



Sugarcane Fermentation: Probiotics and Gut Benefits

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Article History	Abstract:
Received: 3/12/2023 Revised: 21/12/2023 Accepted: 10/01/2024	Sugarcane is rich in dietary fibers and is known for its positive effects on the gastrointestinal tract. It offers a wide array of health benefits for mammals. The sugar industry generates substantial residue amounts. Fermenting sugarcane with probiotic strains positively impacted gut flora in all instances. Maintaining the viability of these probiotic microorganisms is crucial when creating functional food products. Several factors can reduce their effectiveness in the gut. Sugarcane juice contains high levels of nutrients, minerals, and polyphenolic compounds, devoid of allergens and easily accessible. Fruit juices serve as excellent carriers for probiotics. Creating probiotic beverages while preserving taste and appearance is an innovative approach. The combination of probiotics and other dietary substances is gaining interest in promoting gastrointestinal health. Sugarcane juice, rich in nutrients and beneficial properties, is an optimal vehicle for probiotic organisms, contributing to overall health. Consequently, selecting appropriate probiotics and ensuring their effective delivery poses a technological challenge. This paper offers an overview of research articles summarizing procedures and techniques for enhancing probiotic viability. It also discusses ongoing research and challenges while outlining future opportunities for researchers based on existing literature.
CC License CC-BY-NC-SA 4.0	Keywords: Sugarcane, Probiotics, Dietary fibers, Gastrointestinal health, Residue management, Viability of probiotics

1. INTRODUCTION

The agricultural and food industries continuously propose advancements that lead to ongoing exploration and emerging innovations. Catering to diverse consumer preferences, needs, and acceptances is a dynamic process, underscoring the importance of maintaining food quality through technological advancements. Additionally, societal heritage, habits, and sustainability considerations significantly impact the innovations adopted within the food industry. Sugarcane stands as a significant agricultural commodity, with sugarcane tops, often lower in sugar content and typically discarded, resulting in substantial waste. Finding ways to repurpose this residue would be environmentally beneficial [1]. Presently, there is a growing trend toward health consciousness,

driving manufacturers to prioritize the development of functional foods. Consequently, the successful marketing and acceptance of new food varieties rely not only on consistent food quality but also on the additional value derived from food functionalities. These innovative functional foods encompass both natural and processed foods fortified with active compounds known for their biological effects. When these compounds are delivered in specified amounts, they offer clinically proven health benefits beyond those provided by basic nutrients [2].

Sugarcane (*Saccharum officinarum* L.) juice, obtained by crushing mature sugarcane, is a non-alcoholic beverage known for its thick and cloudy consistency, presenting shades from light brown to dark green. Its typical composition per 100 mL includes moisture (75.70–80.10 g), carbohydrates (19.68–22.88 g), protein (0.28–0.44 g), lipid (0.12–0.17 g), and ash (0.21–0.27 g). Consequently, sugarcane juice contains high water and carbohydrate content while having low levels of protein and lipid. It boasts significant amounts of carbohydrates, minerals (such as potassium, calcium, phosphorus, magnesium, and iron), and vitamins (mainly B and C), making it a robust product with an energy value of 80–100 kcal/100 mL and a pH ranging from 4 to 5 [3].

Sugarcane juice has been traditionally used in various regions worldwide to treat several human ailments. In systems like Ayurveda and Unani medicine in India, it has been employed either alone or in combination with other plant products. Extracts from sugarcane have shown diverse biological effects, including immune system stimulation, anti-clotting properties, anti-inflammatory actions, acting as a vaccine adjuvant, regulating acetylcholine release, and exhibiting anti-stress effects [4]. The juice enhances the body's natural immunity against various infections caused by viruses, bacteria, and protozoa, influencing the levels of immune cells like macrophages, neutrophils, and natural killer cells. Previous studies have explored the use of Sweet Lime juice as the sole source for probiotic fermentation, demonstrating successful growth of *Lactobacillus acidophilus* culture. Physiochemical parameters such as pH, TSS (total soluble solids), and acidity were found suitable for the culture's growth in both juice samples. Shelf-life studies revealed that *L. acidophilus* culture survived throughout a 3-week refrigeration period in sugarcane juice [5]. Additionally, recent research has explored the direct addition of freeze-dried probiotic culture *Lactobacillus casei* to sugarcane juice, replacing traditional methods of culture activation and propagation in MRS broth or juice. This approach leads to a simpler and faster manufacturing process with high counts of probiotics (>10⁹ CFU/mL), a crucial aspect in probiotic applications [6].

Sugarcane juice, derived from *S. officinarum* L, is a popular beverage in tropical and subtropical regions, renowned for its broad spectrum of health benefits. Traditionally used in Ayurveda to address liver diseases and jaundice, tropical sugarcane is recognized for its sweetness and rich juice content. Packed with iron and carbohydrates, this nutritious juice serves as a valuable energy source for the body. Abundant in minerals and organic acids, it supports vital organs like the kidneys, stomach, brain, eyes, and genital organs. It's also utilized to replenish lost protein during fever and in treating febrile disorders to prevent protein and nutrient depletion. Consumption aids in promoting urination, maintaining clear urine, and enhancing kidney function. Additionally, sugarcane juice is beneficial for acidity-related conditions such as nephritis, cystitis, gonorrhea, and an enlarged prostate [7]. Often paired with ginger juice, lime juice, and coconut water for added advantages, the combination of lime and sugarcane juice is recognized as a home remedy for jaundice. To fully harness its health benefits, sugarcane juice must be freshly extracted, clean, and processed in hygienic conditions. Sugarcane also exhibits protective properties against contamination, offering support to the immune system during illnesses. Direct consumption of the juice from sugarcane not only aids in dental hygiene by cleaning teeth but also strengthens jaw muscles. In instances of low body nutrition, sugarcane stands as an effective remedy, offering a multifaceted approach to health beyond ailments [8,9].

2. NUTRITIONAL COMPOSITION OF SUGARCANE

Sugarcane stalks are processed to extract their juice, which is highly nutritious and comprises natural sugars, minerals, vitamins, amino acids, organic acids, starch, phosphates, and gums. A 100 mL serving of sugarcane juice provides approximately 40 kcal of energy, along with 10 mg of calcium, 1.1 mg of iron, and 6 µg of carotene upon consumption [10]. Apart from its cooling effects, it is believed to possess properties that aid in conditions like discharge, dysuria, anuria, jaundice, cancer, cardiovascular, and urinary infections. In Ayurvedic medicine, sugarcane was used both as a standalone remedy and in combination with various herbs and plants. Sugarcane exhibits diuretic properties, promoting urinary flow and stimulating immunity in chickens. Regular intake of sugarcane juice supports the urinary system and assists kidneys in optimal functioning. The natural compounds found in sugarcane, including carotene, polyphenols, flavonoids, and chlorophylls, impart its characteristic color and participate in complex reactions due to their double bond unsaturation. Sugarcane juice components are classified into four categories: caramels, polyphenolic compounds, plant dyes, and sugar

breakdown products combined with amino derivatives. The soluble part of the juice comprises reducing and non-reducing sugars, organic acids, amino acids, proteins, and salts, while the insoluble part consists of suspended particles. The chemical profile of sugarcane juice includes varying percentages of non-reducing sugar, sucrose, reducing sugars, fiber, organic substances, inorganic substances, and nitrogenous content. The relative composition of constituents in the suspended and soluble phases depends on factors such as environmental conditions, sugarcane variety, plant growth stage, soil conditions, and harvesting methods. Weather conditions significantly influence soil levels in the juice, impacting the particle size of suspended matter as demonstrated through centrifugation [11].

3. BENEFICIAL ROLE OF SUGARCANE

Sugarcane, scientifically known as *S. officinarum*, offers beneficial properties like fiber, vitamin B, and various minerals including magnesium, manganese, sodium, calcium, iron, and potassium. It's predominantly a fruit that provides relatively fewer calories, aiding in weight management [12]. Different types of sugarcane across cultures vary in their calorie content; for instance, panela, a form of unrefined sugar, contains approximately 385 Kcal per 100g consumed. However, individuals with diabetes should avoid sugarcane due to its high sugar content, which quickly elevates blood sugar levels, impacting bodily processes. While sugarcane does contain sodium and cholesterol, it's notably low in saturated fats. For those aiming for healthy weight loss without the need to restrict various food types, it's a recommended dietary option [13]. Sugarcane's low glycemic index can be attributed to its sugars being directly processed by the liver. Sugarcane is credited with properties that aid in combating cancers and bodily abscesses. It's also beneficial for maintaining healthy gums by eliminating harmful bacteria, alleviating acid reflux, and significantly boosting energy levels. Overall, sugarcane offers numerous nutritional benefits and properties that contribute to bodily well-being, including its role in eradicating cancers and abscesses, supporting gum health by removing harmful bacteria, aiding in acid reflux relief, and notably enhancing overall energy levels in the body [14].

4. ROLE OF PROBIOTICS IN THE BODY

In October 2001, the World Health Organization (WHO) defined "Probiotics" as live microorganisms administered in adequate amounts that confer a health benefit to the host. These "Good Bacteria" function by eliminating pathogens in the intestine, aiding in maintaining gut health, and can be found in various food sources, fermented foods, dietary supplements, and beauty products [15]. The primary representatives of Probiotics are *Lactobacillus* and *Bifidobacterium* species, recognized for their long history of safe use and prevalence in the human digestive system. Additionally, other species such as *Lactococcus*, *Enterococcus*, *Propionibacteria*, and *Saccharomyces* (e.g., *Saccharomyces cerevisiae* and *Saccharomyces boulardii*) are included due to their health-promoting effects [16]. Fruits and vegetables serve as ideal carriers of probiotic cultures due to their rich nutritional content, absence of competing microorganisms, and lack of allergenic components. For instance, the Probiotic culture *L. casei* exhibits high survival rates in fruit juices. Probiotics primarily target the modulation of gut microbiota, which plays a crucial role in enhancing overall health [17]. The United Nations' Food and Agriculture Organization/WHO emphasize the need for probiotic strains to maintain viability through the upper digestive system to ensure health-promoting effects upon reaching their site of action [18]. For probiotics to be effective, they need to remain viable and functional at their intended location within the body. Probiotics have shown various benefits in treating conditions such as cardiovascular disease, colon cancer, diarrhea, *helicobacter pylori* eradication, allergies, hepatic encephalopathy, immune response, inflammatory bowel disease, lactose malabsorption, necrotizing enterocolitis, non-alcoholic fatty liver disease, and prevention of systemic infections [19]. While the source of the microorganism is less significant than its functionality, confirming the effectiveness of each potentially probiotic strain is crucial. Prebiotics, on the other hand, are dietary substances that support selected groups of gut microorganisms, favoring beneficial bacteria over harmful ones. Common prebiotics include oligofructose, insulin, galacto-oligosaccharides, and lactulose [20]. There's substantial evidence supporting the beneficial effects of probiotics, including enhanced digestive health, improved immune responses, reduced serum cholesterol, and cancer prevention. However, while some health benefits are well-documented, others require further investigation for validation [21]. Notably, probiotics have strong evidence supporting their use in treating acute diarrheal infections, preventing antibiotic-related diarrhoea, and improving lactose digestion, but further research is needed to recommend them for other clinical conditions [22].

5. INNOVATIONS OF PROBIOTICS IN PHARMACY

Probiotics have emerged as promising therapeutic agents within the realm of pharmacy, showcasing their potential to mitigate various health conditions [23]. In pharmaceutical settings, these live microorganisms are being explored for their ability to foster a balanced gut microbiome, thereby aiding in the management of gastrointestinal disorders like irritable bowel syndrome (IBS), inflammatory bowel diseases (IBD), and antibiotic-associated diarrhea [24]. Moreover, their immunomodulatory properties have spurred investigations into their potential roles in bolstering immune function and addressing allergic conditions. Innovative pharmaceutical formulations, designed to protect probiotic viability and ensure targeted delivery, are paving the way for their integration into treatments, potentially offering safe and effective interventions for diverse health concerns. However, rigorous research and stringent quality control measures are vital to establish standardized protocols and validate their efficacy, dosage, and safety in clinical pharmacy settings [25].

6. MECHANISM OF PROBIOTICS

Probiotics, consisting mainly of strains like *Lactobacillus* and *Bifidobacterium*, play a crucial role in modulating the gut microbiota, impacting various bodily functions. *Lactobacillus* strains, including *L. acidophilus*, *L. plantarum*, and *L. rhamnosus*, are among the most extensively studied and commonly used probiotics [26]. These bacteria aid in restoring the microbial balance within the gut. *L. acidophilus*, for instance, helps maintain a healthy balance by producing lactic acid, which inhibits the growth of harmful bacteria. *L. plantarum* contributes to gut health by supporting a robust gut barrier and promoting immune responses. *Bifidobacterium* strains, such as *B. bifidum* and *B. longum*, are known for their ability to break down dietary fibers, producing beneficial compounds like short-chain fatty acids [27]. These compounds support gut health and exhibit anti-inflammatory properties. These probiotic strains, along with others like *Saccharomyces boulardii* and *Streptococcus thermophilus*, participate in competitive exclusion, preventing harmful bacteria from thriving in the gut environment [28]. *Saccharomyces boulardii*, a yeast-based probiotic, has been linked to reducing diarrhea and maintaining gut health by modulating immune responses. *Streptococcus thermophilus* contributes to lactose digestion and supports overall digestive health [29].

The mechanisms through which specific probiotic strains exert their beneficial effects encompass a range of actions within the body, all contributing to enhanced digestive health, fortified immunity, and overall well-being. Firstly, probiotics engage in competitive exclusion, a process where they compete with harmful bacteria for space and nutrients within the gut environment [30]. Strains like *Lactobacillus* and *Bifidobacterium* outcompete these pathogens, preventing colonization and proliferation. This competitive advantage leads to a healthier microbial balance in the gut, promoting a more favorable environment for overall digestive health. Certain probiotic strains actively contribute to fortifying the gut barrier. These probiotics enhance the gut's defense mechanism by stimulating the production of proteins that maintain the integrity of the intestinal lining [31]. A strengthened gut barrier reduces permeability, preventing the entry of harmful substances into the bloodstream and supporting gut health and function. Probiotics also interact with the immune system localized in the gut [32]. These beneficial bacteria modulate immune responses, influencing immune cells to strike a balanced and appropriate response. By regulating the immune system, probiotics help manage inflammation and promote a more harmonized immune function, contributing significantly to overall health and well-being [33].

Another key mechanism involves the fermentation of undigested carbohydrates by probiotics, primarily in the colon. This fermentation process yields short-chain fatty acids (SCFAs) like butyrate, acetate, and propionate. SCFAs serve as an energy source for colonic cells, possess anti-inflammatory properties, and play a pivotal role in maintaining gut health. Additionally, certain probiotic strains produce bioactive compounds like antimicrobial peptides and organic acids [34]. These substances exhibit antimicrobial properties, inhibiting the growth and activity of harmful bacteria within the gut environment. These collective actions of probiotics synergistically contribute to improved digestion, a balanced immune system, reduced inflammation, and overall gut health. However, it's crucial to consider that the effects and mechanisms may vary between different probiotic strains. Tailoring probiotic supplementation to specific strains and individual health conditions is essential to maximize the intended health benefits. Factors such as strain specificity, dosage, and an individual's gut health status are pivotal in determining the effectiveness of probiotic interventions [35].

7. CONCLUSION

Sugarcane juice exhibits promising potential as a contributor to improved gut health. Its rich composition of dietary fibers, minerals, vitamins, and polyphenolic compounds offers multifaceted benefits for digestive well-being. The presence of dietary fibers aids in regularizing bowel movements, while the sugars and polyphenols act as prebiotics, fostering the growth of beneficial gut bacteria. Additionally, the juice's antioxidant properties

may aid in reducing gut inflammation and maintaining intestinal integrity. Regular consumption of sugarcane juice, as part of a balanced diet, holds promise in nurturing a diverse gut microbiome and supporting optimal digestive function. However, further research is warranted to comprehensively understand its specific impacts and dosages for achieving optimal gut health benefits.

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