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BEYOND FERMENTED TEA: RECENT ADVANCES IN KOMBUCHA FERMENTATION, FUNCTIONAL BIOACTIVES, SAFETY, AND INDUSTRIAL APPLICATIONS

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ABSTRACT

Kombucha is a fermented functional beverage traditionally prepared by fermenting sweetened tea with a symbiotic culture of bacteria and yeasts (SCOBY). During fermentation, the microbial consortium converts sugars into a wide range of bioactive metabolites, including organic acids, polyphenols, flavonoids, vitamins, amino acids, ethanol, and bacterial cellulose, which collectively contribute to the nutritional and functional properties of the beverage. In recent years, kombucha has gained considerable scientific and commercial attention owing to its reported antioxidant, antimicrobial, anti-inflammatory, antidiabetic, hepatoprotective, and anticancer activities. The incorporation of medicinal plants, fruits, vegetables, and other botanical substrates has further expanded the diversity and functional potential of kombucha by enhancing its phytochemical composition and sensory attributes. In addition to its application as a functional beverage, bacterial cellulose produced during kombucha fermentation has emerged as a valuable biomaterial for food packaging, wound dressing, tissue engineering, and environmental remediation. Despite these advances, challenges related to microbial standardization, fermentation control, quality assurance, product safety, and limited clinical evidence continue to restrict broader industrial and therapeutic applications. This review comprehensively summarizes recent advances in kombucha research, including its historical background, microbial ecology, fermentation mechanisms, chemical composition, biological activities, industrial applications, safety concerns, and future research directions.

KEYWORDS: Kombucha, SCOBY, Functional beverage, Fermentation, Bioactive metabolites, and Polyphenols.

INTRODUCTION

Functional foods have attracted increasing attention because of their potential to promote health beyond basic nutrition. Among fermented functional beverages, kombucha has emerged as one of the fastest-growing products due to its unique sensory characteristics, diverse microbial community, and abundance of bioactive metabolites (Jayabalan et al., 2014). Traditionally prepared by fermenting sweetened black or green tea with a symbiotic culture of bacteria and yeasts (SCOBY), kombucha has been consumed for centuries in several Asian and European countries and is now widely marketed worldwide as a health-promoting beverage (Villarreal-Soto et al., 2018).

The fermentation of kombucha is a dynamic biochemical process involving cooperative interactions between acetic acid bacteria, osmophilic yeasts, and, in some cases, lactic acid bacteria. During fermentation, yeasts hydrolyse sucrose into glucose and fructose through invertase activity and convert these sugars into ethanol and carbon dioxide. Acetic acid bacteria subsequently oxidize ethanol into acetic acid and other organic acids while simultaneously producing bacterial cellulose that forms the characteristic SCOBY pellicle. These microbial interactions generate numerous metabolites that contribute to the beverage's flavour, acidity, nutritional value, and biological properties (Marsh et al., 2014; Savary et al., 2021).

The chemical composition of kombucha is influenced by several factors, including tea variety, sugar concentration, fermentation duration, temperature, microbial composition, and the incorporation of additional plant materials. The fermented beverage contains organic acids, polyphenols, flavonoids, vitamins, amino acids, minerals, enzymes, volatile compounds, and exopolysaccharides, many of which exhibit antioxidant and antimicrobial activities (de Miranda et al., 2022; Mousavi et al., 2020). Microbial fermentation also facilitates the biotransformation of plant-derived phytochemicals into smaller, more bioavailable molecules, thereby enhancing their biological activity and functional value (Laavanya et al., 2021).

Growing consumer preference for natural, minimally processed, and health-promoting foods has stimulated extensive research into kombucha produced from medicinal herbs, fruits, vegetables, cereals, flowers, and spices. These alternative substrates enrich the beverage with diverse phytochemicals while improving sensory quality and expanding its potential applications in the functional food industry (Kapp & Sumner, 2019).

Although numerous studies have reported beneficial biological activities of kombucha, including antioxidant, antimicrobial, anti-inflammatory, antidiabetic, hepatoprotective, and anticancer effects, much of the current evidence is derived from in vitro experiments and animal models. Well-designed clinical studies and standardized fermentation protocols are still required to validate these health claims, establish product safety, and facilitate regulatory approval for broader commercial and therapeutic applications (Bhattacharya et al., 2016; Arasteh et al., 2020).

Therefore, this review aims to provide a comprehensive overview of kombucha by summarizing its historical development, microbial ecology, fermentation mechanisms, bioactive compounds, health-promoting properties, industrial applications, safety considerations, and future research opportunities. Particular emphasis is placed on recent developments in herbal kombucha, emerging technologies for fermentation optimization, and the industrial potential of kombucha-derived bacterial cellulose.

MICROBIAL ECOLOGY OF THE SYMBIOTIC CULTURE OF BACTERIA AND YEASTS (SCOBY)

SCOBY Culture

The unique characteristics of kombucha are primarily attributed to the symbiotic culture of bacteria and yeasts (SCOBY), a complex microbial consortium that drives the fermentation process. The microbial composition of SCOBY varies according to geographical origin, fermentation conditions, tea type, sugar concentration, and fermentation duration. Despite this variability, the microbial community generally consists of acetic acid bacteria (AAB), osmophilic yeasts, and occasionally lactic acid bacteria (LAB), which interact synergistically to produce the characteristic metabolites of kombucha (Coelho et al., 2020).

Acetic acid bacteria in the production of Kombucha

Acetic acid bacteria constitute the dominant bacterial population in mature SCOBYs and are responsible for oxidizing ethanol produced by yeasts into acetic acid. Among them, species belonging to the genus *Komagataeibacter* are the most prevalent and efficient cellulose producers. Other commonly reported genera include *Acetobacter*, *Gluconobacter*, and *Gluconacetobacter (*Kaashyap et al., 2021). The cellulose synthesized by these bacteria forms the floating pellicle that protects the microbial consortium from environmental stress while facilitating oxygen diffusion required for aerobic metabolism (Liu et al., 2024). Comparative metagenomic studies have consistently shown that *Komagataeibacter xylinus*, *Komagataeibacter hansenii*, and *Komagataeibacter saccharivorans* dominate mature kombucha cultures because of their superior cellulose-producing ability and acid tolerance (Tran et al., 2020).

Yeast isolated from Kombucha

Yeasts play an equally important role by initiating sugar metabolism. They secrete invertase, which hydrolyses sucrose into glucose and fructose, followed by alcoholic fermentation that generates ethanol and carbon dioxide. The ethanol produced subsequently serves as the primary substrate for acetic acid bacteria, illustrating the metabolic cooperation between the two microbial groups. Frequently reported yeast genera include *Saccharomyces*, *Zygosaccharomyces*, *Brettanomyces*, *Pichia*, *Candida*, *Schizosaccharomyces*, and *Debaryomyces*. The relative abundance of these yeasts influences flavour development, volatile compound formation, ethanol concentration, and fermentation efficiency (Wang et al., 2024; Goes Neto et al., 2021; Antolak et al., 2021).

Role of Lactic acid bacteria in Kombucha

Although acetic acid bacteria and yeasts dominate the fermentation ecosystem, several investigations have also detected lactic acid bacteria, including species of *Lactobacillus*, *Lacticaseibacillus*, *Lactiplantibacillus*, and *Leuconostoc*. These bacteria contribute to the production of lactic acid and other antimicrobial metabolites, thereby improving microbial stability and potentially enhancing the probiotic characteristics of kombucha. However, their abundance is generally lower than that of acetic acid bacteria and yeasts and depends largely on the fermentation substrate and environmental conditions (Wang et al., 2026; Kim et al., 2026).

Consequently, the development of standardized microbial starter cultures is increasingly recognized as an important strategy for producing kombucha with consistent quality, improved safety, and predictable functional properties. Future studies integrating genomics, transcriptomics, and metabolomics are expected to provide deeper insights into microbial interactions and metabolic pathways involved in kombucha fermentation (Liao et al., 2024; Nie et al., 2024).

FERMENTATION PROCESS AND BIOCHEMICAL CHANGES DURING KOMBUCHA FERMENTATION

Kombucha fermentation is a dynamic biochemical process driven by the synergistic interactions of acetic acid bacteria, yeasts, and, in some cases, lactic acid bacteria. Sucrose serves as the primary carbon source and is initially hydrolysed by yeast-derived invertase into glucose and fructose. These monosaccharides are subsequently metabolized through glycolysis to produce ethanol and carbon dioxide. Ethanol produced by the yeasts becomes the principal substrate for acetic acid bacteria, which oxidize it into acetic acid while simultaneously producing gluconic acid, glucuronic acid, and bacterial cellulose. This metabolic cooperation is essential for establishing the characteristic acidity, flavour profile, and functional properties of kombucha (Chou et al., 2024; Laureys et al., 2020).

During fermentation, significant physicochemical changes occur in the beverage. The pH decreases progressively from approximately 5.0 to values below 3.5 because of the accumulation of organic acids, while titratable acidity increases continuously. Simultaneously, sucrose concentration declines as fermentable sugars are utilized by the microbial community, whereas transient ethanol production reaches its maximum during the intermediate stages before being converted into organic acids by acetic acid bacteria. These biochemical transformations not only improve microbial stability by inhibiting spoilage organisms but also contribute to the characteristic sweet-sour taste of kombucha (Khazi et al., 2024; Sreeramulu et al., 2000).

The production of bioactive metabolites also increases throughout fermentation. Organic acids, including acetic, gluconic, glucuronic, lactic, malic, and citric acids, accumulate in varying concentrations depending on the microbial composition and fermentation conditions. In parallel, microbial enzymes catalyse the transformation of complex tea polyphenols into lower-molecular-weight phenolic compounds with improved bioavailability and antioxidant potential. Several metabolomic studies have demonstrated that fermentation modifies the concentration of catechins, flavonoids, amino acids, and volatile compounds, thereby enhancing the nutritional quality and sensory characteristics of the beverage (Villarreal-Soto et al., 2020; Bortolomedi et al., 2022).

Fermentation conditions markedly influence the biochemical profile of kombucha. Temperature, fermentation duration, tea variety, sugar concentration, inoculum size, and oxygen availability collectively determine microbial growth, metabolite production, antioxidant capacity, and sensory quality. Fermentation periods of 7–14 days are generally considered optimal for balancing acidity and flavour, whereas prolonged fermentation may lead to excessive acidification and reduced consumer acceptability. Likewise, the use of green tea, black tea, herbal infusions, or fruit substrates produces distinct metabolite profiles because of differences in their phytochemical composition (Cardoso et al., 2020; de Miranda et al., 2022).

Recent advances in metabolomics have provided new insights into the biochemical complexity of kombucha fermentation. Integrated microbiome–metabolome analyses have revealed strong correlations between microbial succession and metabolite formation, demonstrating that variations in SCOBY composition directly influence the production of organic acids, phenolic derivatives, amino acids, and volatile flavour compounds. Such findings have contributed to the development of controlled fermentation strategies aimed at improving product consistency, functional properties, and industrial scalability (Jansen et al., 2024).

BIOACTIVE COMPOUNDS OF KOMBUCHA

The health-promoting properties of kombucha are primarily attributed to its diverse profile of bioactive compounds, which originate both from the tea substrate and from microbial metabolism during fermentation. The qualitative and quantitative composition of these compounds varies according to the type of tea or herbal substrate, microbial composition of the SCOBY, fermentation duration, sugar concentration, and environmental conditions. During fermentation, microbial enzymes modify naturally occurring phytochemicals and generate new metabolites with enhanced biological activities, resulting in a beverage possessing greater functional potential than the unfermented substrate (Bortolomedi et al., 2022).

Among the identified metabolites, phenolic compounds constitute the most abundant and biologically significant class. Tea leaves are naturally rich in catechins, epicatechin, epigallocatechin gallate (EGCG), epicatechin gallate (ECG), gallic acid, chlorogenic acid, caffeic acid, and rutin. During fermentation, microbial hydrolytic enzymes transform complex polyphenols into lower-molecular-weight phenolics that exhibit improved bioavailability and stronger antioxidant activity. Several studies have demonstrated that the total phenolic content and radical scavenging activity increase progressively during the early stages of fermentation before stabilizing or declining during prolonged fermentation, depending on substrate composition and fermentation conditions (Kochman et al., 2020; La Torre et al., 2021).

Flavonoids represent another important group of phytochemicals contributing to the biological properties of kombucha. Fermentation enhances the release of flavonoids from plant tissues through enzymatic degradation of cell wall components, thereby increasing their extractability. Major flavonoids identified in kombucha include quercetin, kaempferol, myricetin, catechin, epicatechin, and their glycosylated derivatives. These compounds have been associated with antioxidant, anti-inflammatory, antimicrobial, cardioprotective, and antidiabetic activities through their ability to scavenge reactive oxygen species, chelate transition metals, and regulate cellular signalling pathways (de Oliveria et al., 2024).

Organic acids are among the principal fermentation-derived metabolites responsible for the characteristic acidic taste, microbial stability, and preservative properties of kombucha. Acetic acid is the predominant organic acid, followed by gluconic acid, glucuronic acid, lactic acid, malic acid, citric acid, tartaric acid, succinic acid, and oxalic acid. These metabolites contribute to pH reduction, inhibit spoilage microorganisms, and influence the sensory quality of the beverage. Among them, glucuronic acid has received particular attention because of its involvement in hepatic detoxification pathways, although additional clinical evidence is required to confirm its health benefits in humans (Xiao et al., 2024; Pereira, 2026).

In addition to phenolics and organic acids, kombucha contains vitamins, amino acids, minerals, and volatile compounds generated during microbial fermentation. Water-soluble vitamins, particularly those belonging to the B-complex group, together with vitamin C, are frequently detected in fermented kombucha, although their concentrations vary considerably depending on microbial composition and fermentation conditions. Essential minerals, including potassium, magnesium, calcium, iron, manganese, zinc, and copper, are also retained from the original substrate and contribute to the nutritional value of the beverage. Furthermore, amino acids released during fermentation participate in flavour development and serve as precursors for numerous aroma compounds (Massoud et al., 2024).

Recent metabolomic and chromatographic studies have substantially expanded knowledge of kombucha chemistry, revealing that the biological properties of the beverage arise from synergistic interactions among multiple classes of metabolites rather than from a single bioactive compound.

FACTORS AFFECTING KOMBUCHA FERMENTATION AND BIOACTIVE COMPOSITION

The quality, chemical composition, and biological properties of kombucha are significantly influenced by several intrinsic and extrinsic factors that regulate microbial growth and metabolic activity during fermentation. These factors include the type of fermentation substrate, sugar concentration, microbial composition of the SCOBY, fermentation temperature, fermentation duration, oxygen availability, inoculum ratio, and initial pH. Variations in these parameters directly affect microbial succession, metabolite production, antioxidant capacity, flavour development, and overall product quality (Dartora et al., 2023).

Effect of Tea and Herbal Substrates

In addition to traditional black and green tea, several medicinal herbs, including winter savory (Satureja montana), peppermint (Mentha × piperita), stinging nettle (Urtica dioica), wild thyme (Thymus serpyllum), elderberry (Sambucus nigra), and quince (Cydonia oblonga), have been successfully used as substrates for kombucha fermentation. Herbal kombuchas generally exhibited higher phenolic and flavonoid contents, enhanced antioxidant activity, and improved ACE inhibitory activity compared to traditional tea-based kombucha. Among these, peppermint-based kombucha showed the highest phenolic and flavonoid contents, while elderberry-based kombucha produced the highest acetic acid content, highlighting the potential of medicinal herbs to enhance the functional properties of kombucha (Vitas et al., 2020)

Effect of Sugar Concentration

Sucrose serves as the primary carbon and energy source for the SCOBY. During fermentation, yeast invertase hydrolyses sucrose into glucose and fructose, which are subsequently metabolized into ethanol and organic acids. Insufficient sugar concentrations restrict microbial growth and metabolite production, whereas excessive sugar may delay fermentation and increase residual sugar in the final beverage. Most studies have reported that sucrose concentrations between 50 and 100 g/L provide favourable conditions for balanced microbial activity and optimal production of organic acids and phenolic metabolites (Muhialdin et al., 2019; Hartini et al., 2026).

Effect of Fermentation Temperature

Temperature is one of the most critical factors influencing microbial metabolism and fermentation kinetics. Most acetic acid bacteria and yeasts exhibit optimal activity between 25 and 30°C. Fermentation at lower temperatures slows microbial growth and prolongs fermentation, whereas temperatures above 35°C may inhibit microbial viability and negatively affect flavour development. Appropriate temperature control promotes cellulose synthesis, organic acid production, and antioxidant activity while minimizing undesirable microbial contamination (De Filippis et al., 2018).

Effect of Fermentation Time

Fermentation duration strongly influences the physicochemical and nutritional characteristics of kombucha. During the initial stages, yeasts actively metabolize sugars, resulting in ethanol production and rapid microbial proliferation. As fermentation progresses, acetic acid bacteria convert ethanol into acetic and gluconic acids, leading to a gradual reduction in pH and increased titratable acidity. Simultaneously, concentrations of phenolic compounds and flavonoids often increase because of microbial biotransformation. Fermentation periods of 7–14 days generally produce beverages with desirable acidity, enhanced antioxidant activity, and acceptable sensory properties, whereas prolonged fermentation may result in excessive acidification and reduced consumer acceptability (Li et al., 2022).

Effect of Oxygen Availability

Acetic acid bacteria are obligate aerobes and require sufficient oxygen for ethanol oxidation and bacterial cellulose production. Consequently, kombucha fermentation is generally performed under static aerobic conditions using breathable coverings that permit oxygen diffusion while preventing microbial contamination. Reduced oxygen availability limits acetic acid production and cellulose formation, whereas adequate aeration enhances microbial activity and improves fermentation efficiency (Tran et al., 2022).

Effect of SCOBY Composition

The microbial diversity within the SCOBY significantly influences fermentation performance and metabolite composition. Differences in bacterial and yeast populations may alter organic acid profiles, volatile compounds, phenolic biotransformation, and sensory attributes. Advances in microbial ecology have demonstrated that standardized starter cultures containing selected strains of *Komagataeibacter* and *Saccharomyces* can improve fermentation reproducibility and product consistency compared with traditionally propagated SCOBYs. Such standardization is increasingly considered essential for industrial-scale kombucha production (Sfoglia et al., 2025; Senthilkumar et al., 2026).

Overall, kombucha fermentation is governed by the complex interaction of multiple environmental and microbial factors rather than a single parameter. Careful optimization of substrate composition, fermentation conditions, and microbial inoculum is therefore essential for producing a beverage with consistent quality, desirable sensory characteristics, and enhanced functional properties.

BIOLOGICAL ACTIVITIES OF KOMBUCHA

Kombucha has emerged as a promising functional beverage because of its diverse biological activities, which are attributed to the synergistic effects of tea-derived phytochemicals and metabolites generated during microbial fermentation. During fermentation, the SCOBY biotransforms polyphenols, flavonoids, sugars, and amino acids into a wide range of bioactive compounds, including organic acids, phenolic derivatives, vitamins, and bacterial cellulose. These biochemical modifications enhance the antioxidant potential and contribute to the antimicrobial, anti-inflammatory, hypoglycaemic, hypolipidaemic, hepatoprotective, antihypertensive, and antiproliferative properties of kombucha (Costa et al., 2023)

Among the reported health benefits, antioxidant activity has been investigated most extensively. Kombucha produced from green and black tea exhibited distinct phenolic profiles, resulting in differences in antioxidant capacity, antibacterial activity, and antiproliferative effects. Green tea kombucha showed superior antibacterial and antiproliferative activity, whereas black tea kombucha contained a greater diversity of phenolic compounds and exhibited higher antioxidant capacity (Cardoso et al., 2020). Fermentation significantly enhances the concentration and bioavailability of phenolic compounds, thereby improving free radical-scavenging activity through DPPH, ABTS, and FRAP assays (Jakubczyk et al., 2025)**.** In addition, Lopes et al. (2021) observed that fermentation of yerba-maté with SCOBY significantly increased both antioxidant and antibacterial activities compared with the unfermented infusion, indicating that substrate selection markedly influences the functional quality of kombucha. These findings collectively suggest that antioxidant activity depends on the interaction between fermentation conditions, microbial metabolism, and the phytochemical composition of the substrate.

The antimicrobial activity of kombucha has been widely reported against both Gram-positive and Gram-negative bacteria, including *Escherichia coli*, *Staphylococcus aureus*, *Salmonella enterica*, *Listeria monocytogenes*, and *Pseudomonas aeruginosa*, as well as opportunistic fungi such as *Candida albicans (Nyiew et al., 2022; Hou et al., 2021)*. Sreeramulu et al. (2001) first demonstrated that fermented kombucha exhibited stronger antimicrobial activity than unfermented tea, primarily because of the accumulation of acetic acid during fermentation. Subsequently, Bhattacharya et al. (2016) showed that the polyphenolic fraction isolated from kombucha inhibited the virulence of *Vibrio cholerae*, indicating that antimicrobial activity is mediated not only by organic acids and low pH but also by fermentation-derived phenolic compounds. Furthermore, Cardoso et al. (2020) confirmed that green tea kombucha inhibited a broader spectrum of pathogenic bacteria than black tea kombucha, emphasizing the influence of substrate composition on antimicrobial efficacy. These observations highlight the potential application of kombucha as a natural antimicrobial agent and food preservative.

In addition to its antioxidant and antimicrobial properties, kombucha has demonstrated promising anti-inflammatory, hepatoprotective, hypoglycaemic, hypolipidaemic, antihypertensive, and antiproliferative activities in experimental models (Anantachoke et al., 2023). Bellassoued et al. (2015) reported that kombucha supplementation significantly reduced oxidative stress and improved lipid metabolism in hypercholesterolaemic rats, suggesting a protective effect against cardiovascular disorders. Moreover, several in vitro studies have demonstrated antiproliferative activity against human cancer cell lines, which has been associated with catechins, flavonoids, and other fermentation-derived phenolic compounds. Despite these promising observations, differences in fermentation substrates, microbial composition, analytical methodologies, and experimental models have resulted in considerable variability among studies, limiting direct comparisons.

INDUSTRIAL APPLICATIONS AND COMMERCIALIZATION OF KOMBUCHA

The global demand for kombucha has increased substantially over the past decade owing to growing consumer awareness of functional foods and beverages. The use of plant by-products during the second fermentation of kombucha supports the principles of the circular economy by valorizing agricultural waste into value-added functional beverages. These by-products enrich the beverage with diverse bioactive metabolites while influencing the microbial community and fermentation profile. This sustainable approach enhances the nutritional and functional properties of kombucha and promotes environmentally friendly food production (Chiarini et al., 2026). These innovations have transformed kombucha from a traditional fermented tea into a commercially valuable beverage with considerable market potential.

Commercial production of kombucha requires strict control of fermentation parameters to ensure product consistency, safety, and sensory quality. Unlike household fermentation, industrial manufacturing employs standardized starter cultures, optimized sucrose concentrations, controlled fermentation temperatures, and hygienic processing practices to minimize batch-to-batch variation. Soares et al. (2023) reported that fermentation variables, particularly substrate composition, temperature, fermentation duration, and inoculum ratio, significantly influence the physicochemical properties, microbial composition, antioxidant activity, and overall quality of kombucha. Consequently, optimization of these parameters has become a major focus of industrial process development.

Recent research has focused on developing novel kombucha beverages using alternative plant substrates to enhance nutritional quality and diversify commercial products. According to Su et al. (2023)**,** numerous medicinal plants, edible flowers, fruits, vegetables, and cereal extracts have been successfully utilized as fermentation substrates, producing kombucha beverages enriched with phenolic compounds, flavonoids, anthocyanins, and other bioactive metabolites. Such substrate diversification not only improves the functional properties of kombucha but also enables manufacturers to develop region-specific products with enhanced consumer appeal.

In addition to beverage production, the SCOBY has emerged as a valuable source of bacterial cellulose with diverse industrial applications. SCOBY-derived cellulose possesses excellent mechanical strength, high water-holding capacity, biocompatibility, and biodegradability, making it suitable for applications in food packaging, biomedical materials, wound dressings, tissue engineering, and sustainable biomaterials. Cubas et al. (2023) emphasized that the utilization of food-processing wastes as fermentation substrates for bacterial cellulose production represents an environmentally sustainable approach that supports circular bioeconomy principles while reducing industrial waste generation.

Despite rapid commercialization, several challenges continue to limit the large-scale production of kombucha. Product quality is influenced by variations in microbial composition, fermentation conditions, raw material quality, and storage stability. Moreover, maintaining consistent alcohol content, carbonation, flavour profile, and microbial safety remains a major challenge for manufacturers. Advances in microbial ecology, precision fermentation, metabolomics, and quality-control technologies will facilitate the development of standardized kombucha products with improved safety, reproducibility, and functional efficacy. Integration of these technologies with sustainable manufacturing practices is expected to drive the next generation of functional fermented beverages (Li et al., 2024)

CONCLUSION

Kombucha is a traditional fermented beverage that has gained significant scientific and commercial attention due to its potential functional and health-promoting properties. The symbiotic activity of bacteria and yeast within the SCOBY drives the biotransformation of tea substrates into a complex mixture of organic acids, polyphenol derivatives, vitamins, enzymes, and bioactive metabolites. These compounds collectively contribute to its reported antioxidant, antimicrobial, and possible probiotic effects. Current literature suggests that kombucha may offer beneficial roles in gut health modulation, oxidative stress reduction, and inhibition of certain pathogenic microorganisms. However, these effects are highly dependent on fermentation conditions, microbial composition, and raw material quality. Variability in preparation methods especially in non-standardized or home-based fermentation can lead to significant differences in chemical composition, acidity, and microbial safety. Despite its promising biofunctional profile, kombucha is not without limitations. Concerns regarding microbial contamination, excessive acidity, and residual alcohol content highlight the need for strict quality control measures and standardized production protocols. Implementation of Good Manufacturing Practices (GMP) and systematic monitoring of physicochemical and microbiological parameters are essential for ensuring consumer safety and product consistency. In conclusion, kombucha represents a promising functional beverage with substantial potential for nutraceutical and industrial applications. However, further well-designed clinical studies, metabolomic profiling, and standardization of fermentation practices are required to fully validate its health claims and establish globally accepted quality guidelines.

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Conflict of Interest

There is no conflict of interest

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