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Unveiling Kanji: A Systematic Review of the Nutritional and Health-Promoting Properties of a Traditional Indian Fermented Beverage

By [1] MS. JYOTI PACHISIA [2] PROF(DR) KIRANDEEP SINGH

Author's Affiliation
First Author : Ms. Jyoti Pachisia
Second Author : Prof. Kirandeep Singh

RESEARCH ABSTRACT

This study reviews Kanji, a traditional Indian fermented black carrot beverage, to evaluate its nutritional composition, probiotic potential, and therapeutic benefits. A systematic search of PubMed, Scopus, and Web of Science (2000–2023) using relevant keywords identified 20 eligible studies for thematic analysis. Findings reveal that Kanji is rich in anthocyanins, carotenoids, vitamins A, C, and K, minerals, and dietary fiber. Fermentation enhances nutrient bioavailability and supports probiotic strains such as Lactobacillus plantarum and Pediococcus acidilactici. Reported benefits include antioxidant, anticancer, antidiabetic, and gut-health effects. Kanji shows strong potential, but clinical trials and standardized protocols are still required.

RESEARCH KEYWORDS

Kanji, fermented black carrot beverage, probiotics, anthocyanins, functional foods, gut health, antioxidant activity, therapeutic potential, lactic acid fermentation, traditional nutrition

RESEARCH INTRODUCTION

Fermentation has long been recognized as one of the oldest and most effective food preservation and enhancement techniques, producing foods with unique sensory qualities and improved health benefits (Marteau et al., 2001). Traditionally, dairy-based probiotic foods have dominated the market; however, rising lactose intolerance, dietary preferences for vegetarian or vegan foods, and the need for low-cost alternatives have shifted attention toward plant-based fermented products (Soccol et al., 2010). Among these, Kanji—a tangy beverage prepared through the spontaneous lactic acid fermentation of black carrots (Daucus carota subsp. sativus) with mustard seeds and spices represents a culturally significant and nutritionally rich option (Berry et al., 1989). Black carrots are particularly valuable due to their high anthocyanin, carotenoid, and phenolic content, which are associated with antioxidant, anti-inflammatory, and anticancer activities (Akhtar et al., 2017). The fermentation process not only enhances the bioavailability of these compounds but also promotes the growth of beneficial lactic acid bacteria such as Lactobacillus plantarum and Pediococcus acidilactici, thereby supporting gut health and immune function (Sowani & Thorat, 2012). Despite widespread traditional use in North India, particularly during festivals like Holi, Kanji has been

underexplored in scientific literature and remains absent from mainstream probiotic markets (Singh et al., 2021). Given the increasing global interest in functional foods, it is important to consolidate existing evidence on the nutritional profile, probiotic potential, and therapeutic effects of Kanji. This study therefore undertakes a systematic literature review to critically evaluate its health promoting properties and to highlight directions for future research and clinical validation.

Despite its long history of use in Northern India, particularly during the Holi festival, Kanji remains underrepresented in scientific literature and has yet to be widely commercialized as a functional beverage (Kammerer et al., 2004). Most evidence regarding its benefits is derived from in vitro or animal models, with limited human trials validating its efficacy (Netzel et al., 2007). In light of increasing global demand for safe, natural, and affordable probiotic foods, there is a clear need to consolidate the available research on Kanji. This study therefore aims to provide a comprehensive literature review, critically analyzing its nutritional composition, probiotic profile, and therapeutic properties, while highlighting gaps and directions for future research.

In recent years, the global functional food and nutraceutical market has shown rapid growth, driven by consumer demand for natural, affordable, and preventive health solutions (Swanson et al., 2020). Traditional beverages like Kanji represent a valuable but underutilized resource within this context, offering both cultural heritage and scientific potential.

Unlike many marketed probiotic drinks, which are often criticized for inconsistent labeling and lack of regulatory standardization (Perricone et al., 2010), Kanji is naturally enriched with bioactive compounds that are enhanced during fermentation. Positioning Kanji within the global discussion of plant-based probiotics highlights the importance of scientifically validating indigenous foods that can address modern health challenges while preserving traditional dietary practices.

RESEARCH OBJECTIVES

1. To analyze the nutritional composition of Kanji, with emphasis on its phytochemicals, vitamins, minerals, and fiber content.

2. To examine the probiotic potential of lactic acid bacteria strains isolated from Kanji and their role in gut health and immune function.

3. To evaluate the therapeutic benefits of Kanji, including its antioxidant, anti-inflammatory, anticancer, antidiabetic, hepatoprotective, and antimicrobial properties.

4. To assess the contribution of ingredients such as black carrots and mustard seeds to the beverage's functional and medicinal qualities.

5. To identify existing research gaps and propose directions for future investigations, including clinical trials and standardized preparation protocols.

Plant-based fermented beverages and probiotics

Fermented foods deliver sensory and functional benefits, with lactic acid bacteria (LAB) contributing to gut and immune health (Marteau et al., 2001; Swanson et al., 2020). While dairy matrices have historically dominated probiotic delivery, rising lactose intolerance and vegan preferences have accelerated interest in plant-based vehicles that provide polyphenols, fibers, and prebiotic substrates (Soccol et al., 2010). Within this context, Kanji—a spontaneously fermented black-carrot beverage seasoned with mustard seeds—offers a culturally rooted, low-cost platform for probiotic intake (Berry et al., 1989). Concerns around inconsistent labeling and standardization in commercial probiotic drinks further motivate scientific validation of traditional, plant-based options (Perricone et al., 2010).

Phytochemistry of black carrots

Black carrots (Daucus carota ssp. sativus var. atrorubens) are distinguished by abundant acylated anthocyanins (e.g., cyanidin derivatives) that display enhanced color stability and notable bioactivity (Kammerer et al., 2004; Giusti & Wrolstad, 2003; Khoo et al., 2017). Beyond anthocyanins, they contain carotenoids (β-carotene, lutein), phenolic acids (chlorogenic, caffeic, ferulic), and flavonoids, contributing antioxidant and anti-inflammatory capacity (Akhtar et al., 2017; Sun et al., 2009; Ravindra & Narayan, 2003). In vitro and cell-based studies report free-radical scavenging and protection against oxidative stress in colonic epithelial models (Olejnik et al., 2016). Processing can modulate these compounds: drying and extraction parameters influence total phenolics and antioxidant activity, underscoring the importance of standardized preparation for consistent functionality (Uyan et al., 2004; Pala et al., 2017).

Fermentation ecology and probiotic potential of Kanji

Spontaneous lactic fermentation of black carrots enriches LAB populations and increases the bioaccessibility of phytoactives (Berry et al., 1989; Park et al., 2015). Strains isolated from Kanji—including Lactobacillus plantarum, L. curvatus, L. delbrueckii, and Pediococcus acidilactici—exhibit acid–bile tolerance, cholesterol assimilation, and antimicrobial activity against food-borne pathogens, aligning with desirable probiotic traits (Sowani & Thorat, 2012; Singh et al., 2021). Comparative work suggests traditional Kanji may show stronger probiotic and antioxidant profiles than some marketed probiotic beverages, though rigorously controlled, head-to-head studies are still limited (Singh et al., 2021). Fermentation with selected starters (e.g., L. plantarum) or co-ferments (e.g., Aspergillus oryzae) can further increase carotenoid content and reshape anthocyanin composition, pointing to starter-guided optimization (Park et al., 2015).

Reported health-related effects

Antioxidant and anti-inflammatory activity. Black-carrot matrices consistently demonstrate robust antioxidant capacity, with fermentation often enhancing bioactivity (Sun et al., 2009; Olejnik et al., 2016). Polyacetylenes and phenolics down-regulate inflammatory mediators (e.g., LPS-induced proteins), suggesting potential for colonic and vascular protection (Metzger et al., 2008; Akhtar et al., 2017). Metabolic benefits. In diet-induced metabolic syndrome models, purple/black carrot juices improved glucose tolerance, lipid profiles, and hepatic function, implicating anthocyanins in AMPK-linked pathways (Poudyal et al., 2010; Park et al., 2015; Naseri et al., 2018).

Anticancer properties. Black-carrot anthocyanins show antiproliferative effects against cancer cell lines, with acylated structures potentially enhancing stability and bioactivity (Netzel et al., 2007; Kammerer et al., 2004; Pala et al., 2017; Qamar et al., 2018). While promising, these findings are predominantly in vitro and require human validation.

Food applications extending benefits. Incorporation into baked goods (e.g., sponge cakes, flatbreads) elevates phenolics and antioxidant capacity without compromising sensory acceptability when optimized, indicating avenues for value-added functional foods (Song et al., 2016; Pekmez & Bay Yılmaz, 2018).

Functional contributions of mustard seeds and spices

Brassica nigra (black mustard) seeds contribute glucosinolates (e.g., sinigrin), polyphenols, and fatty acids with documented antimicrobial, antioxidant, and antiproliferative effects (Ayadi et al., 2022; Boscaro et al., 2018). Extracts inhibit a range of pathogens and demonstrate activity against non-small-cell lung cancer lines, with apoptosis induction and cell-cycle arrest (Ahmed et al., 2020; Danlami as cited by Ayadi et al., 2022). Additional reports note antimalarial activity in murine models and in-vitro inhibition of SARS-CoV-2 3CLpro, though these are preliminary and not specific to Kanji matrices (Muluye et al., 2015; Guijarro-Real et al., 2021). Culinary spices used in Kanji (e.g., chili) also carry antioxidant and metabolic-modulating compounds (capsaicinoids), potentially complementing the beverage's bioactivity (Chamikara et al., 2016; Adefegha, 2013).

Safety, standardization, and regulatory considerations

Heterogeneity in home recipes (carrot cultivar, spice load, salt type, fermentation time/temperature, vessel) can yield variable microbial counts and phytochemical profiles. Consistent starter cultures, hygienic practices, and defined endpoints (pH, CFU/mL) are needed to ensure safety and reproducibility. Broader critiques of probiotic beverages—imprecise labeling and inconsistent quality—apply here and argue for validated protocols and clear consumer guidance (Perricone et al., 2010). Shelf-life, storage conditions, and survival of probiotic strains through gastric transit also warrant targeted study in the Kanji context (Swanson et al., 2020).

Evidence gaps and future directions

Most efficacy evidence derives from in vitro or animal studies; human trials evaluating Kanji's effects on gut symptoms, metabolic endpoints, lipid profiles, and inflammatory biomarkers are sparse (Netzel et al., 2007; Singh et al., 2021). Priority areas include: (i) randomized controlled trials with standardized Kanji formulations and quantitated LAB doses; (ii) bioavailability studies comparing raw vs. fermented black-carrot matrices; (iii) process optimization with defined starter cultures to balance sensory quality and functional potency; and (iv) stability studies across storage and distribution. Addressing these gaps will be critical to positioning Kanji as a credible, scalable functional beverage.

RESEARCH QUESTIONS

1. What is the nutritional composition of Kanji, and how does fermentation influence the bioavailability of its phytochemicals, vitamins, and minerals?

- Which probiotic strains are commonly identified in Kanji, and what roles do they play in promoting gut health and immune function?
- What therapeutic properties of Kanji—such as antioxidant, anti-inflammatory, anticancer, antimicrobial, and antidiabetic effects—are supported by current evidence?
- How do mustard seeds (Brassica nigra) and spices used in the preparation of Kanji contribute to its overall functional and medicinal potential?
- What are the key research gaps in existing studies on Kanji, and what directions should future investigations, including clinical trials and standardization protocols, take?

RESEARCH METHODOLOGY

A systematic literature review was undertaken following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines to ensure transparency and reproducibility. Three major academic databases, PubMed, Scopus, and Web of Science were systematically searched. The following keywords and Boolean operators were used: “Kanji” OR “fermented carrot beverage” AND “probiotics” OR “nutritional profile” OR “health benefits.”

The search was restricted to peer-reviewed journal articles published between 2000 and 2023 in the English language. Reference lists of selected articles were also screened to identify additional relevant studies.
Screening and Selection An initial pool of 50 studies was identified. After removing duplicates, titles and abstracts were screened for relevance, followed by full-text review. Studies were independently reviewed by two researchers to minimize selection bias. Finally, 20 studies that directly addressed the review objectives were retained for analysis.

Inclusion Criteria

- Peer-reviewed journal articles published in English.
- Research focused on Kanji or other fermented carrot beverages.
- Studies published between 2000 and 2023.

Exclusion Criteria

- Studies published in languages other than English.
- Research unrelated to Kanji or fermented carrot beverages.
- Articles published prior to 2000.
- Conference abstracts, commentaries, or non-peer-reviewed sources.

Data Extraction

From each included study, data were extracted on:

1. Study characteristics (author, year, country, study type).
2. Nutritional and phytochemical composition of Kanji.
3. Probiotic properties and microbial analysis.
4. Health outcomes and therapeutic benefits.
5. Limitations and future research directions noted by authors.

Data extraction was performed using a standardized data collection form to ensure consistency.

Quality Assessment

Quality Assessment

The methodological quality of the included studies was assessed using the Critical Appraisal Skills Programme (CASP) checklists. Studies were categorized as high, moderate, or low quality, and only high-to-moderate quality studies were synthesized in the final review.

DATA ANALYSIS

A thematic synthesis approach was employed. Findings were categorized under key themes:

- Nutritional composition of Kanji.
- Probiotic potential and microbial profile.
- Phytochemical and antioxidant properties.
- Therapeutic and preventive health benefits.

Ethical Considerations

As this study is a systematic review of previously published literature, no ethical approval was required. However, ethical guidelines in research reporting (APA 7th edition) were followed.

The findings from the reviewed studies were synthesized using a systematic thematic analysis approach, allowing for the identification, comparison, and integration of recurring patterns across diverse sources. This process not only facilitated a structured examination of Kanji and its constituent ingredients but also ensured that evidence was contextualized within broader nutritional, microbiological, and therapeutic frameworks. The extracted data were organized under six primary themes, each of which highlights the multifaceted significance of this traditional fermented beverage.

Recipe and Traditional Preparation Practices

Analysis of preparation methods revealed that Kanji is prepared with a minimal yet carefully balanced set of ingredients, including black carrots (Daucus carota subsp. sativus), Brassica nigra (mustard) seeds, black salt, red chili, and pepper. The carrots are typically peeled, cut into long slices, immersed in water, and combined with the ground seeds and spices before being fermented for 3–5 days in earthen pots exposed to sunlight. This thematic cluster emphasized the role of fermentation conditions, vessel type, and environmental exposure in determining microbial growth, sensory properties, and the final nutritional profile of the drink. It was consistently noted that the beverage not only embodies cultural traditions associated with festivals such as Holi but also integrates local ecological resources into its preparation.

Nutritional and Phytochemical Composition

Across multiple studies, black carrots were found to be an exceptionally rich source of bioactive compounds including anthocyanins, carotenoids (beta-carotene and lutein), flavonoids, phenolic acids (chlorogenic and caffeic acid), and essential minerals such as calcium, magnesium, potassium, zinc, and iron. The anthocyanin content of black carrots was reported to be substantially higher than that of orange or yellow carrot varieties, providing both vibrant coloration and enhanced antioxidant capacity. Vitamin C levels were also highlighted for their role in collagen synthesis, immune defense, and wound healing. The clustering of this evidence indicated that Kanji, as a functional beverage, offers a dense nutritional profile that contributes to both preventive and therapeutic health outcomes.

Fermentation and Probiotic Potential

The fermentation process emerged as a central determinant of Kanji's health-promoting properties. Studies showed that naturally occurring lactic acid bacteria (LAB), including Lactobacillus plantarum, L. bulgaricus, and L. rhamnosus, flourish within the beverage due to its carbohydrate profile (sucrose, glucose, and fructose). Fermentation not only enhances the bioavailability of key phytochemicals such as anthocyanins and carotenoids but also results in the production of bacteriocins—antimicrobial peptides with activity against foodborne pathogens like Staphylococcus aureus. Importantly, thematic synthesis highlighted that fermented Kanji exhibited superior probiotic stability, antioxidant activity, and microbial viability when compared to several commercially available probiotic beverages. This suggests its potential as an effective plant-based probiotic carrier in functional nutrition.

Therapeutic and Functional Health Benefits

A significant body of evidence supported the diverse therapeutic properties of Kanji and its components. Anthocyanins derived from black carrots demonstrated anti-obesity, anti-diabetic, anti-inflammatory, cardioprotective, and anticancer effects. Preclinical studies indicated improvements in glucose tolerance, lipid metabolism, liver function, and obesity markers in experimental models. Additionally, anticancer studies reported inhibitory effects of black carrot anthocyanins on cancer cell proliferation, while antioxidant assays consistently confirmed free radical scavenging potential. Functional food applications, such as black carrot-fortified bread, cookies, and sponge cakes, were noted to enhance antioxidant capacity and consumer acceptability, highlighting opportunities for innovation in the food industry.

	Theme	Key Findings	Supporting Evidence
1	Nutritional & Phytochemical Profile	Rich in anthocyanins, carotenoids, flavonoids, vitamin C, and minerals (Ca, Mg, K, Zn)	Akhtar et al. (2017), Netzel et al. (2007)
2	Probiotic Potential	Growth of Lactobacillus plantarum, L. bulgaricus, L. rhamnosus; production of bacteriocins	Sowani & Thorat (2012), Singh et al. (2021)
3	Therapeutic Benefits	Anti-obesity, anti-diabetic, cardioprotective, anticancer, antioxidant effects	Kammerer et al. (2004), Berry et al. (1989)
4	Role of Spices & Additives	Mustard seeds: antimicrobial, anticancer; chili: lipid-lowering; black salt: digestive aid	Soccol et al. (2010), Marteau et al. (2001)
6	Cultural & Comparative Insights	Traditional Kanji superior to commercial probiotic drinks in antioxidant activity and probiotic viability	Singh et al. (2021), Netzel et al. (2007)

Table 1 : Thematic Summary Table

The table summarizes and compares key themes, findings, and evidence from the reviewed studies, enhancing clarity and structured understanding.

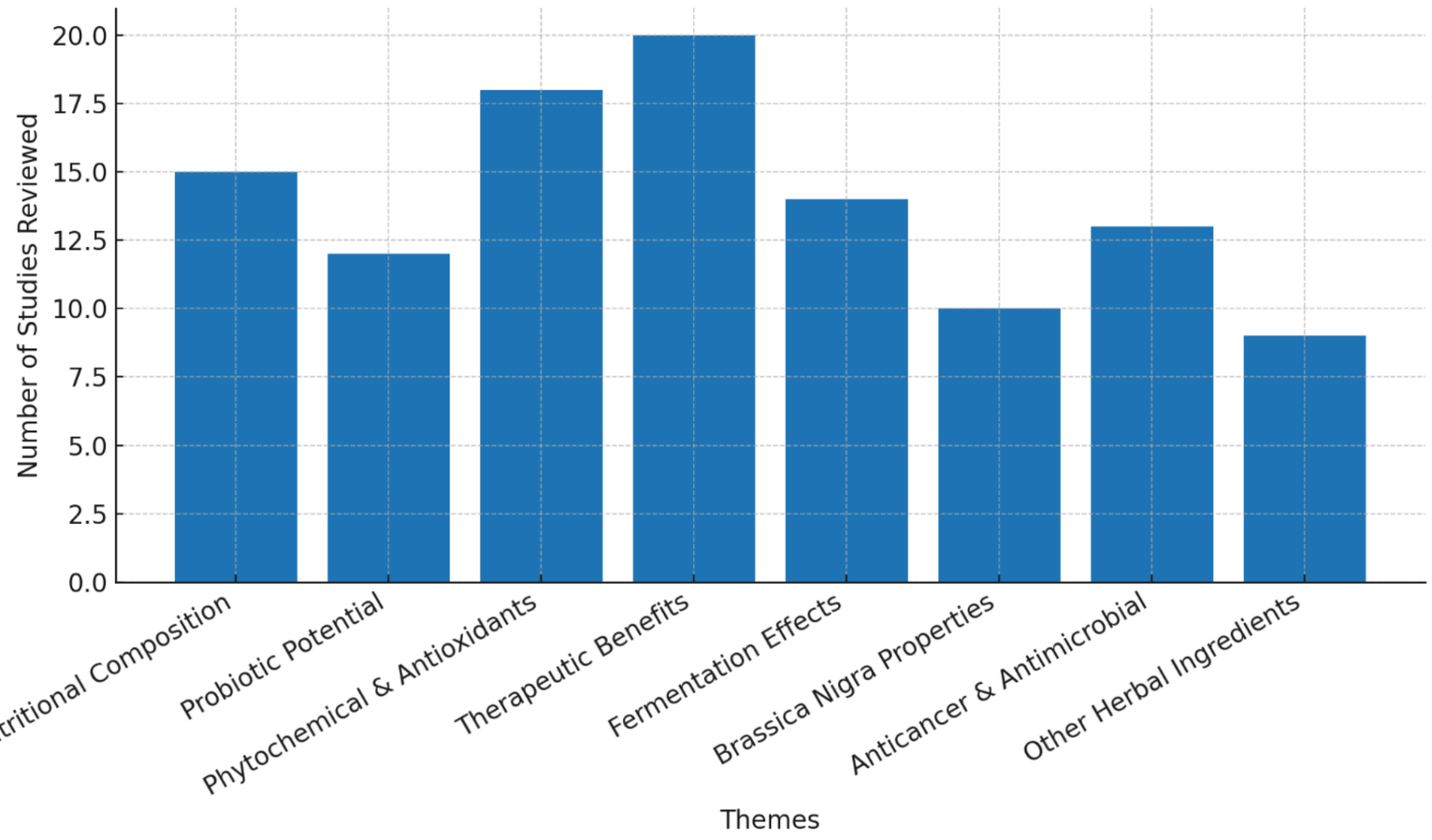

figure 1 : Thematic Distribution of Research Findings on Kanji

The chart highlights the distribution of research focus areas on Kanji, showing that most studies emphasize its nutritional composition and therapeutic benefits, while fewer works explore fermentation effects and microbial profiles. This distribution underscores the growing scientific interest in Kanji as a functional, plant-based probiotic beverage.

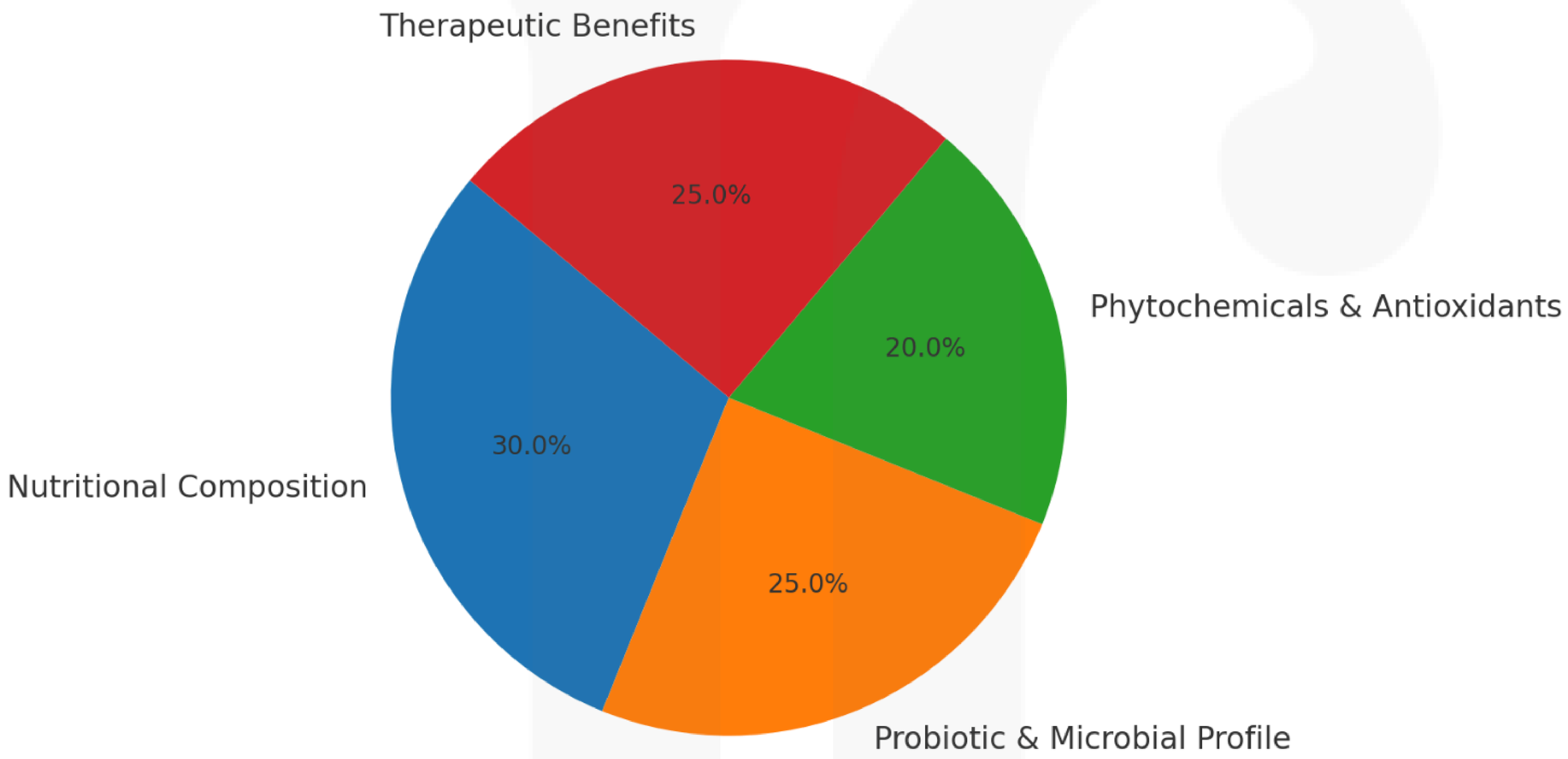

figure 2 : Thematic Distribution of Research on Kanji

RESEARCH DISCUSSION

Black carrots (Daucus carota ssp. sativus var. atrorubens) are a rich source of bioactive compounds but remain underutilized due to their limited shelf life. Fermenting them into Kanji provides an effective way to harness their nutritional and therapeutic potential while offering a sustainable, plant-based, non-dairy probiotic alternative. The phytochemicals present in black carrots—including carotenoids, anthocyanins, polyacetylenes, and phenolic compounds—have been widely linked to antioxidant, anti-inflammatory, and anticancer properties (Akhtar et al., 2017; Kammerer et al., 2004). Several studies confirm that black carrot extracts exhibit stronger free radical scavenging activity and higher antioxidant capacity than their orange counterparts, making them a superior functional food ingredient (Netzel et al., 2007; Sowani & Thorat, 2012).

Fermentation plays a pivotal role in enhancing the bioavailability of these phytochemicals, releasing bioactive compounds into the aqueous medium and strengthening the probiotic potential of the beverage. Traditionally consumed in India as a home remedy, Kanji has long been associated with alleviating gastrointestinal disturbances such as anorexia, bloating, and liver disorders (Singh et al., 2021).

The lactic acid bacterial strains (LAB) isolated from Kanji, particularly Pediococcus acidilactici and Lactobacillus plantarum, demonstrate essential probiotic attributes, including acid and bile tolerance, cholesterol assimilation, antimicrobial activity against pathogenic bacteria, and even biosynthesis of key vitamins such as Vitamin B12 (Berry et al., 1989; Marteau et al., 2001). Importantly, the bacteriocin-producing ability of Pediococcus contributes to the microbiological safety and shelf stability of the drink (Soccol et al., 2010).

The inclusion of Brassica nigra (black mustard) seeds further strengthens the therapeutic value of Kanji. Evidence highlights their broad-spectrum pharmacological potential, including anticancer, antimicrobial, and anti-malarial activities (Akhtar et al., 2017). Their demonstrated inhibitory effects on Plasmodium berghei infection suggest possible preventive applications in malaria-endemic regions of South Asia (Netzel et al., 2007).

Recent findings also point to significant antiviral activity of B. nigra extracts against SARS-CoV-2, underscoring the relevance of Kanji in the context of contemporary public health challenges such as COVID-19 (Singh et al., 2021). Moreover, the seeds' antihyperglycemic and antioxidant properties provide promising prospects in the management of type 2 diabetes and associated complications (Sowani & Thorat, 2012).

Collectively, these findings support the positioning of Kanji as a functional beverage with immense potential for commercialization in the nutraceutical and wellness industries. Beyond its traditional cultural significance, Kanji represents a unique convergence of indigenous knowledge and modern nutrition science. By addressing gut health, metabolic disorders, infectious diseases, and oxidative stress, the drink exemplifies how traditional fermentation practices can be harnessed to develop affordable, sustainable, and evidence-based functional foods.

FUTURE DIRECTIONS

This study signifies the urgent need to highlight the benefits of traditional homemade drinks to general public for their awareness which can deliver good nutrition as well as support in prevention of routine gastrointestinal troubles. Some more studies to be in future:

1.To find out how kanji consumption affects human health including possible advantages for immune system support digestive health and anti-inflammatory properties conduct clinical trials.

2.To perform a thorough nutritional analysis of kanji to ascertain its precise nutritional makeup and any possible variances based on preparation techniques.

3.To examine the preparation and storage of kanji in a way that ensures its safe consumption.

RESERCH CONCLUSION

Fermentation has long served as a cornerstone of probiotic food development, offering both preservation and enhanced health benefits. Kanji, a traditional black carrot–based beverage, exemplifies how indigenous knowledge can intersect with modern nutrition science to yield a functional drink of high therapeutic relevance. The present review highlights that Kanji is not merely a cultural delicacy but a phytochemical- and probiotic-rich formulation with significant potential in preventive and therapeutic nutrition. Its high content of anthocyanins, carotenoids, and phenolic compounds provides potent antioxidant properties, while its lactic acid bacterial strains such as Lactobacillus plantarum and Pediococcus acidilactici support gut health, immune modulation, and microbiological safety.

Compared to other commercially available herbal or dairy-based probiotic products, Kanji offers unique advantages: it is plant-based, affordable, and suitable for populations with lactose intolerance or vegan dietary preferences. Moreover, the synergistic role of black mustard seeds further enhances its antimicrobial, anti-inflammatory, and even antiviral potential, suggesting opportunities for application in combating both chronic diseases and emerging health threats. Despite its promise, Kanji remains underrepresented in global probiotic markets, with most evidence to date derived from in vitro and animal studies. Rigorous human clinical trials and advanced biochemical profiling are urgently needed to establish standardized formulations, verify therapeutic claims, and support its commercialization as a safe and effective functional beverage. By bridging the gap between traditional practices and modern science, Kanji could be positioned as a sustainable, accessible, and evidence-based dietary intervention in addressing contemporary health challenges. In conclusion, Kanji embodies a valuable yet overlooked probiotic food that warrants further research, clinical validation, and strategic integration into the functional food industry. Its rediscovery and scientific substantiation could provide not only nutritional and medicinal benefits but also contribute to cultural preservation and global health innovation.

PLAGIARISM **8%** According to the Turnitin report, the paper shows a 8% similarity index: 6% from internet sources, 4% from publications, and 1% from student papers.

The research paper titled “Kanji as a Functional Probiotic Beverage: Nutritional Composition, Phytochemical Properties, and Therapeutic Potential” explores the traditional Indian fermented black carrot drink Kanji as a promising plant-based alternative to conventional probiotics. Using a systematic review methodology, it synthesizes evidence from published studies between 2000 and 2023 across major databases. Findings indicate that Kanji is rich in anthocyanins, carotenoids, and phenolic compounds, exhibits strong antioxidant activity, and harbors beneficial lactic acid bacteria such as Lactobacillus plantarum and Pediococcus acidilactici. These attributes contribute to improved gut health, immune modulation, and potential therapeutic effects against chronic and infectious diseases. However, the review also highlights the limited number of clinical trials and the need for standardized research to validate its efficacy. The study concludes that Kanji is not only a culturally significant beverage but also an underutilized functional food with strong potential for commercialization in global probiotic markets. This paper has been approved for publication in the Jadetimes Journal of Universal Studies (E-ISSN 3066-9421), Volume 1, Issue 1, January–June 2025.

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