believe that the classification of good or poor should be applied to diets rather than individual meals. As a result, all foods must be regarded as "functional" in the widest sense. However, certain foods have the potential to selectively modify specific physiological processes, leading to an improved quality of life or a decreased risk of disease (Glinsmann., 1996). It's becoming harder to distinguish between foods and drugs due to the idea that some foods or their ingredients may provide a special health benefit. Traditionally, a drug refers to any substance that is intended for the purpose of diagnosing, curing, alleviating, treating, or preventing a disease. Changing the FNB definition to focus on "functional" rather than "health" could perhaps address some of the concerns with medications versus nutrients (Clydesdale., 1997). Furthermore, the greater intake of functional foods and their bioactive components should be seen as a means to achieve optimal nutrition rather than as a promotion of higher consumption of healthy foods or a mere marketing tactic (Clydesdale., 1997). Three factors are probably contributing to the growing interest in functional foods: rising health care expenditures, new laws, and scientific advancements (Braden et al., 1997). The healthcare sector in the United States represents approximately 14% of the Gross National Product (GNP). The proportion of national wealth allocated to health care, measured as a percentage of the gross national product (GNP), is consistently increasing on a global scale. Many people believe that inappropriate food habits contribute to poor health and the resulting costs of healthcare (Bidlack et al., 1996). Dietary factors are considered to be contributing factors to the primary causes of death among Americans, such as coronary heart disease and specific types of malignancies (Kannel., 1998). While it would be wrong to think of food as "magic bullets" for treating illnesses, it would also be wrong to ignore data suggesting that poor eating habits can make illnesses worse. Therefore, fortification is a technique; we can improve the nutritional profile of any food commodity.

The fruit known as jamun (*Syzygium cumini L.*), which belongs to the Myrtaceae family, has a short shelf life of one to two days. This fruit has been utilized for its nutritional and therapeutic properties in ancient medicinal systems like Siddha, Tibetan, Unani, Sri Lankan, and Ayurveda for the potential treatment of diarrhoea, menstrual problems, obesity, haemorrhage, and vaginal discharge (Ayyanar and Babu, 2012). In the past, seeds of S. cumini have been traditionally utilized by conventional medical practitioners for many centuries as an effective treatment for diabetes (Ratsimamanga, 1998). S. cumini leaf juice, mango leaves, and myrobalan, combined with honey and goat milk, were used to cure dysentery or with cardamom or cinnamon to treat diarrhoea in children (Nadkarni, 1976). The leaves of S. cumini have been utilized for the treatment of renal difficulties, indigestion, and diabetes (de Albuquerque et al., 2007). Similarly, the bark of S. cumini has been employed for the management of diabetes, diarrhoea, hunger stimulation, and headache relief. In addition, bark juice was used in traditional medicine to treat inflammations (Sudarsanam et al., 1995) and was administered to women who had a history of recurrent abortion (Chhetri et al., 2005). The juice of S. cumini fruit has been employed for the treatment of stomach ailments, diabetes, and diarrhoea (Jain et al., 2005). The seed, bark, leaves, pulp, and skin of S. cumini fruit have been found to possess antioxidant, anti-inflammatory, anticancer, and antidiabetic properties (Zhang and Lin, 2009; Modi et al., 2010; Aqil et al., 2016; Ayyanar and Babu, 2012). There is evidence to support the hepatoprotective, cardioprotective, chemopreventive, and antipyretic effects of the jamun (Das and Sarma, 2009; Syama et al., 2017; Arun et al., 2011; Muruganandan et al., 2001). Not only do these seeds have cultural value, but they also provide a biodegradable way to reduce waste and lessen environmental impact. After

the pulp is used to make goods like jams and juices, the seeds and skin that are left over are thrown away as garbage (Nparks, 2021). The production of waste, accounts for 10–47% of the total mass of the fruit (Al-Dhabi., 2020), poses a problem for the jamun processing sector and raises environmental concerns. Nevertheless, this waste also presents a chance. A significant amount of lost seeds and skins has the potential to be converted into valuable byproducts (Singh., 2022). Current research is primarily dedicated to investigating alternate applications for jamun fruit waste. This is motivated by several considerations, including the growing emphasis on environmental sustainability, more stringent government rules for trash disposal, and the economic challenges posed by such waste in business (Kannan and Puraikalan, 2015). Through the efficient utilization of jamun fruit waste, scientists may make valuable contributions to the development of a more environment friendly fruit processing business and create extra sources of income for both processors and farmers (Priyanka and Mishra ., 2015).

Dairy products promote human physical and mental health as well as prevent diseases linked to poor nutrition. The development of fortified dairy products has seen a significant rise in the growing demands of health-conscious customers desiring natural and healthy food choices. Cheese is a versatile dairy product that may be produced in various flavors and aromas through fresh or fermented methods and is widely enjoyed across the globe. The global consumption of cheese is consistently increasing and is projected to increase by 13.5% between 2016 and 2025 (OECD/FAO., 2016). Cheese contains essential nutrients and bioactive compounds that contribute to improving human health. These foods can be regarded as highly nutritious since they include ample amounts of protein, fat, essential vitamins (A, D, B2, B12, B5), and minerals (calcium, phosphorus, magnesium, zinc, iodine, and potassium). During the last three decades, worldwide cheese output has experienced an average yearly growth rate of approximately 4%. The increasing consumer demands have driven food researchers and cheese producers to focus on improving the quality of existing products as well as developing novel products (Kisworo et al., 2022).

**Chemical composition analysis of *Syzygium Cumini* seeds**

Syzygium cumini seeds has a unique bioactive composition and nutritional profile. Jamboline, often referred to as antimellin, is a glucoside present in the seeds of *Syzygium cumini*, that inhibits the conversion of starch into sugar in the body, hence assisting in maintaining glucose levels within optimal limits (Singh et al., 2019). Fresh jamun fruit typically contains 60–80% water, making it a very hydrating fruit. Carbohydrates make up the bulk of the fruit, which contains anywhere from 15% to 20% sugar. Glucose, fructose, and sucrose are the main sugar components. Jamun typically contains just half a percent to one percent of its fresh weight in protein (Singh et al., 2022). When fresh, the fat level is often under 1% of the total weight, which is extremely low. Reports indicate that jamun contains dietary fiber in amounts ranging from 1% to 3% of its fresh weight. A number of minerals, including iron, magnesium, potassium, and phosphorus, are abundant in jamun fruit. The most common mineral is potassium, followed closely by phosphorus. 20–30 mg of ascorbic acid per hundred grams of fresh weight is found in jamun, making it a vitamin C-rich food (Priyanka and Mishra., 2015). Vitamins A and B complex are among the additional vitamins found in minute amounts in the berry. Citric, malic, and oxalic acids are only a few of the many organic acids found in abundance in jamun fruit. These natural acids not only help the fruit retain its sour flavor, but they also make it easier to store. The many bioactive substances found in jamun, including tannins, anthocyanins, and

flavonoids (Qamar et al., 2022). Several variables, including cultivar, growth conditions, and maturity, can affect the exact physio chemical makeup of Syzygium cumini (Venu Gopal and Anu-Appaiah., 2017).

The jamun fruit's unique dark purple to black colour is a result of the high concentration of anthocyanins, a class of flavonoid pigmentous substances. The primary anthocyanins present in jamun include delphinidin-3-gentiobioside, malvidin-3-laminaribioside, petunidin-3-gentiobioside, and cyanidin-3-diglucoside. The concentration of anthocyanins in a fruit increases as it reaches maturity; however, there are exceptions to this pattern. There is a widespread belief that anthocyanins have advantageous properties for health, including the potential to decrease inflammation and maybe prevent diabetes (Kannan and Puraikalan., 2015). Jamun is rich in several flavonoids, such as anthocyanins, myricetin, quercetin, and kaempferol, among others. The presence of flavonoids in the fruit contributes to its antioxidant properties and potential health benefits in combating cancer and heart disease (Shashank et al., 2013). Jamun fruit contains tannins, which are a type of poly-phenolic compound known for their astringent properties. Tannins, responsible for imparting astringency to the fruit,

The mature jamun fruits are effectively used to make wine, preserves, squashes, jellies, and health beverages ( Warrier et al. 1996). The tree is used for its fruits, but also for its seeds, which are particularly important in the treatment of several disorders, with the most notable being Diabetes mellitus (Sagrawat et al. 2006). The jamun plants have been found to possess various beneficial properties, including antioxidant, anti-inflammatory, neuropsychopharmacological, anti-microbial, anti-bacterial, anti-HIV, antileishmanial, antifungal, nitric oxide scavenging, free radical scavenging, anti-diarrheal, antifertility, gastroprotective, anti-ulcerogenic, and radio-protective activities (Ramteke et al. 2015). Primary bioactive chemicals are secondary metabolites, which are natural products derived from the jamun plant. Originally, the plant extracts have been employed for the remedy of many ailments and conditions. The utilization of jamun extracts for the prevention and treatment of many ailments has been well-established, and it is currently widely acknowledged for its antidiabetic properties. Therapeutic effects of essential oils found in jamun, which contain lauric acid, phytochemicals, lipids, and phenols with antioxidant properties (Shalini et al. 2018). In addition, it is the secondary metabolites of plants that maintain pharmacological and toxicological qualities in animals and humans, which are relevant to their mechanism of action.

## Mozzarella Cheese Syzygium Cumini Supplementation Methods

### Addition of Jamun Powder directly

Adding jamun pulp or powder directly in a product can make more nutritious and healthy to the product. Using this technique, processed jamun powder is added straight into the cheese-making procedure. Here is an innovative approach:

**Jamun Powder Incorporation:** The process involves blending and emulsifying jamun powder before adding it directly to the curd during the milling stage. This process enables a dynamic dispersion of jamun powder throughout the cheese matrix, resulting in a visually captivating product that offers a blast of jamun flavor and color with every mouthful (Do Nascimento-Silva et al., 2022). A straightforward and expandable technique for including jamun powder is through

direct addition. It enables the incorporation of Jamun's fiber, vitamins, and minerals into the cheese structure, potentially improving its nutritional composition (Alikatte et al., 2012). Addition of dehydrated jamun powder or the addition of jamun extract are the two possible ways that can be followed:

**Dehydrated jamun powder:** Dehydrated jamun powder can be added at several points while making cheese. Adding it at the beginning of curd formation enables more even distribution of taste, however adding it later (after milling) can result in concentrated pockets of powerful jamun flavor in specific areas. This method provides an enhanced influence over the intensity of the jamun flavor within the cheese.but before addition, modifications to the cheese's pH buffering system may be required to maintain optimal cheese maturing due to the acidity of jamun seed. It is essential to determine the ideal particle size or amount of powder in order to achieve a well-balanced flavor profile and prevent excessive bitterness caused by jamun tannins (Jasmine and Daisy., 2017).

**Jamun Extract Infusion**

This method involves the production of a highly concentrated jamun extract by techniques such as solvent extraction or supercritical fluid extraction. Subsequently, the extract is deliberately included in the cheese-making procedure (Raza et al., 2017). After milling, curd washing with jamun extract involves rinsing the curds with a cold solution made from jamun extract. This careful infusion enables the bioactive compounds and some flavor components from the extract to penetrate the cheese curd, slightly enhancing the end product with the health advantages and taste characteristics of jamun without causing substantial changes to the texture of the cheese.
Extraction infusion offers a more accurate approach to integrating appropriate amounts of bioactive components from Jamun. It reduces the effects of moisture content and acidity originating from the fruit (El-Shenawy., 2009).

**Brine Infusion with Jamun Extract:** The cheese can be immersed in a brine solution that contains a specific quantity of jamun extract throughout the brining process. This method enables the precise and regulated distribution of taste and beneficial substances across the entirety of the cheese (Sankhari et al., 2010).

**Table 1: Composition of Jamun seeds powder**

Age of the fruit, soil type, location, and climate are the factors responsible for the variations in the nutritional profile of JS (Raza et al., 2015). The composition of jamun seeds powder has been ascertained by a variety of analytical techniques and research projects Khadivi et al. 2022) (Daulatabad et al., 1998) (Rydlewski et al., 2017) (Kshirsagar et al., 2019). The nutritional profile of jamun seeds powder are shown in Table 1.

**Table 1: Nutritional profile of Jamun seeds powder**

| Seeds powder | Per 100 g |
|---|---|
| Moisture (g) | 16.34 g |
| Protein (g) | 6.3–8.5 g |
| Fat (g) | 0.83–1.18 g |
| Crude fibre (g) | 2.3–16.9 g |
| Carbohydrates (g) | 41.5-43.5 g |
| Ash (h) | 2.04 g |
| Calcium (mg) | 0.41 mg |
| Phosphorus (mg) | 0.17 mg |
| pH | 3.79–4.83 |
| Acidity | 0.02–0.06 |
| Tannins | 168.24 mg |
| Polyphenols | 361.40 mg |
| Energy | 332.64 Kcal |
| Glucose | 70 % |
| **Lipids/Fatty acid profile** | 1.03 % |
| Total oil | 30 mg |
| SFA | 2.91 mg |
| MUFA | 292.79 mg |
| PUFA | 7.43 mg |
| n-6 | 0.55 mg |
| n-3 | 7.08 mg |
| Unsaponifiable matter | 19 mg/g |
| **Other important compounds** | |
| n-hexadecanoic acid | 20% |
| Hexadecamethyl-cyclooctasiloxane | 0.8% |
| 2-bromo-octadecanal | 2.6% |
| 3-(octadecyloxy) propyl ester stearic acid | 1.5% |
| 2,4,5-trimethoxy-benzaldehyde | 40% |

**Applications of Jamun seeds powder in foods**

An examination of the physicochemical, proximate, vitamin, and mineral content of jamun seeds powder has found that it has adequate levels of protein, fat, ascorbic acid, and minerals such as iron, calcium, and potassium. Thus, food scientists can utilize jamun seeds powder to develop functional foods (Singh and Kocher., 2020). It adds nutrition and health benefits to breads, muffins, and biscuits, such as blood sugar management. The powder adds antioxidants and minerals to smoothies, shakes, and energy drinks. It fills the requirement for healthy foods in breakfast cereals, granola bars, and nutritional snacks. Jamun seed powder adds flavor and health benefits to porridge, puddings, and sauces in traditional and modern cuisines. Functional foods and dietary supplements also use it to treat diabetes and cardiovascular disease due to its ability

to lower blood sugar and cholesterol levels (Alok and Akanksha., 2011). Therefore, jamun seed powder is a significant food ingredient since it boosts nutrition and health.

**Table 2. Different applications of jamun seeds powder in food products.**

| Food Products | Percentage of jamun seeds powder | Result | Reference |
|---|---|---|---|
| Composite cake | 10% | Improved the quantity and quality of protein, carbohydrate, and fiber content. | (Marufa et al., 2019) |
| Jamun seeds supplemented noodles | 8% | Increase cooking time, weight and volume | (Monika Sood et al., 2018) |
| Jamun seeds supplemented cheese | 4%, 6% | Improved the nutritional profile of cheese | (Dagadkhair et al., 2017) |
| Jamun seeds supplemented toffee | 5% | Enhanced the phytochemical content | (Mahalakshmi et al., 2022) |
| Jamun seeds fortified sharbat | 2%, 4%, 6% | Enhanced Bioactive profile | (Mahalakshmi et al., 2022) |
| Jamun seeds vermicelli | 10% | Enhanced Bioactive profile | (Mahalakshmi et al., 2022) |
| Jamun seeds paste | 2%, 4%, 6% | Enhanced the nutritional value | (Mahalakshmi et al., 2022) |
| Jamun seeds syrup | 2%, 4%, 6% | Enhanced the nutritional value | (Mahalakshmi et al., 2022) |
| Jamun seeds fortified khoa | - | Improved the nutritional and health-benefits | (Vedika Anil Thakur and Sury Pratap., 2023) |
| Jamun seeds fortified low fat cookies | 10%, 15%, 20%, 25% | Improved the nutritional and health-benefits | (Sanjay Kumar et al., 2023) |

## Therapeutic benefits of *Syzygium cumini* seeds

Jamun fruit seeds have been proven to benefit diabetic patients with a number of problems, including reducing blood glucose levels and delaying the onset of implications like cataracts and neuropathy. Jamun seeds possesses the ability to reduce blood sugar levels, making it an essential element in the treatment of diabetes. For a considerable period of time, individuals have utilized jamun seed powder as an integrated approach to regulating their blood sugar levels. It provides qualities that regulate sweating and natural urination while also cleansing the body. It has cardio-protective, hypolipidemic, and immunomodulatory effects. Fruit reduces blood sugar levels. Furthermore, it functions as a blood purifier, digestive aid, liver stimulant, and coolant.
Jamboline, a glycoside included in jamun seeds, helps regulate blood glucose levels to maintain them below tolerable limits (Helmstadter 2008). Utilizing seed extract for treating diabetes offers benefits by reducing symptoms such as polyuria and polydipsia (Joshi et al., 2019). Syzygium cumini seeds include saponins, tannins, and flavonoids, which have been found to possess antidiabetic, anti-inflammatory, and anti-dyslipidemic activities (Karthic et al., 2008). Powdered seeds have the potential to be used as a treatment for diabetes (Moussa et al., 2020).
The seeds possess anti-HIV, anti-diarrheal, antihyperglycemic, and antibacterial properties. Jamboline, also known as antimellin, is an alkaloid that is present in the seeds. It has the ability to inhibit the enzymatic conversion of sugar into starch (Chaudhary and Mukhopadhyay., 2012). Diabetes, allergies, viral infections, inflammation, and stomach ulcers can all be effectively managed using jamun seeds (Dagadkhair et al., 2017). In addition, it exhibits diuretic, anti-nociceptive, hypothermic, chemo-protective, and cardio-protective effects (Katiyar et al., 2016; Anjali et al., 2017). Myricetin, oxalic acid, gallic acid, citronellol, cyanidin diglucoside, hotrienol, phytosterols, flavonoids, carotenoids, and polyphenols are bioactive chemicals that have been found and associated with various health benefits (Chhikara et al., 2018).

## Biological functions of *Syzygium cumini* seeds:

### 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). Extracts from black jamun seeds decreased the activity of the enzyme by 59.1–90.6% (Gajera et al. 2017). 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). The antidiabetic 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). 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).

### Antihyperlipidemic and Antihypercholesterolemic activity

Jamun seeds contain many bioactive compounds that aid in regulating the blood lipid profile (Prince et al., 2004). Human investigations have demonstrated that jamun seeds possess antihyperlipidemic properties. When patients with prediabetes were administered a daily dosage of 4.5 g of jamun seed capsuled powder, their total cholesterol and LDL cholesterol levels exhibited a significant decrease, dropping from 266 to 216 mg/dL and from 189 to 139 mg/dL, respectively (Parveen et al., 2020).

**Anticancer activity**

found that human hepatoma cells underwent apoptosis when exposed to jamun seed extract. The study found that the mitochondrial potential and hepatocyte nuclear factor-1 were both reduced when different quantities (10, 20, and 40 g/mL) of the extract were utilized. The Western blotting test validated the impact of crude and hydrolyzed jamun seed extracts on cancer cell viability, as measured by the mmt assay. Both extracts showed a substantial decrease in the growth of A549, a type of non-small-cell lung cancer in humans (Aqil et al., 2012). The IC50 values for the crude and hydrolyzed extracts were 64 g/mL and 38 g/mL, respectively. The methanolic extract of jamun seeds exhibited cytotoxic activity against the colon cancer cell line, with an IC50 value of 1.24 g/m. The methanolic extract of jamun seeds exhibited cytotoxic activity against the colon cancer cell line, with an IC50 value of 1.24 g/m (Elhawary et al., 2022).

**Anti-inflammatory activity**

Due to the presence of numerous bioactive chemicals, the powder or extract derived from jamun seeds can serve as an anti-inflammatory agent, effectively reducing both acute and chronic inflammation. This was corroborated by multiple in vivo experiments (Kumar et al., 2008). The jamun seed extract has the ability to inhibit both adenosine deaminase and DPP-4 in human lymphocytes. It is highly probable that the bioactive compounds in the extract will engage with the DPP-ADA complex and modify purinergic signaling (Belle et al. 2013).

**Antioxidant activity**

The antioxidant capacity of jamun seeds was assessed by a series of in vitro procedures, which included several techniques for extracting bioactive components. The seeds of underutilized native black jamun landraces in the Gir forest region of India contain phenolic compounds such as gallic acid, ellagic acid, ferulic acid, catechin, and quercetin. These compounds were found to effectively inhibit the action of DPPH (Gajera et al., 2017).

**Antimicrobial activity**

The jamun seed extract has shown significant antibacterial activity against multi drug-resistant human bacterial infections. The agar well diffusion and micro-broth dilution experiments yielded results suggesting that the jamun seed extract has potential as a unique antibacterial agent (Bag et al., 2012). The extracts of jamun seeds have the potential to inhibit bacteria that manufacture lactamase, an enzyme that makes them resistant to drugs (Jasmine et al., 2010). *Aeromonas hydrophila, Chromobacterium violaceum, E. coli, Pseudomonas aeruginosa, Salmonella*

*enterica serovar Typhimurium, Serratia marcescens, Listeria monocytogenes*, and *aureus* have shown susceptibility to phenolic extracts derived from jamun seeds (Santos et al., 2020).

**Anti-fungal activity**

Bioactive chemicals extracted from jamun seeds using water and methanol showed anti fungal properties. These extracts were effective against various dermatophytic fungi, including *Aspergillus niger, Candida albicans, Tricophyton rubrum, T. mentagrophytes, and Microsporum gypseum* (Chandrasekaran and Venkatesalu., 2004).

## Cheese

Cheese, a staple meal with a rich and ancient history that extends over thousands of years, offers a wide variety of flavors, textures, and practical applications (Fox et al., 2017). Currently, there are 130 countries engaged in the production of different varieties of cheese, with a global production volume of 2000 × 104 tons. The Netherlands and Germany are the two largest global exporters of cheese. Cheese is an essential dairy product; however, the cheese sector needs greater attention and emphasis (El Sheikha., 2018).The production of this product involves complex techniques that alter the fat and protein composition of milk to achieve certain desired characteristics. Historically, cheese making relied on the inherent acidity of unpasteurized milk. However, in modern times, pasteurization and the utilization of starter cultures are applied to guarantee consistent quality and safety (El Sheikha, 2018). The global consumption of cheese is steadily rising as a result of its versatility and the growing demand from customers for healthier and more innovative varieties of cheese (OECD/FAO, 2016).

Mozzarella, a popular cheese known for its partially firm texture, exemplifies the intricate relationship between cheese functionality and production processes (Zheng et al., 2018). The unique and flexible texture of the dough is achieved using a hot-stretching method, which provides the required elasticity for manufacturing pizza (Viji et al., 2022). Nevertheless, to attain optimal performance, precise regulation of factors such as fat content, moisture level, and specific strains of initial cultures is required (Vogt et al., 2015). Fresh mozzarella has a high melting capacity but a short shelf life, while aged cheese has a limited ability to stretch. This highlights the importance of achieving a perfect balance for maximum pizza performance.

Given the significant demand for mozzarella, particularly in countries such as Pakistan where pizza is highly favored, it is crucial to explore methods for local production (Tirloni et al., 2019). The inadequate local cheese production fails to meet the demand for premium mozzarella, resulting in a reliance on imported products (Hebishy et al., 2022). The research efforts aimed at developing freeze-dried starter cultures from local sources offer a promising approach to reduce reliance on imports and enhance the quality of domestically produced mozzarella cheese. Through doing research and investigating novel techniques to strengthen cheese, we can augment the variety and nutritious quality of the dairy sector. Adding JS powder to cheese not only improves its functionality but also boosts its preservation capabilities due to its antibacterial and antioxidant characteristics. It is important to address safety concerns when consuming jamun seeds and to utilize them within permitted limits. The addition of JS powder to a functional confection considerably improved its prebiotic activity (2.16 ± 0.05), which was comparable to

the prebiotic activity of inulin. Furthermore, the glycemic index was reduced. Furthermore, in laboratory studies, research has demonstrated the functional confection's capacity to reduce the risk of diabetes. JS can be included in a wide range of convenient food items, such as baked goods (bread, biscuits, cakes, and cookies), extruded snacks, low-calorie foods, beverages, and therapeutic foods, to enable its extensive use.

## Fortification

Fortification is the act of adding vital nutritious components to a food product, regardless of whether or not they are normally found in foods. This is implemented to proactively address or rectify identified nutrient. The fundamental principles Codex also states that the primary need for implementing any fortification program is to enhance nutritional intake for the population or target group. This evidence may be based on investigations of clinical or sub clinical deficiencies, assessments of insufficient nutrient intake, or possible deficiencies resulting from alterations to common food products (Codex Alimentarius Commission). Food fortification has been employed for an extensive duration to effectively address the insufficiency of several B vitamins, such as thiamine, riboflavin, and niacin, in addition to iodine and iron (Burgi et al., 1990). To address the widespread deficiency rate in populations, government organizations and food policy makers endorse food enrichment and fortification to different extents, which has been demonstrated as a successful technique (The World Health Report). Approximately 2 billion individuals globally are affected by micronutrients deficiency (Liu et al., 2018). The essential components utilized for dietary fortification include iron, iodine, folate (vitamin B9), vitamin B12, other B vitamins (thiamine, riboflavin, niacin, and vitamin B6), vitamin C, vitamin D, calcium, selenium, fibers, proteins, and fatty acids.

## Conclusions and Future Perspectives

Jamun is extensively cultivated in various Asian nations, including India, Myanmar, and Sri Lanka. The conversion of jamun fruit into jam, juice, wine, and jellies results in a significant amount of seed waste. The jamun seeds waste generated by processing industries is disposed of in open places, resulting in environmental issues like groundwater pollution and the creation of unclean conditions in nearby regions. Researchers have determined that jamun seeds can serve as a beneficial and nutritious dietary element, providing essential nutrients such as carbohydrates, protein, lipids, vitamins, and minerals. Research on the functional food characteristics of jamun seed powder has confirmed its suitability for use in various bakery goods, including breads and cookies. Studies on toxicity have demonstrated that jamun seeds has a relatively benign profile, even at doses of up to 3000 mg/kg body weight. Nevertheless, it is crucial to do a thorough study on the utilization of jamun seeds in the development of functional foods or as a natural preservative in order to improve or achieve specific nutritional characteristics without compromising sensory appeal and adhering to safety regulations. The incorporation of jamun seeds in a wide range of convenient food products, including bakery items (such as breads, biscuits, cakes, and cookies), extruded snacks, reduced-calorie foods, drinks, and therapeutic foods, would also create prospects for the large-scale utilization of jamun seeds. Jamun seeds high jamboline content enables the creation of specialized diets for patients with diabetes and

other illnesses. Further research is necessary to assess the extent to which bioactive chemicals from jamun seeds can be absorbed and utilized by the body, as well as to determine their safety.

Jamun seeds are a cost-effective natural source of an anti-diabetic drug, with increasing recognition of their antioxidant, anti-inflammatory, and antibacterial properties. The jamun fruit seed has a diverse range of bioactive chemicals, including terpenoids, phenolic compounds, and saponins. It has significant levels of gallic acid, ellagic acid, and hydrolysable tannins. In numerous products, their application as antibacterial, antioxidant, anticancer, antidiabetic, and anti-inflammatory has been discovered. By fortifying jamun seed powder with cheese, a highly nutritious and health-promoting product will be created. Our analysis reveals that jamun seed has numerous health benefits. Therefore, using the extracted seed powder in cheese would enhance its health benefits, particularly for diabetes patients.